ISSUES IN THE MANAGEMENT OF FRACTURES ASSOCIATED WITH COMPARTMENT SYNDROME

By

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2012

DECLARATION

I hereby declare that this dissertation entitled "Issues in the Management of Fractures associated with Compartment Syndrome" is a bonafide and genuine research work prepared by me under the guidance of Dr.V.Shyam Sundar, M.S Ortho, Professor, Department of Orthopaedics, PSGIMS & R, Coimbatore.

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CERTIFICATE

This is to certify that the dissertation entitled "**Issues in the Management of Fractures associated with Compartment Syndrome**" is a bonafide research work done by Dr.T.VETRI GANAPATHY under the guidance of **Dr.V.Shyam Sundar M.S (Ortho**), Professor, Department of Orthopaedics, PSGIMS&R, Coimbatore.

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CERTIFICATE

This is to certify that the dissertation entitled “**Issues in the Management of Fractures associated with Compartment Syndrome**” was carried out by Dr.T.VETRI GANAPATHY under my guidance, in partial fulfillment of the requirement for the degree of M.S (Orthopaedics)

Place: Coimbatore **Dr.V.SHYAM SUNDAR**

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Dr.T.VETRI GANAPATHY

INTRODUCTION

INTRODUCTION

Compartment syndrome has been identified as an acute devastating orthopaedic emergency.

Till date, compartment syndrome is one of the major complications in an injured limb. And early fasciotomy is the only way to prevent any complications due to compartment syndrome. Delay in diagnosis had been identified as the only cause of failure of treatment.

This retrospective study proposes to analyse the issues in management of fractures complicated by compartment syndrome occurring pre-operatively and post-operatively.

AIM AND OBJECTIVES

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Aim

To retrospectively study the issues in management of fractures complicated by compartment syndrome occurring pre-operatively, and post-operatively

Objectives

- To study the issues involved in the rationale for deciding the method of fracture stabilization following fasciotomy
- To study the problems, complications and functional outcome of fracture stabilization
- To analyze and establish methods to the optimally manage the issues involved

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Definition

Mubarak defined Compartment syndrome as

"a condition in which accumulating fluid and/or external compression creates high pressure within a closed fascial space, reducing perfusion of the tissues within that compartment below a level necessary for viability" [25]

Meyer and Mubarak found that, Acute compartment syndrome commonly occurs in leg (anterior and deep compartment) and forearm (volar compartment), but it can develop in any skeletal muscle enclosed in an osseofascial boundaries. [25]

History

First description of compartment syndrome is attributed to Hamilton (1850), but none of his descriptions were found. It was Richard von Volkmann (1881) who first described in detail about the ischaemic contracture of muscles following tight bandaging. But he was not able to elicit the cause for the development of the ischaemia and the contractures. Following him, a large number of reports on the occurrence of ischaemic contracture of muscles were made. However, it was only after four decades that Jepson (1926) described fasciotomy as a method of prevention of ischaemic contracture. Seddon (1966) advised early fasciotomy in preventing the complications of the compartment syndrome. And he also identified pain and parasethesia as signs of the condition. It was McQuillan and Nolan (1968) who first described in detail about the pathophysiology of compartment syndrome and the vicious cycle involved in it the progression of the syndrome. Measurement of compartment syndrome took precedence after Rorabeck and Macnab (1975) devised a method to measure the intracompartmental pressure in animal models. This method was adapted and modified by Whiteside (1975) in measuring compartmental pressure in injured limbs. Mubarack (1978) popularized Whiteside's technique while using a Wick catheter and measuring the intracompartmental pressure successfully.[31] McQueen reported compartment syndrome in open fractures. And reports of different causes like snakebite, burns, drug overdosage and others leading to compartment syndrome were made.

Applied Anatomy

The compartment syndrome commonly involves the leg and forearm and their anatomy is discussed. The bulkiness of the muscles of the leg and forearm leads to decrease in the compartment size and indirectly increasing the compartment pressure, which may predispose to compartment syndrome. The precarious blood supply of the leg and forearm are high risk for injury along their course and hence more prone for compartment syndrome.

Leg

There are four compartments in the leg: Anterior, Lateral, Superficial and Deep Posterior. Each compartment is made of the tibia, the fibula and intermusclar septums. The anterior compartment is most frequently involved. Clawing of toes is a sequale of compartment syndrome involving the deep posterior compartment. In open fractures, compartment syndrome can occur if any one or more of the compartments are not exposed.

