Compartment Syndrome of the Foot – Implications for Military Surgeons

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Abstract

Introduction: Compartment syndrome of the foot is a rare complication of injury to the foot. Treatment by decompression of the compartments is debatable. The debate surrounding decompression stems from the rarity of the condition, the lack of consensus regarding the anatomy of the foot compartments and whether to accept the inevitable contractures by not decompressing. The aim of this paper is two fold; firstly to sample current military orthopaedic experience and secondly establish if there exists a consensus of opinion in how and if to perform fasciotomy of the foot thereby providing guidance to other clinicians.

Method: A questionnaire was sent to 10 DMS orthopaedic consultants to identify their experience with foot compartment syndrome and performing foot fasciotomies.

Results: Five had performed a foot fasciotomy (average 2, range 1-6) over an average of 6.2 years as consultant and an average of 7.3 months deployed. Most commonly two dorsal and a medial incision were used to decompress the foot. One surgeon advocated not decompressing the foot and accepting the subsequent contractures,

Conclusion: DMS clinicians need to remain vigilant to compartment syndrome of the foot and especially in cases of crush or blast injury or of multiple fractures. If diagnosed or even if an impending compartment syndrome is suspected then, in line with the current weight of expert opinion, the foot should be decompressed and the deployed orthopaedic surgeon should be capable of performing it. Evidence concerning their battlefield use is limited. Extensive UK military trials are ongoing and the results of which are expected to clarify questions regarding complication rate and efficacy.

Introduction

Compartment syndrome can occur in any myofascial compartment and although it may be caused by a wide array of mechanisms is due to the same basic pathophysiological process. An increase in the volume of contents of the compartment, such as soft tissue swelling or bleeding results in increased pressure within the compartment. The most common site for development of compartment syndrome is the lower leg [1]. In a review of 1748 cases of limb compartment syndrome [1], 907 were confirmed in the text as lower leg (52%) and a further 254 (15%) cases reported as 'lower limb'. Despite this, the foot accounted for only 62 (3.5%) of the 1748 reported cases of compartment syndrome.

Compartment syndrome of the foot has been reported following crush injuries, blast injuries and fractures, especially those involving the fore to mid foot joints (Lisfranc joint), mid to hind foot joints (Chopard joint) or the calcaneum [3-5]. The diagnosis of compartment syndrome of the foot remains challenging and the sequelae of missing or not adequately treating can be disabling and painful [6]. However the operative management of compartment syndrome can be complicated by developing infection of the wounds, infection in the fracture sites especially if there is a need operative fixation and the wounds are likely to require grafting for closure [7]. The complications associated with missing or not decompressing a foot with compartment syndrome includes contracture and toe deformities [8]. It is these deformities that are the focus of the debate as to whether to decompress or not.

It has been reported that military casualties are at increased risk of developing an acute compartment syndrome [9] because the injury patterns seen in the combat environment are generated more so by blast and crush type injuries which are associated with tissue destruction and massive swelling. The study by Ritenour [9] looked at combat casualties and fasciotomies amongst US soldiers. Of the 494 fasciotomies performed in operational times 4.9% were foot fasciotomy, slightly higher than the 3.5% rate described in a civilian study [1]. In addition the consequences of contractures and toe deformities will be greater with the requirements of military training and operations. However, this must be balanced against the increased risk of infection in military casualties, the consequences of which are also career threatening.

Given the conflicting views in the published literature, the rarity of the condition in civilian orthopaedic practice and the potentially significant effects of both foot fasciotomy and non-decompressed foot compartment syndromes in military personnel we aimed to establish the experience and views of military orthopaedic surgeons in managing foot compartment syndrome and foot fasciotomy as well as reviewing the available literature to try and establish guidelines to improve outcomes in this condition. We selected to canvas the opinion of half of the regular consultant orthopaedic cadre, which were based at the authors places of work, two of the MDHU's (Ministry of Defence Hospital Units). We aimed to seek a representative sample of opinion and not a

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comprehensive survey. Our reasoning for this is that the debate regarding compartment syndrome of the foot is ongoing and widespread and our aim is not to present the corporate opinion but to fuel debate and inform colleagues of the current opinion, ultimately assisting the decision making process for the deployed military trauma surgeon.

Methods

A questionnaire was sent to 10 of the currently serving Trauma and Orthopaedic surgeons. This asked questions regarding their experience in performing foot fasciotomy in their civilian practice and on deployed operational duties.

