Chapter 10
Foot Compartment Syndrome Controversy

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Background

- Foot compartment syndrome is a rare but debilitating condition.
- Clinical presentation and evaluation can differ with classically reported signs and symptoms of compartment syndrome in other areas.
- Controversy exists in the amount of existing myofascial compartments of the foot.
- Multiple surgical approaches have been described for myofascial decompression.
- Controversy exists regarding acute versus delayed management of foot compartment syndrome.

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Table 10.1 Compartments and associated muscles of the foot

Compartment	Muscular structures	Location
Medial	Abductor hallucis, flexor hallucis brevis	Plantar medial to the first metatarsal
Superficial (superficial central)	Flexor digitorum longus Flexor digitorum brevis	
Lateral	Abductor digiti minimi Flexor digiti minimi brevis	Inferolateral surface of the fifth metatarsal
Adductor	Oblique head of the adductor hallucis	Plantar forefoot
Interossei (four compartments)	Each compartment includes the dorsal and plantar interosseous muscle of its location	Between each of the metatarsals
Calcaneal (deep central)	Quadratus plantae	

Foot Compartmental Anatomy

Early anatomic reports described four myofascial compartments of the foot: medial, lateral, central, and interosseous. Although surgical applications were previously based on these four compartments, recent research suggests the presence of nine myofascial compartments in the foot – medial, superficial, lateral, adductor, calcaneal [1, 2] – and four interosseous compartments [3]. Some authors describe a tenth compartment, the dorsal compartment, bounded by the skin which contains the extensor digitorum brevis and the extensor hallucis brevis [4, 5].

Table 10.1 shows compartments and associated muscles of the foot.

Etiology of Foot Compartment Syndrome

Foot compartment syndrome (FCS) is relatively uncommon, accounting for less than 5% of limb compartment syndrome cases [6]. It is caused by increased pressure secondary to hemorrhage or edema within an anatomic compartment. Ischemia results when this intra-compartmental pressure exceeds the capillary perfusion pressure [6]. It may be seen in the setting of high-energy injuries including crush mechanisms with and without osseous injury, Chopart and Lisfranc fractures dislocations, mid- and forefoot trauma, and calcaneal fractures [3, 7]. The most common cause of FCS is fracture of the calcaneus, accounting for 4.7–17% of cases [8–10]. This is likely in part related to the existing communication between the calcaneal compartment and the deep posterior compartment of the lower leg. Similarly, FCS can also be seen in tibia fracture and ankle fracture dislocations [11, 12]. Other causes of FCS include surgical procedures, occlusive dressings, frost bite, ischemia/reperfusion syndrome associated with vascular injuries, and exertional compartment syndrome [3, 5, 7, 13–15].

Clinical Evaluation

FCS is a clinical diagnosis, based on signs and symptoms of muscle ischemia. Classic clinical findings associated with compartment syndrome include pain out of proportion, paresthesia, pallor, pulselessness, and paralysis; however, these tend to be less reliable for evaluation of FCS than previously thought [6, 16]. Many types of injuries in the foot produce considerable pain; thus, pain out of proportion is not a reliable clinical finding in FCS. Pain with gentle, passive dorsiflexion of the toes has been described for diagnosing FCS; however, its utility remains questionable since this mainly tests the long flexor muscles which reside within the leg as opposed to within the foot compartments. Paresthesias can also be unreliable for diagnosing FCS because of the difficulty in determining whether the sensory deficits occurred secondary to nerve ischemia or to the initial injury. Palpable pulses (dorsalis pedis/posterior tibial) are usually present in FCS since the common sites for palpating foot pulses are extracompartmental; therefore, it is thought that vascular examinations are not sensitive enough to rule out the diagnosis of a compartment syndrome [3]. Several studies describe tense swelling as the most consistent physical examination finding in FCS [16, 17]. We have noted that tense swelling associated with severe pain not responsive to appropriate narcotic analgesia is a useful, though imperfect criteria in determining the presence of foot compartment syndrome.