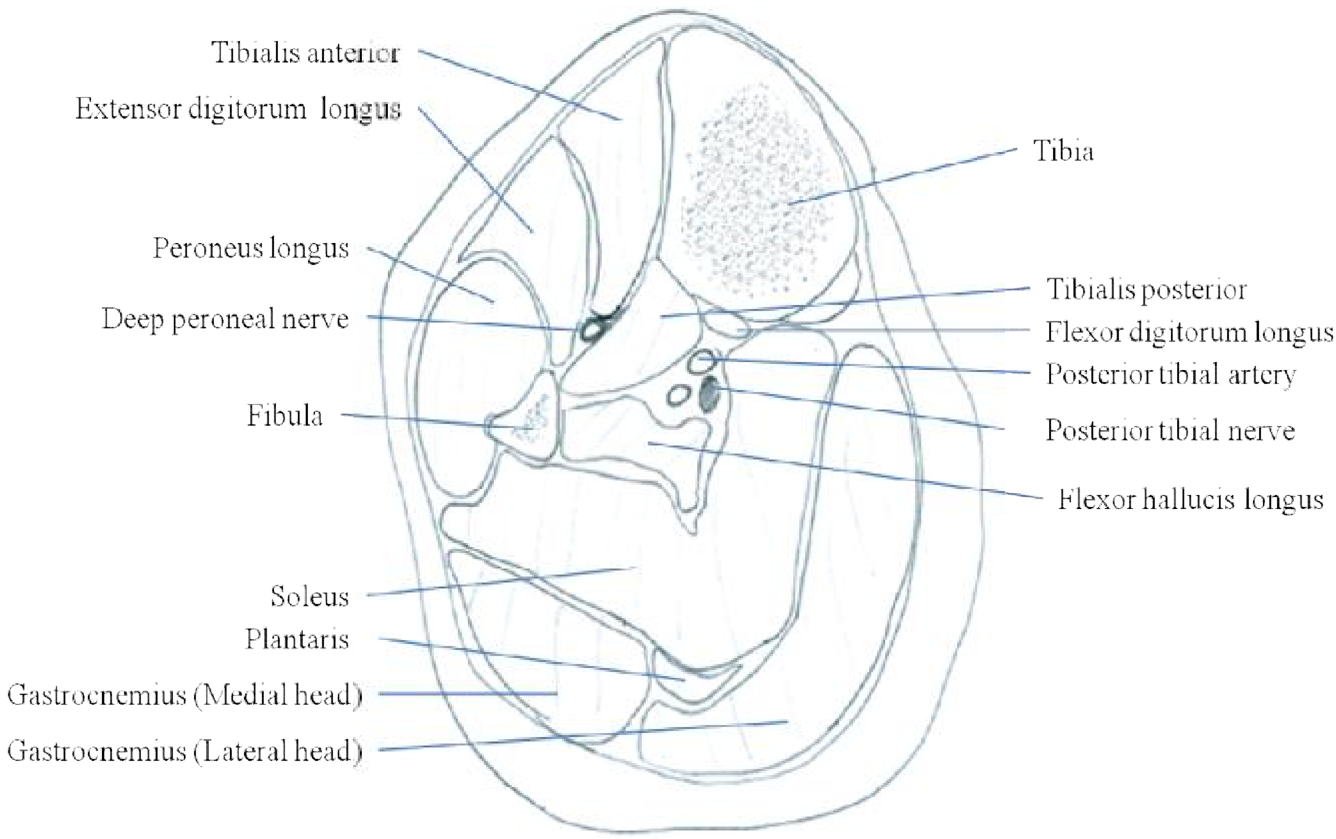


Figure 1 - Cross section of Leg showing the different compartments

COMPARTMENT	CONTENTS
Anterior	Tibialis anterior Extensor digitorum longus Extensor hallucis longus Peroneus tertius Deep peroneal (anterior tibial) nerve and vessels
Lateral	Peroneus longus Peroneus brevis Superficial peroneal nerve
Superficial posterior	Gastrocnemius Soleus Plantaris
Deep posterior	Tibialis posterior Flexor digitorum longus Flexor hallucis longus Posterior tibial nerve

Forearm

There are three compartments in the forearm: Volar, Dorsal and Mobile wad. The compartments are made of the radius, the ulna and the interosseous membrane. The median nerve must be preferably decompressed throughout its course including the carpal tunnel during fasciotomy. And disruption of the brachial artery in the arm is the commonest cause of compartment syndrome in forearm.

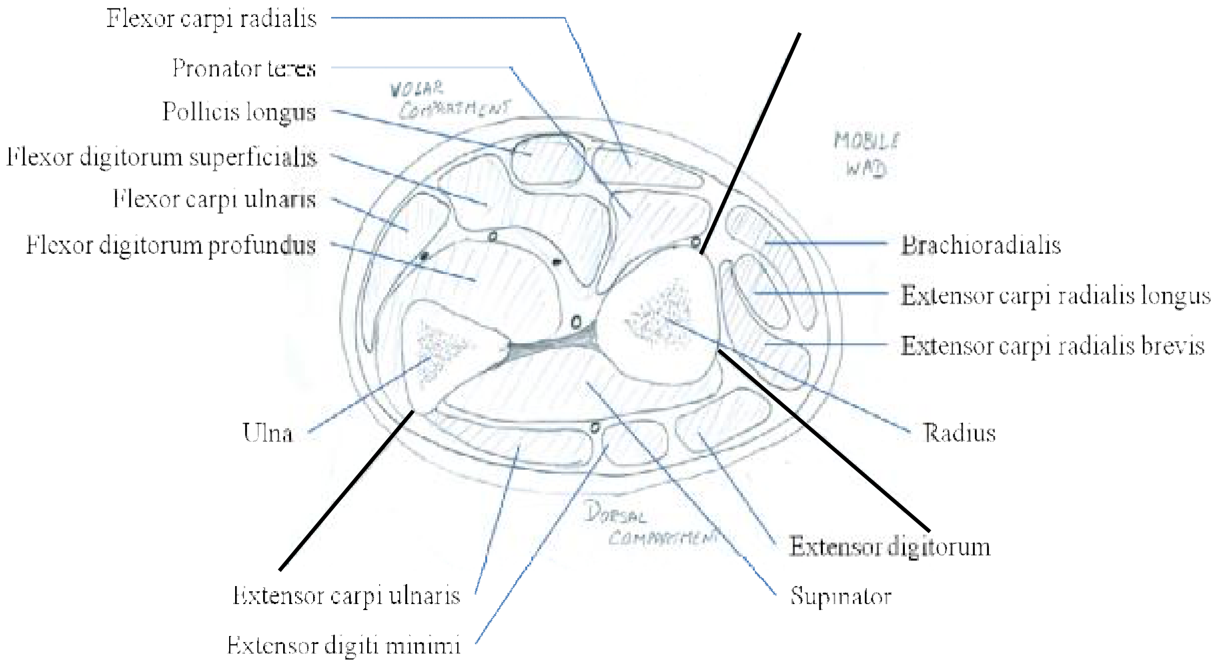


Figure 2 - Cross section of Forearm showing the different compartments

COMPARTMENT	CONTENTS
Volar	Flexor carpi radialis longus and brevis Flexor digitorum superficialis and profundus Flexor carpi ulnaris Pronator teres Pollicis longus Median nerve Ulnar nerve
Dorsal	Extensor digitorum Supinator Extensor digiti minimi Extensor carpi ulnaris
Mobile wad	Brachioradialis Extensor carpi radialis longus and brevis

Etiology

The basic cause of compartment syndrome is by any of the three causes:

- Increase in the compartment pressure (factors within the compartment like fracture haematoma, muscle edema)
- Decrease in compartment size (external factors like casting)
- Both