Results

All 10 consultants agreed to comment. The mean time spent as a consultant was 6.2 years (1 to 10 years). The average total length of time in months spent on operational deployment as a consultant was 7.3 months (3 to 12 months). Of the 10 consultants, five (50%) had performed a foot fasciotomy while deployed on military duty. The five who had performed a foot fasciotomy whist deployed had performed an average of two, but this is skewed as one surgeon had performed six fasciotomies over a total of five months of deployments. The mechanisms of injury ranged from road traffic accident to blast injury and gunshot wounds.

Not performing a fasciotomy in the presence of compartment syndrome was suggested by one consultant as it was felt that the morbidity of the incisions outweighed the complication of claw toes that could be overcome by wiring the phalanges prophylactically. However, one of the resounding themes emerging from those questioned was that if there was crush injury or complex foot fractures then the clinician should maintain a high index of suspicion and a low threshold for decompressing the foot. The majority of surgeons questioned would perform a faciotomy if compartment syndrome was identified and the majority would use the three incision approach.

Literature Review

Pathophysiology and Anatomy:

The pathophysiology of compartment syndrome is established and well documented in the literature. A traumatic event (crust, blast or fracture) causes an increase in the interstitial fluid (blood followed by oedema) content within the fascial compartment. Once the compartment pressure rises above that of capillary filling pressure there will be a fall in the capillary perfusion [10]. This hypoperfusion will sequentially lead to muscle and tissue ischaemia, necrosis, fibrosis and ultimately contracture, most commonly in the foot claw toes caused by the preserved extrinsic toe flexors and extensors overpowering the damaged intrinsic muscles[11].

The intrinsic muscles of the foot receive their blood supply from the medial and lateral plantar arteries, both of which are branches of the posterior tibial artery. These plantar arteries are both compressed if there is bleeding in the region of the origin of the quadrates plantae muscle [12] in a compartment that until 1990 had not been described [13], the calcaneal compartment. This explains the development of lesser toe clawing after occult calcaneal compartment syndrome related to fracture of the calcaneum. Debate exists as to the exact number of myofascial compartments contained in the foot. Manoli [13] described a total of nine compartments identified by injecting dyed gelatine into un-embalmed feet and sectioning them (Table 1). This was prompted by his observation of the development of clawing of the lesser toes after calcaneal fractures. Others have described between 3 and 10 compartments of the feet [14,15]. Manoli also identified that the calcaneal compartment communicated with the deep posterior compartment of the leg and not as previously thought one of the central compartments.

Hindfoot (1)	Forefoot (5)	Full length (3)
CALCANEAL Quadratus plantae hallucis Posterior tibial, lateral & medial plantar minimi, flexor Neurovascular bundle	INTEROSSEUS (4) Interossei – four ADDUCTOR Adductor hallucis	MEDIAL Flexor & abductor LATERAL Abductor digiti digiti minimi SUPERFICIAL Flexor digitorum brevis, 4 lumbricals, tendon to FDL

Table 1- Nine compartments and their contents as described by Manoli [13]

Diagnosis

Diagnosis of compartment syndrome of the foot revolves around the same guiding principles as diagnosing compartment syndrome of any myofascial compartment. The clinical sign of pain on passive stretch of the muscles contained in the compartment is generally accepted as the most sensitive diagnostic indicator of compartment syndrome [16]. However in a review of twelve cases of compartment syndrome of the feet the most consistent physical finding (present in all twelve) was tense swelling [3]. The only reliable way of diagnosing compartment syndrome is to measure compartment pressures, a belief held by many including Myerson [4] and explored in a study in which he measured compartment pressures in two areas:

Central – Below 1st metatarsal, through abductor hallucis advancing 3cm
Interosseous – Dorsally between 2nd or 3rd intermetatarsal webspace advancing 1cm.

They considered interstitial compartment pressures of 30mmHg in either of the compartments measured to be pathological and treated it by fasciotomy. In the event of the patient being hypotensive this has to be taken into account as tissue perfusion will be less therefore the threshold for developing muscle ischaemia secondary to reduced perfusion will be less and the threshold for decompression lowered.

Operative technique:

Manoli, who identified nine compartments, [13] maintains that to decompress the foot two dorsal incisions and one medial are required. The dorsal incisions decompress the adductor and interosseous compartments and the medial incision the others (calcaneal, medial, lateral and superficial).

Other studies have looked at models of compartment syndrome to try to establish the best means of decompressing the foot. Another study of cadaveric feet [5] used dissection to provide an anatomical basis for surgical decompression. They

identified three tough vertical fascial septae that extend from the hind to the midfoot. They suggested that the foot could be entirely decompressed through one incision over the non-weight bearing instep (5cm from the posterior edge of the heel extending 5cm distally). The key difference between the various methods described is that the three incision method employed by Manoli has been looked at experimentally and appears to be the most clinically used approach to decompression.