While a through history and physical examination is the most important aspect to the diagnosis of FCS, it is not always clear if FCS is present. In this setting, the most objective means of diagnosing FCS is through compartment pressure monitoring [17–20]. This is particularly useful for diagnosing compartment syndrome in obtunded patients, patients with severe head or spinal cord injuries, or those who present with peripheral nerve injuries [3, 18]. Several techniques for compartment pressures measurement have been described, but a commercial pressure monitor is likely the most reproducible, accurate, and easiest to use and is available in most hospitals [1, 2]. Due to the inconsistency regarding the anatomical compartments of the foot, there is no consensus regarding which or how many compartments' pressures should be measured. Currently, no evidence exists to provide a recommendation on how many compartment pressures should be measured in the diagnosis of FCS. The general consensus seems to be that the calcaneal compartment consistently demonstrates the highest pressures. Therefore, if pressure monitoring is utilized in the diagnosis of acute compartment syndrome of the foot, the calcaneal compartment should be checked [7]. Indications for treatment should be based on history/mechanism of injury, clinical findings, serial examinations over time, and a differential pressure reading between diastolic blood pressure and intra-compartmental pressure of less than 30 mm Hg [3].

Treatment Options

Initial management of suspected compartment syndrome includes the removal of all restrictive dressings, prevention of systemic hypotension, and serial examinations [18, 21]. Maligned osseous injuries of the forefoot/midfoot injuries should be reduced immediately. While reduction of calcaneal injuries may not be feasible, hindfoot dislocations

should be reduced immediately if this is the suspected etiology of FCS. Additionally, the foot should be elevated to facilitate venous drainage, but not higher than the level of the heart to avoid compromising arterial blood flow [13, 18]. It has been described that a third of patients may develop FCS after more than 24 hours from the time of injury. Hence, in high-risk patients, serial examinations should be performed looking for signs of increased pain or until symptoms resolve [18, 21]. Once the diagnosis of foot compartment syndrome has been established, several authors recommend fasciotomies of the foot compartments [3, 11, 14, 18, 20, 22, 23]. Conversely, others do not consider the diagnosis of FCS to be an emergency and recommend against surgical management with the expectation of managing the sequelae of nonsurgical treatment [24].

Surgical Compartment Release

Multiple fasciotomy techniques have been described for the surgical management of FCS. The goal is to prevent ischemic contracture deformity of the foot and minimize development of neuropathic pain. The potential benefits of this procedure diminish the further out the decompression is completed from the time of diagnosis [6, 7]. Surgical techniques include the medial approach of Henry, combined medial and lateral incisions, two dorsal incisions, or a combination of these based on the underlying injury [3, 7, 18, 21, 25, 26]. A long plantar medial utilitarian incision has also been described [27, 28]. Currently, the three-incision approach is most commonly used, and it is based on the nine-compartment model of the foot. A medial incision is made 4 cm anterior to the posterior aspect of the heel and 3 cm superior to the plantar surface of the foot and is extended 6 cm distally. Through this medial approach, the media, superficial central, deep central, and lateral compartments are released. Two dorsal incisions are made to release the interosseous and adductor compartments. One incision just medial to the second metatarsal and one just lateral to the fourth metatarsal, this ensures an adequate skin bridge [6, 13, 28]. Overall, there are multiple fasciotomy techniques that exist for treating foot compartment syndrome, but no clear consensus on which technique provides the best patient outcome [3]. Additionally, the underlying nature of the injury as well as the potential for surgical intervention to treat the injury should be considered when planning incisions for compartment release, as specific placement of certain incisions is critical for definitive surgical treatment of these conditions.

Potential Complications and Sequelae

Surgical

Many authors recommend fasciotomy as treatment of choice for acute compartment syndrome of the foot; however, this is not without morbidity. After the fasciotomy has been performed, many recommend maintaining skin incisions open and performing secondary debridement, with or without the use of negative pressure wound

dressing. This can be utilized until the swelling subsides enough for delayed primary closure or application of a split-thickness skin graft [3, 17, 18, 20, 22]. Even with this technique, the rate of superficial infection has been reported to be as high as 20%. Skin sloughing, necessitating split-thickness skin grafting, has also been described [20, 22]. In one study, near two-thirds of patients who underwent decompressive fasciotomy complained of pain, discomfort, and stiffness with ambulation at a 1-year follow-up, and 17% of patients developed postoperative paresthesias [17]. In addition, residual claw toe, injury to the medial plantar nerve, and severe scarring have also been reported [3]. Results have been variable with regard to quality of life after fasciotomy for FCS. In a prior retrospective study, only four of 26 patients who underwent foot fasciotomies were able to return to work [17]. However, most recent data reports that 78% of patients who underwent fasciotomies for FCS were able to return to work [29]. While these studies do provide outcome information after fasciotomies of the foot, the impact of the underlying bony injury on the overall patient outcome compared with the impact of the fasciotomy is unclear [3].