According to Whiteside, Acute compartment syndrome occurs most commonly secondary to fractures. He also identified arterial injury, temporary vascular occlusion, snake bite, drug overdose, burns, acute exertional states, and gunshot wounds as other causes of compartment syndrome.[40] Blick et al showed that compartment syndrome can occur in open fractures also, and the incidence is directly related to the amount of soft tissue injury. So Grade III (Gustillo and Anderson) open communited fractures were also at risk.[3] McQueen stratified that the younger age group were at a higher risk of compartment syndrome, three times more than the older age group. He attributed the higher prevalence in younger age group to their larger muscle mass. The larger muscle mass reduces the compartment space. Hence, when the muscles swell after a trauma or insult, there is lesser space for it to swell.[21]

Compartment syndrome has also been reported following internal fixation of fractures. Fractured ends when not reduced, tend to override. When the shortened fractures are reduced, there is a sudden decrease in the compartment volume due to the stretching of compartment to their original lengths. Incidence of compartment syndromes following intramedually nailing of acute tibial and femur fractures have been reported by Gershuni et al and also by Meyer and Mubarak.[10, 25]

Pathophysiology

Whiteside noted that development of edema in the muscles proportional to the amount of tissue injury is the cause of compartment syndrome. It is further complicated by the presence of fracture haematoma, which reduces the intra-compartmental volume and hence increasing compartment pressure.[40] The main factor in development of compartment syndrome is the non-yielding nature of the fascia enclosing the skeleto-muscular compartments, as noted by Meyer and Mubarak, Azar, McQueen and Whiteside. [1, 21, 25, 40]

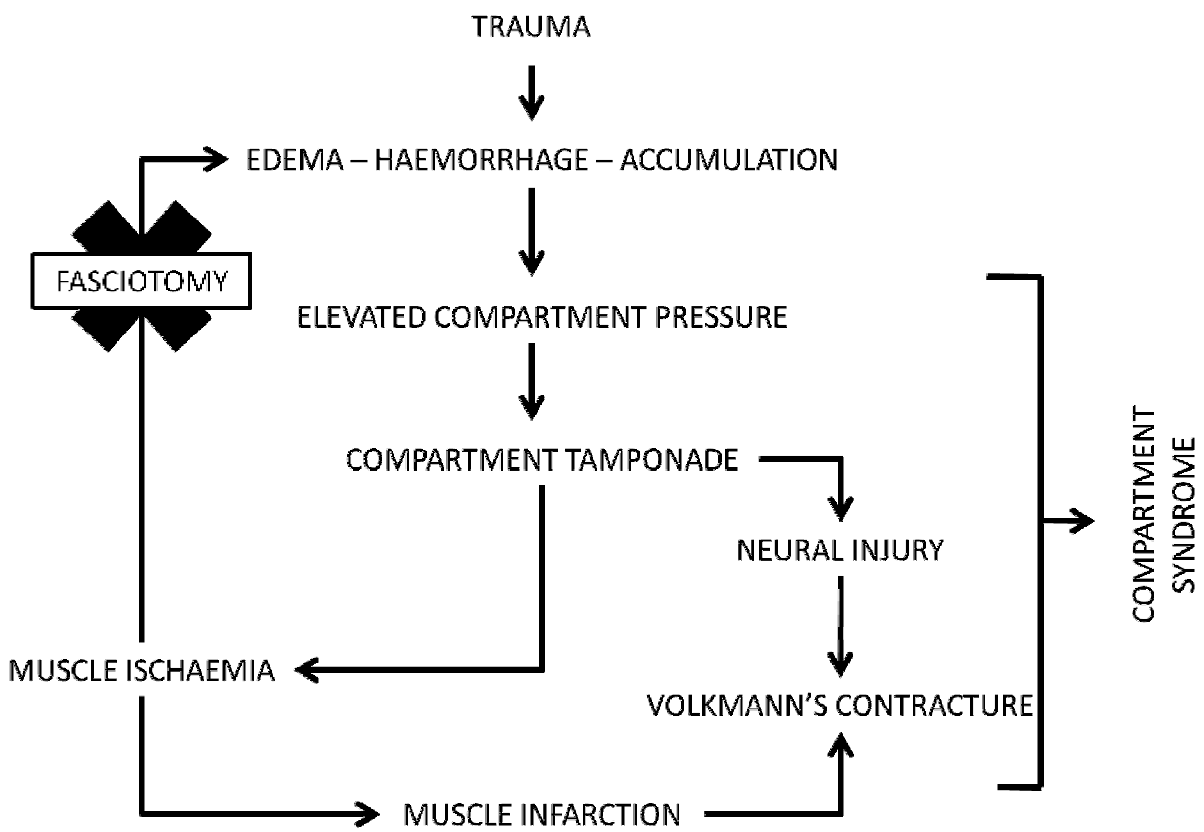


Image 1: PATHOPHYSIOLOGY OF A COMPARTMENT SYNDROME

Decompression by Fasciotomy breaks the cycle. But once Muscle infarction or Neural injury sets in, it becomes irreversible.

Meyer RS, Mubarak SJ. Compartment syndromes. In: Chapman MW, eds. Chapman's Orthopaedic Surgery. 3rd ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2001: chap 13.

The dissipation of energy into the muscles during trauma leads to intracellular swelling. Unchecked muscle ischaemia leads to development of further edema in the muscles.[25] Blick et al found that edematous limbs were more prone to develop compartment syndrome post-operatively. They also advocated waiting for the edema to settle before opting for any method of internal fixation.[3] And according to Rorabeck and Clarke, the cause of permanent nerve damage in compartment syndrome was the prolonged duration of increased pressure within the compartment. And they showed that the nerve damage is reversible, if the pressure was relieved before it reached a critical time period.[32] Whiteside et al, Petrasek et al and Heckman et al showed that both muscle ischaemia and neural injury were reversible within 4 hours from onset of ischaemia. But the results were variable after 6 hours and the changes became irreversible after 8 hours.[13, 30, 40] As the muscle necrosis involves the central portion of the muscle primarily. Hence, visual analysis of the muscle is not reliable. Lindsday et al have shown that Type 1(slow-twitch, oxidative metabolism dependent) muscle fibres are more susceptible to ischaemia than Type 2(fast-twitch, anaerobic metabolism dependent) muscle fibres.[17] It was suggested that the increased incidence of compartment syndrome in the anterior compartment muscles of leg was probably due to the muscles being predominantly Type I fibres. Whiteside et al, Heckman et al and Matava et al showed by experimental methods that muscle ischaemia develops when intra-compartmental pressure is within 10mmHg of diastolic pressure.[13, 18, 40] This also explains that hypertension in patients is protective of compartment syndrome, as the patients are able to sustain higher tissue pressures without ischaemia.[40]

<u>Diagnosis</u>

For long, Pain, Paraesthesia, Pulselessness, Pallor and Paralysis, have been and are being described to clinically diagnose compartment syndrome. Except for pain, and paraesthesia, the other signs develop only after the ischaemic injury has been established, and fasciotomy at this stage does not have a good prognosis.