The timing of decompression is vital to the outcome and function of the patient. The large review of all published reports on compartment syndrome by Hayakawa et al [1] looked at, amongst other parameters, outcome relating to timing of fasciotomy. 88% of patients had an acceptable outcome when fasciotomy had been performed within 6 hours compared to 15% having acceptable outcome after a delay of greater than 12 hours. The rate of amputation related directly to compartment syndrome rose from 3.2% with 6 hour delays to 14% with 12 hour delays. After 24 hours decompression may cause more morbidity than the sequelae of not decompression. Finklestein [17] concluded that if the muscle within the compartment was non-viable that leaving the skin intact over the muscle was the best form of treatment and then dealing with the sequelae following the stabilisation of the acute process.

Complications

Complications can be considered as two separate groups; those arising as a result of performing a fasciotomy and those that result from not performing a fasciotomy or missing compartment syndrome. Infection is arguable the most significant complication following fasciotomy and made more significant in presence of metal work from fracture fixation. Infection rates of extremity fasciotomy have been shown to increase as time to surgery increases. In an American study 7.3% of lower limb fasciotomies performed within six hours became infected, this increased to 28% if there was a delay of greater than twelve hours to decompression [8]. Further delay before decompressing will expose dead muscle and tissue to the environment and the argument that skin is the best biological dressing becomes valid [2]. Once a fasciotomy is performed then closing the wounds can be problematic and many advise that primary closure is not attempted until five to seven days after decompression. In a series of fourteen cases of foot compartment syndrome treated with fasciotomy three underwent delayed primary closure, seven required delayed split skin grafting while the rest had primary grafting or free flaps to provide adequate tissue coverage [4].

If undiagnosed or untreated then the resulting deformity from contractures of the intrinsic muscles of the foot can be painful and debilitating. Most commonly the deformity is painful hammer or claw toes from contracture of the flexor digitorum brevis and contracture at the proximal interphalangeal joint or from ischaemic damage to the weak intrinsic muscle of the foot (short flexors, interossei and lumbricles) leading to hyperextension of the metatarsophalangeal (MP) joints and flexion at the PIP joints [8]. The options for treating an established deformity of the flexors includes lengthening of the flexor tendons, capsular release, flexor to extensor tendon transfer or in rigid of fixed hammer and mallet deformity tenotomy can be performed percutaneously. As a last resort for fixed deformity with joint subluxation then resection arthroplasty and athrodesis can be performed [8].

Discussion

Compartment syndrome of the foot is relatively uncommon both in the military and civilian environment. However our survey has demonstrated that 50% of the military orthopaedic surgeons have had to perform at least 1 (mean 2) foot fasciotomies whilst on deployment. Whilst we have only surveyed half of the current cadre, this confirms that a foot fasciotomy is a required skill of deploying military surgeon. Given that these may not be seen during civilian training, then there is a requirement for guidance for the deploying military surgeon.

Finally there remains a requirement for long-term follow-up of both operative and non-operative management, however given the rarity of the condition, the difficulty in follow up of combat casualties, as well as the problem if an adverse outcome was related to the injury or the fasciotomy, then this may never be possible.

DMS clinicians need to remain vigilant to the threat of developing compartment syndrome and should have heightened suspicion in cases of crush or blast injury or of multiple fractures. Measuring the compartment pressure is the only reliable objective measure and can be simply done. If diagnosed or even if an impending compartment syndrome is suspected then they should decompress the foot using the three incisions as described by Manoli [13] (Figure 1). These should be left open and closure performed by the most appropriate means, this is likely to be achieved after repatriation to the UK.

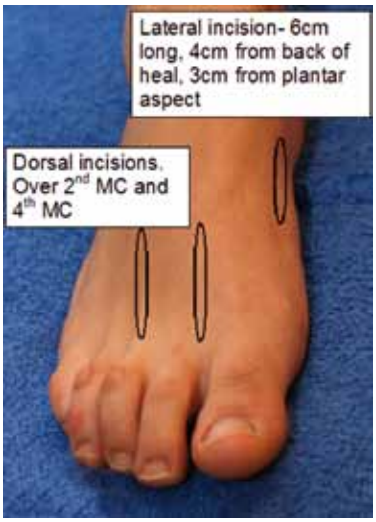

Figure 1 The placement of decompression incisions

Conclusion

Compartment syndrome in the foot remains rare and this is perhaps the main reason for the controversy over its treatment. Diagnosis remain challenging with the most consistent sign is a tense swollen foot for which we advocate early surgical treatment of compartment syndrome using the three incision decompression technique. The decision to decompress or not cannot be based on evidence but has to fall back on opinion, the weight of which is in support of early aggressive treatment which is reflected in the opinion of the consultants surveyed in this paper .

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