Nonsurgical

The goal of nonsurgical management is to achieve a functional, plantigrade, and painless foot. Potential sequelae include development of ischemic contractures, neuropathy, deformity, and chronic pain [11, 30, 31]. Ischemic contractures of the lesser toes can arise secondary to soft-tissue damage within the foot compartments and have been reported to occur within 13 months after the time of injury [11, 17, 28]. The type of toe deformity depends on the involved muscles, and the most commonly associated with contractures in the foot are hammertoe and claw toe deformity [3, 11, 18, 20, 28]. Hammertoes occur as a result of an imbalance between the extrinsic and intrinsic muscles of the foot. Due to FCS, the intrinsic toe flexors are weakened, thereby resulting in overpull of the flexor digitorum longus muscle. This leads to a flexion contracture of the proximal interphalangeal (PIP) joint with the distal interphalangeal joint in neutral or extension [28, 32]. Claw toe deformity also results from extrinsic muscle overpull against relatively weak intrinsic toe musculature (short flexors, interossei, and lumbrical muscles) [7]. This leads to extension of the metatarsophalangeal (MP) joint with flexion in the proximal and interphalangeal (PIP and DIP) joints. The key component in differentiating claw toes from hammer toes is hyperextension of the MP joint [32]. Neurologic deficit and chronic pain may result from injury to the posterior tibial nerve as it crosses near the calcaneal compartment [3, 11].

Controversies

Failure or delay to diagnose acute compartment syndrome may lead to irreparable soft-tissue damage and poor long-term function [3, 7, 22, 33]. Controversy exists regarding acute versus delayed management of FCS. Limited data exists regarding

long-term outcomes of patients who develop an acute FCS. Many authors advocate toward emergent fasciotomy in attempts to improve blood flow by decreasing intracompartmental pressures and prevent nerve-based pain; however, this belief is not universally shared due to the inherent risks of these procedures. Techniques for compartment release are inconsistent in the literature, likely arising from the debate regarding the number of foot compartments that exist and the compartments that are clinically relevant for decompression. To this date, there are no prospective, randomized trials comparing alternative approaches in the treatment of foot compartment syndrome. Further research on the outcomes of acute fasciotomy versus delayed management is needed. Patients must be counseled on the reported outcomes and potential complications of both surgical compartment release and nonsurgical management, thus allowing the patient to make an informed decision regarding treatment.

Take-Home Message

- Failure or delay to diagnose acute compartment syndrome may lead to irreparable soft-tissue damage and poor long-term function.
- Limited data exists regarding long-term outcomes of patients who develop an acute FCS.
- Near two-thirds of patients who underwent decompressive fasciotomy complained of pain, discomfort, and stiffness with ambulation at 1-year follow-up.
- Potential sequelae of nonsurgical management include development of ischemic contractures, neuropathy, deformity, and chronic pain.
- Patients must be counseled on the reported outcomes and potential complications of both surgical compartment release and nonsurgical management, thus allowing the patient to make an informed decision regarding treatment.
- If considering surgical FCS release, surgical approach should take into consideration definitive treatment of the underlying injury.

References

1. Matsen FA 3rd, Winquist RA, Krugmire RB Jr. Diagnosis and management of compartmental syndromes. J Bone Joint Surg Am. 1980;62(2):286–91.
2. Rorabeck CH, et al. Compartmental pressure measurements: an experimental investigation using the slit catheter. J Trauma. 1981;21(6):446–9.
3. Wells DB, Davidson AR, Murphey GA. Acute compartment syndrome of the foot: a review. Curr Orthop Pract. 2018;29(1):11–5.
4. Ling ZX, Kumar VP. The myofascial compartments of the foot: a cadaver study. J Bone Joint Surg Br. 2008;90(8):1114–8.
5. Andrew K, Sands SR, Manoli A 2nd. Foot compartment syndrome - a clinical review. Fuß & Sprunggelenk. 2015;13:11–21.