To quote Whiteside, "*Pain and aggravation of pain by passive stretching of the muscles in the compartment in question are the most sensitive (and generally the only) clinical findings before the onset of ischemic dysfunction in the nerves and muscles*".[40]

Pain is out of proportion of the injury, usually continuous and not relieved by change in position and requiring increased analgesia usage.

And also pain on passive stretching of the involved muscles develops. But stretch pain may not be elicited when irreversible neural ischaemia has been established. Paraesthesia also may present along with pain, indicating onset of neural ischaemia. Pain with paraesthsesia indicate the need for emergency fasciotomy. Skin changes like development of blisters were also considered as indicators for compartment syndrome by a few authors. Twaddle and Amendola noted that there was a delay in diagnosis of compartment syndrome frequently when associated with other injuries, especially peripheral nerve injuries and arterial injuries. And compartment syndromes in open fractures were frequently missed. Blick and Brumback emphasized on expecting compartment syndrome even in open fractures.[3, 37] Twaddle and Amendola also noted that, though tissue pressure measurement helps in diagnosing compartment syndrome early, it is not feasible and cost-effective to monitor all patients. In a conscious and alert patient, diagnosis can be established clinically. Collinge and Person assessed pressure measurement devices and found that there was an error in 27% cases and proposed not to consider pressure measurement devices as determinants for fasciotomy.[37] Compartment pressure monitoring must be considered for anaesthetized patients, polytrauma patients, patients with associated nerve or arterial injury, children and comatose patients.[37]

Tissue pressure measurement

A number of techniques have been described for measuring tissue pressure. Most commonly employed technique is the infusion technique and more recently the use of hand held tissue pressure measurement devices. Needle techniques are appropriate for measurement at different sites and repeated measurements. As long as an appropriate zeroing technique is employed, all methods are accurate. Any electrical arterial-pressure monitoring device can be adapted to measure tissue pressur by using a stop cock and extension tubes.[40]

Infrared imaging is being developed as a non-invasive supportive tool in diagnosing compartment syndrome following blunt trauma. The method works on measuring the surface skin temperature as a correlation between blood flow to the limb and skin temperature is known.[15]

Infusion Technique using electronic arterial-pressure monitor

Required Equipment

- Bed side monitor capable of using arterial line transducers
- Arterial pressure monitoring transducers
- IV extension tubes
- 1.5” 18G needle
- 10-mL syringe
- 3-way stopcock
- Sterile normal saline

Steps

The limb must be cleaned and prepared. The arterial pressure monitoring device transducer is fixed at the level of the limb on an IV stand. A 10-mL syringe is attached to a 3-way stopcock in the arterial pressure monitoring device’s transducer. An IV extension tube with a 1.5” 18G needle is attached to the stopcock and the other is attached to a bag of saline through another IV extension line. After the arterial line

INFUSION TECHNIQUE WITH ELECTRONIC ARTERIAL-PRESSURE MONITOR

Image 1 - Arterial Transducer connected to Monitor and IV set

Image 2 - Zeroing of readings prior to measurement

Image 3 - Insertion of Needle into the desired compartment

Image 4 - Measurement of the compartment pressure

Image 5 - Monitor showing the pressure

transducer and IV tubing are set, the system is flushed with normal saline from the bag. The monitor is zeroed. Then the needle is inserted into the desired compartment and 0.1mL of saline is injected using the stopcock. Then the stopcock is changed back to the monitor and the reading recorded.

Site of tissue pressure measurement

Heckman et al observed in a prospective study that, tissue pressure was highest usually at the level of the fracture or within 5 cm of the fracture, and had a statistically significant drop when measured more proximally or distally. Following which, they suggested that tissue pressure measurements must involve all compartments and be measured both at the level of the fracture and also proximally and distally to the fracture, with the highest pressure as the basis for determining the need for fasciotomy. [12, 13]

Pressure threshold for Fasciotomy

There has always been a disagreement in determining the pressure threshold for fasciotomy. The disagreement is mainly due to the difference in methods of measurement used, as values varied based on methods. Whiteside et al proposed fasciotomy for compartment pressures within 10 to 30 mmHg of the patient's diastolic pressure.[39] This was further modified by Heckman et al, who advised fasciotomy for a difference of 10 to 20 mmHg between diastolic blood pressure and compartment pressure.[12] While Matsen et al suggested fasciotomy when the compartment pressure exceeds 45 mmHg.[19] McQueen and Court-Brown identified diastolic blood pressure of the patient as the key in determining the threshold for fasciotomy. When patients are in shock, compartment syndrome can occur at a lower pressure. While in hypertensive patients, compartment syndrome can occur only at a higher pressure.[24] So they demonstrated that "the difference between diastolic pressure and the measured compartment pressure (Δp) is a more reliable clinical indicator of pending compartment syndrome than the absolute compartment pressure" and recommended a difference of less than 30mmHg to consider fasciotomy.[24] On the contrary, Prayson et al, on studying different methods of measurement, proposed that the measurements may not reflect the true existence of the syndrome.[37]

Treatment of Compartment syndrome

Fasciotomy is the only appropriate treatment for compartment syndrome. But prior to that, any constrictive bandages must be released. Garfin and Mubarak studied the compartment pressure in limbs on cast and showed that, a circumferential cast can contribute to raised intra-compartmental pressure. And also there is a fall in pressure of 30% on splitting the cast on one side. And on splitting the cast on both sides, there is fall of 65% in pressure. While complete removal of the cast caused a fall of further15%.[8] Matsen et al showed that with elevation of a limb at risk of developing a compartment syndrome, there is decreased arterial inflow without significant venous outflow, increasing local ischaemia. And with the limb in a dependent position, significant swelling may occur with increasing risk of compartment syndrome. So, ideally, the limb must be placed at the level of the heart, where the arterio-venous gradient is maintained.[20] The pressure must be measured again and if still elevated, must proceed for fasciotomy.[21] Prognosis have been reported to be good in cases which underwent fasciotomy with minimal delay. Rorabeck noted that in cases with fasciotomy done within 24 hours from onset of clinical symptoms and signs, good results were obtained. Return of function depends on the delay in diagnosis and treatment. Shorter the delay, better the outcome is.[32]

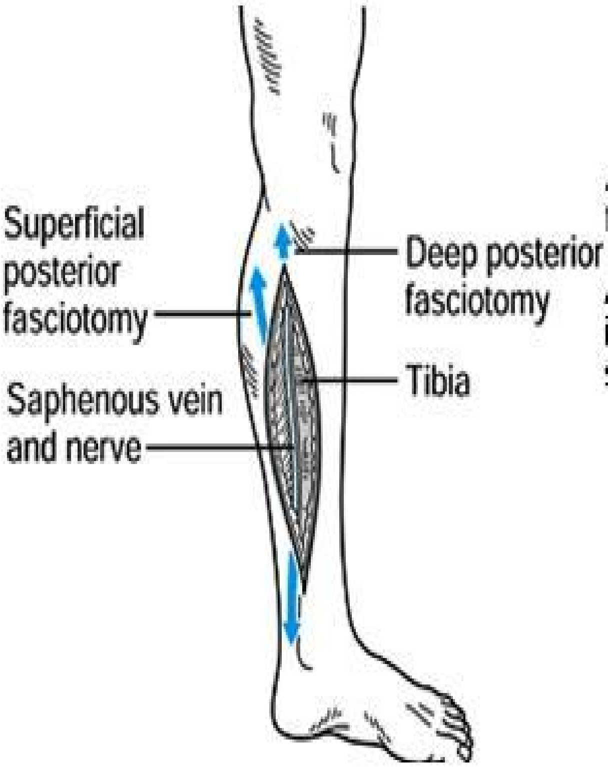
Surgical technique of Fasciotomy

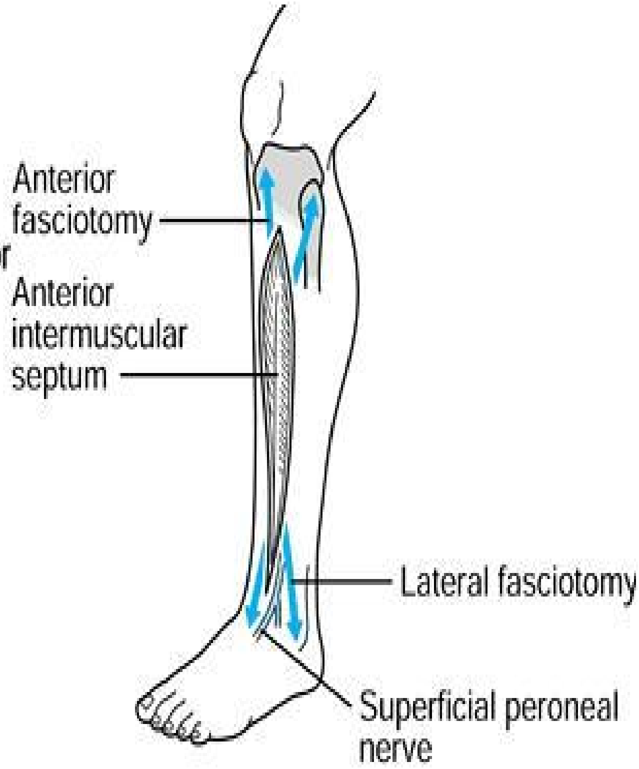
The patient with diagnosed compartments syndrome must be taken up for emergency decompressive fasciotomy. The limb must not be elevated or exsanguinated. Long incisions are preferred for better access to the fascia and prevent any iatrogenic fractures to the neurovascular structures. Obvious areas of muscle necrosis must be debrided and a 'second look' can be taken later for further debridement, if required.

Intra-compartmental pressures can be measured after fasciotomies to ensure adequate decompression.[25] DeLee and Stiehl found that surgical incisions less than 15cm long to produce inadequate decompression.[5]

Leg

Fibulectomy, Single-incision perifibular fasciotomy and Double-incision fasciotomy have been described for decompressing the compartments of the leg. Fibulectomy is a radical procedure and not considered primarily. Single incision is preferred though being difficult, as it is located laterally and away from the fracture site with needing only a single wound closure. But the double-incision technique has been found to be more effective and safer compared to other techniques.[1]





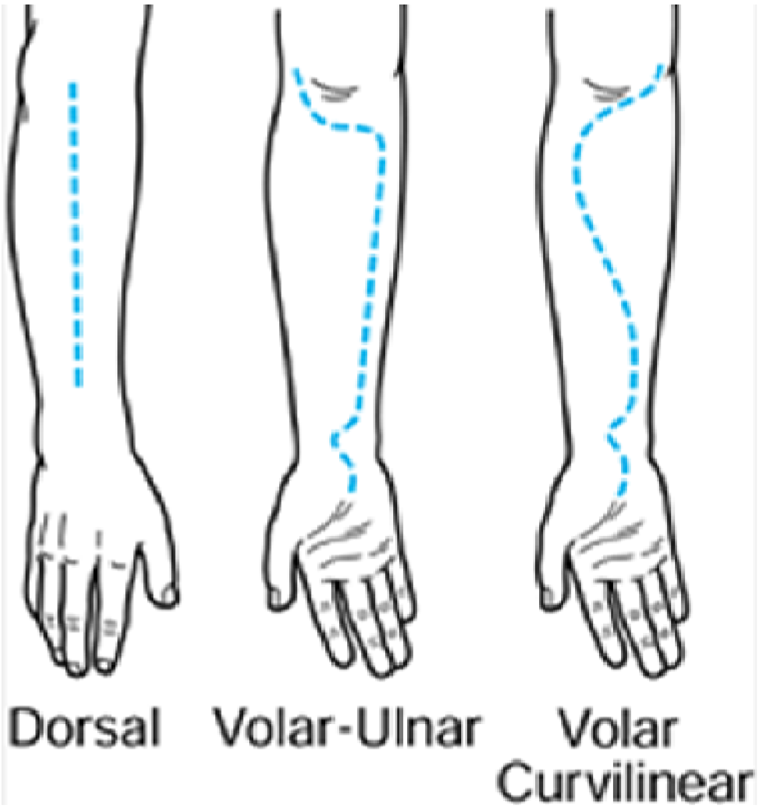
POSTEROMEDIAL ANTEROLATERAL

TWO-INCISION TECHNIQUE FOR FOUR-COMPARTMENT RELEASE OF THE LEG.