6. Middleton S, Clasper J. Compartment syndrome of the foot--implications for military surgeons. J R Army Med Corps. 2010;156(4):241–4.
7. Dodd A, Le I. Foot compartment syndrome: diagnosis and management. J Am Acad Orthop Surg. 2013;21(11):657–64.
8. Andermahr J, et al. Compartment syndrome of the foot. Clin Anat. 2001;14(3):184–9.
9. Perry MD, Manoli A 2nd. Reconstruction of the foot after leg or foot compartment syndrome. Crit Care Nurs Clin North Am. 2012;24(2):311–22.
10. Thakur NA, et al. Injury patterns causing isolated foot compartment syndrome. J Bone Joint Surg Am. 2012;94(11):1030–5.
11. Brey JM, Castro MD. Salvage of compartment syndrome of the leg and foot. Foot Ankle Clin. 2008;13(4):767–72.
12. Neilly D, et al. Acute compartment syndrome of the foot following open reduction and internal fixation of an ankle fracture. Injury. 2015;46(10):2064–8.
13. Fulkerson E, Razi A, Tejwani N. Review: acute compartment syndrome of the foot. Foot Ankle Int. 2003;24(2):180–7.
14. Murdock M, Murdoch MM. Compartment syndrome: a review of the literature. Clin Podiatr Med Surg. 2012;29(2):301–10, viii.
15. Younger A. Arthroscopic fracture reduction with fibular nail. In: Pfeffer MEG, Hintermann B, Sands A, Younger A, editors. Foot and ankle surgery. Philadephia: Elsevier; 2018. p. 619–29.
16. Myerson M. Diagnosis and treatment of compartment syndrome of the foot. Orthopedics. 1990;13(7):711–7.
17. Fakhouri AJ, Manoli A 2nd. Acute foot compartment syndromes. J Orthop Trauma. 1992;6(2):223–8.
18. Myerson M. Acute compartment syndromes of the foot. Bull Hosp Jt Dis Orthop Inst. 1987;47(2):251–61.
19. Myerson MS. Experimental decompression of the fascial compartments of the foot--the basis for fasciotomy in acute compartment syndromes. Foot Ankle. 1988;8(6):308–14.
20. Myerson MS. Management of compartment syndromes of the foot. Clin Orthop Relat Res. 1991;271:239–48.
21. Frink M, et al. Compartment syndrome of the lower leg and foot. Clin Orthop Relat Res. 2010;468(4):940–50.
22. Brink F, et al. Mechanism of injury and treatment of trauma-associated acute compartment syndrome of the foot. Eur J Trauma Emerg Surg. 2014;40(5):529–33.
23. Giannoudis PV, et al. The impact of lower leg compartment syndrome on health related quality of life. Injury. 2002;33(2):117–21.
24. Wallin K, et al. Acute traumatic compartment syndrome in pediatric foot: a systematic review and case report. J Foot Ankle Surg. 2016;55(4):817–20.
25. Manoli A 2nd, Smith DG, Hansen ST Jr. Scarred muscle excision for the treatment of established ischemic contracture of the lower extremity. Clin Orthop Relat Res. 1993;292:309–14.
26. Myerson M. Split-thickness skin excision: its use for immediate wound care in crush injuries of the foot. Foot Ankle. 1989;10(2):54–60.
27. Loeffler RD Jr, Ballard A. Plantar fascial spaces of the foot and a proposed surgical approach. Foot Ankle. 1980;1(1):11–4.
28. Manoli A 2nd, Weber TG. Fasciotomy of the foot: an anatomical study with special reference to release of the calcaneal compartment. Foot Ankle. 1990;10(5):267–75.
29. Han F, et al. A prospective study of surgical outcomes and quality of life in severe foot trauma and associated compartment syndrome after fasciotomy. J Foot Ankle Surg. 2015;54(3):417–23.
30. Botte MJ, et al. Ischemic contracture of the foot and ankle: principles of management and prevention. Orthopedics. 1996;19(3):235–44.
31. Santi MD, Botte MJ. Volkmann's ischemic contracture of the foot and ankle: evaluation and treatment of established deformity. Foot Ankle Int. 1995;16(6):368–77.
32. Rammelt S, Zwipp H. Reconstructive surgery after compartment syndrome of the lower leg and foot. Eur J Trauma Emerg Surg. 2008;34(3):237.
33. Rosenthal R, et al. Sequelae of underdiagnosed foot compartment syndrome after calcaneal fractures. J Foot Ankle Surg. 2013;52(2):158–61.