Redrawn from Mubarak SJ, Hargens AR. Diagnosis and Management of Compartment Syndromes. In: AAOS: Symposium on Trauma to the Leg and Its Sequelae. St. Louis: CV Mosby, 1981

Forearm

Galanakos S et al noted that, a single volar incision to decompress the forearm in lines with the commonly used Henry's approach along with release of the carpal tunnel has been found successful.[27]



DORSAL AND VOLAR INCISIONS FOR FOREARM DECOMPRESSION

Redrawn from Gelberman RH, Zakaib GS, Mubarak SJ, et al. Decompression of Forearm Compartment Syndromes. Clin Orthop 1978;134:225

Fracture management

Rorabeck observed that, Fractures associated with acute compartment syndrome must receive some form of operative stabilization at the time of fasciotomy. As once the fracture is stabilized, soft tissue can be accessed easily and permits their healing.[32] Any delay in decompression must be avoided by carrying out fasciotomy first. Fasciotomy must be followed by some method of fracture stabilization.[21] Two problems have been identified to be significant in management of the fractures[36, 37]:

1. With fasciotomy, the fracture acts as open type
2. The need for the fasciotomy wound to be kept open

Cast management is contraindicated when compartment syndrome is suspected. Management of fractures must not change in presence of acute compartment syndrome. Following a prospective study of tibial fractures, Gerunshi et al concluded that, fasciotomy followed by stable internal fixation was required for good functional outcome in closed tibial fractures associated with acute compartment syndrome.[10] But the method of osteosynthesis depended on the surgeon's skill and status of soft tissue. The method chosen must cause minimal damage to the soft tissues. And after osteosynthesis, soft tissue cover over the bone must be attempted.[10, 21] Skeletal muscle perfusion has been found to be the key in fracture healing following fasciotomy, as the haematoma is lost. The periosteum has been found to share a collateral perfusion with the overlying muscles. Hence following fracture, when periosteal blood supply is lost, the collateral skeletal muscle perfusion is required for fracture healing. And muscle ischaemia in compartment syndrome leads to a decline in periosteal blood supply and contributing to non-union.[30]

Intramedullary Nailing of Tibia

Diaphyseal fractures of tibia are best treated with reamed intramedullary nailing. However, Koval et al and Moed and Strom have implicated that reaming could possibly be a cause of acute compartment syndrome.[16, 26] Intra-compartmental pressure was measured during reamed and unreamed intramedullary nailing of tibia by McQueen et al and Tornetta and French respectively.[22, 35] From their studies, they agreed that intra-compartmental pressure was elevated during reaming and nail insertion, but dissipated postoperatively. And also that nailing was not likely to produce acute compartment syndrome. Nassif et al performed a similar study and found no difference in the intra-compartmental pressure in both reamed and unreamed nailing.[29] Galanakos et al and Shakespeare and Henderson attributed the development of acute compartment syndrome in nailing to fracture reduction and traction. Wrong positioning of limb and high limb elevation were also identified as factors.[7, 34] Hak and Georgiadis agreed on the use of locked unreamed intramedullary nailing of tibia following fasciotomy in acute compartment syndrome, as a method of optimal internal fixation, as the protocol simplifies and bony and soft tissue management.[9, 11]

Wound closure

To prevent persistent elevation of the intra-compartmental pressure, fasciotomy wounds are never closed primarily. After 48 hours, a ‘second look’ procedure is undertaken, and closure is considered only if the muscle groups are viable.[21] Soft-tissue edema is the major factor in deciding the timing of wound closure. Delayed primary closure must be done without tension on the skin edges. And soft-tissue coverage of the muscles, tendons and nerves is possible only after appropriate reduction of edema. So, delayed wound skin closure or split-skin grafting should be done only after edema has subsided sufficiently.[40] If delayed primary closure cannot be achieved, other methods of wound closure should be considered. Dermato-traction and shoe-lace techniques have been employed to avoid complications of split skin grafting. But the method can produce skin edge necrosis and may require a long time, maybe even up to 10 days, for closure.[2, 14] Though split skin grafting offers immediate skin cover, there is higher rate of morbidity, as noted by Fitzgerald et al.[6] Webb found that the use of Vacuum assisted cosure (VAC) has reduced complications and need for split skin grafting.[38]

Missed Compartment syndrome

The main cause of missed or late compartment syndrome is the delay in presentation. The patient usually presents in varying stages of muscle infarction, contracture, secondary deformities and neurologic involvement. The timing of decompression plays a major role in determining the outcome, as fasciotomy, after established muscle necrosis, is most likely to cause secondary infection. The necrosed muscle acts as a suitable culture medium and can lead to a severe sepsis and other systemic effects, similar to crush injury and sometimes even requiring amputation.[21, 40] In the possibility of partial necrosis of the muscles and compartment pressures indicating need for decompression, fasciotomy can be done to salvage the viable muscle. But thorough debridement of the necrotic muscle is mandatory to reduce the chances of infection.[21]

Complications

Rorabeck and Macnab identified persistent muscle weakness, total loss of muscle power, fulminant sepsis needing amputation as complications arising due to delayed presentation.[33] Court-Brown and McQueen identified non-union as a complication.[4] However, it was Nario who was the first to establish that obliteration of "musculo-diaphyseal" vessels following compartment syndrome lead to pseudarthrosis of tibia.

McQueen in his studies postulated that there was decreased blood flow to the long bones following failure of the ischaemic muscles to develop extraosseous blood supply and leading to non-union.[23]

Outcome

Turen concluded from his study that compartment syndrome converted closed fractures into open types and hence significantly lengthening the time of bony healing. And also the method of fixation did not affect the time of healing for closed or open fractures associated with compartment syndrome.[28]

Mullet et al observed that the functional outcome in patients with compartment syndrome following intramedullary nailing, who underwent fasciotomy within 12 hours was good compared to the poor outcome of those who underwent fasciotomy after 24 hours.[37] Similar observations were made by Azar, who also concluded that no benefit can be obtained from fasciotomy after the third or fourth day, as reports of severe infection in the necrotic muscle have been made.[3] In cases of foot drop, tendon transfers and foot stabilization may be required. Eventual scarring and contracture of anterior compartment musculature can prevent foot drop, till which a foot drop brace is required.

MATERIALS & METHODS

MATERIALS AND METHODS:

A review of patients admitted in the Orthopaedic department at our institution from January 2005 to December 2010 was carried out. Patients who presented with or developed compartment syndrome and associated with fractures were chosen.

Compartment syndrome was diagnosed clinically in all the cases, except one. Passive stretch pain and severe pain out of proportion were the main clinical indicators considered. Paraesthesia, paralysis and pulselesness were considered to be supportive of the diagnosis. Compartment pressure was measured in one patient who had a spinal injury. Decision to perform fasciotomy was carried out based on the Δp value. Δp was calculated by the difference between the patient's diastolic pressure and compartment pressure. Fasciotomy is indicated if the value was less than 30mm Hg.[24]

All the patients who had developed compartment syndrome of the leg were treated with double incision faciotomy, Anterolateral and

Posteromedial. Compartment syndrome of forearm was treated with single volar incision fasciotomy, while that of thigh also was treated with a single lateral incision.

The fractures were treated with external, internal or hybrid fixation.

The fasciotomy wounds were taken up for secondary closure from 4 to 7 days after fasciotomy with split skin grafting.

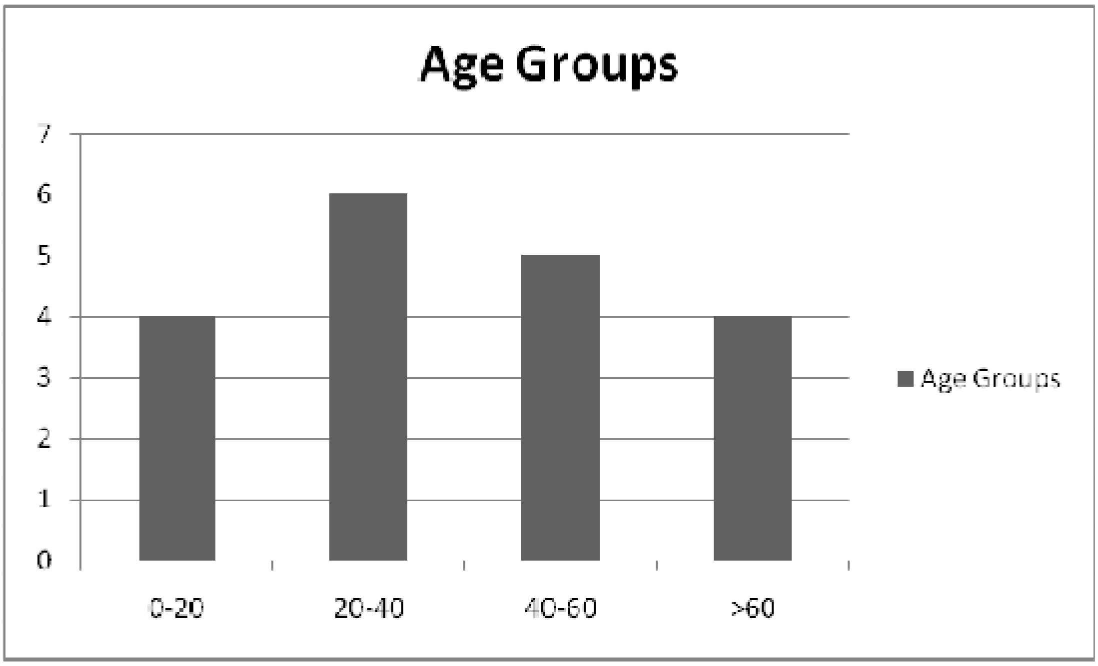
Patients were followed up every month for the first 6 months and then every 6 months. All the patients, who were reviewed, were functionally assessed based on Upper Extremity Functional Index (UEFI) and Lower Extremity Functional Scale (LEFS).

Painless unprotected weight-bearing and presence of bridging callus on X-ray were together considered as signs of bony union.

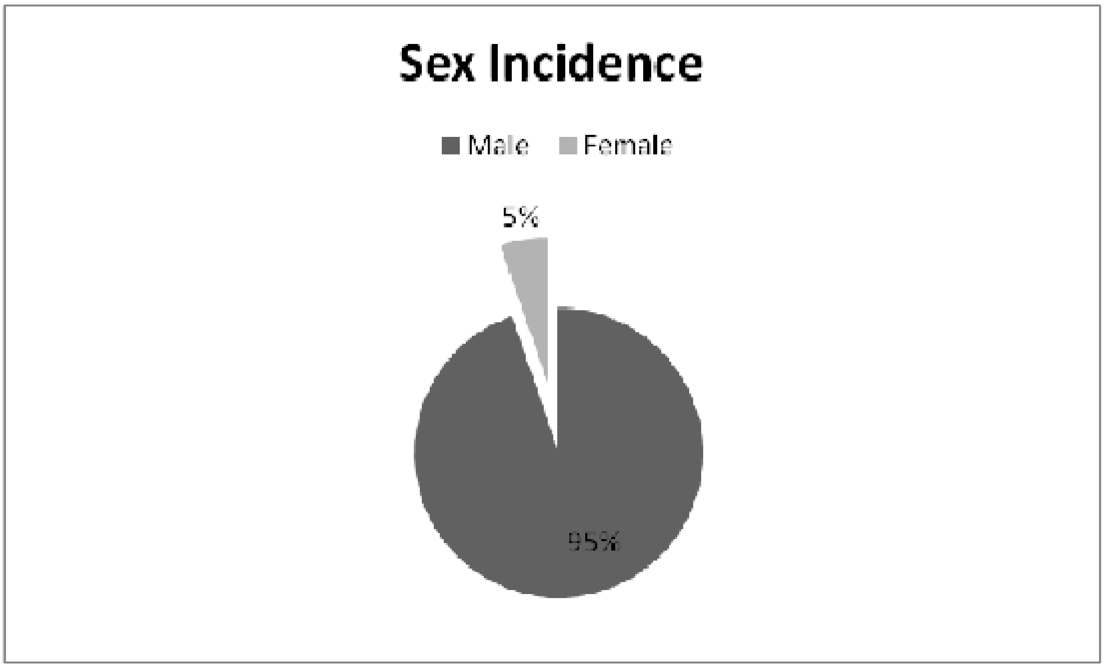
RESULTS

RESULTS

There were 21 patients who were diagnosed with compartment syndrome and underwent fasciotomy for the same. But compartment syndrome in 2 of the patients (one male and female; Cases 4 & 5, Master Chart) were not associated with fractures and hence excluded from the study.



Graph 1- Age distribution



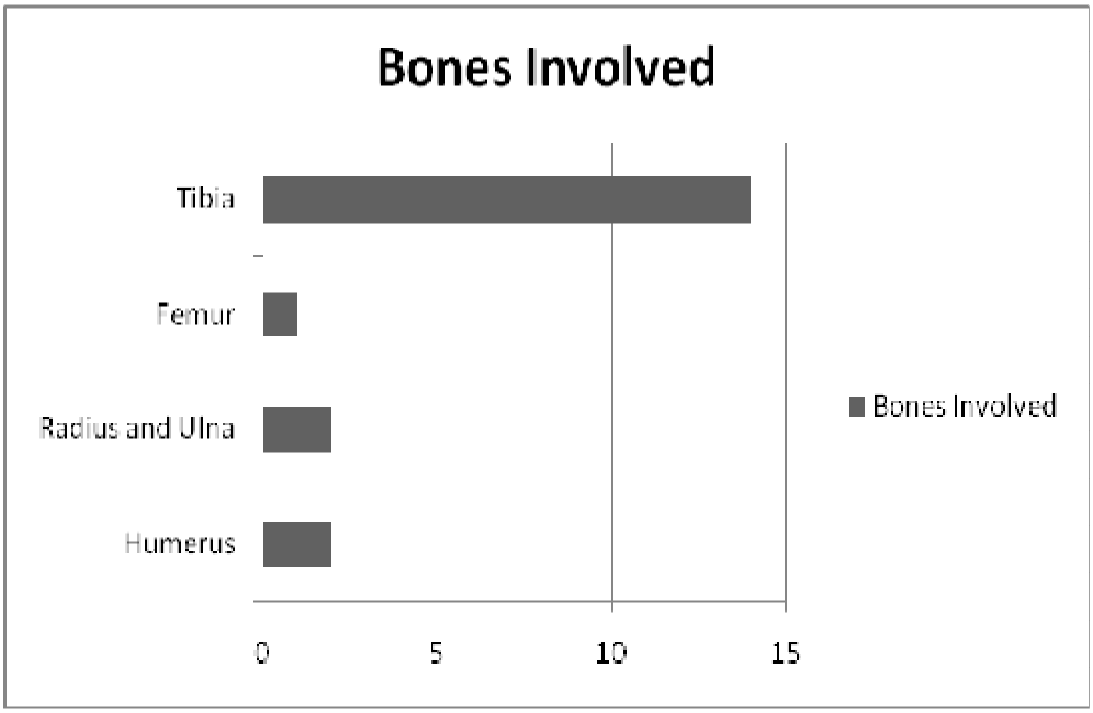
Graph 2- Sex Incidence

Incidence of compartment syndrome was found to be more common in physiologically young males, especially in the 3rd and 4th decades of life. This is probably due to the comparatively increased muscle mass in younger individuals. (Graph 1, 2)

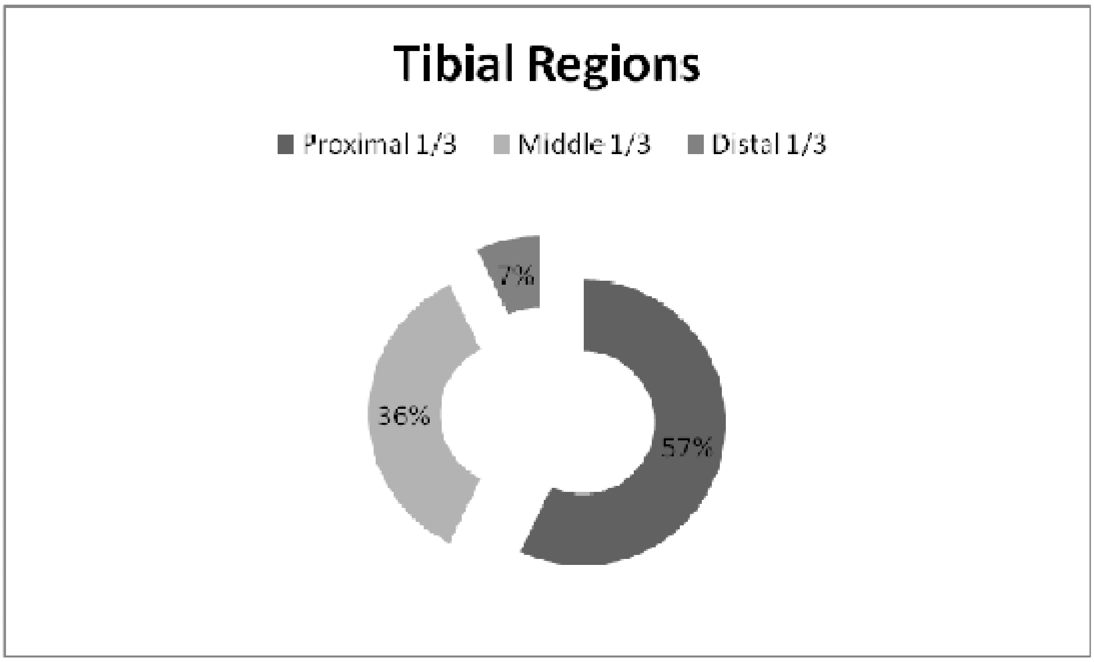
Mode of Injury	No. of cases
Road Traffic Accidents	16
Fall from Height	2
Industrial Injury	1
Trivial Fall	1

Table 1 – Modes of injury

Compartment syndrome is more frequently seen in fractures due to high velocity injuries, mainly in Road Traffic Accidents. (Table 1)



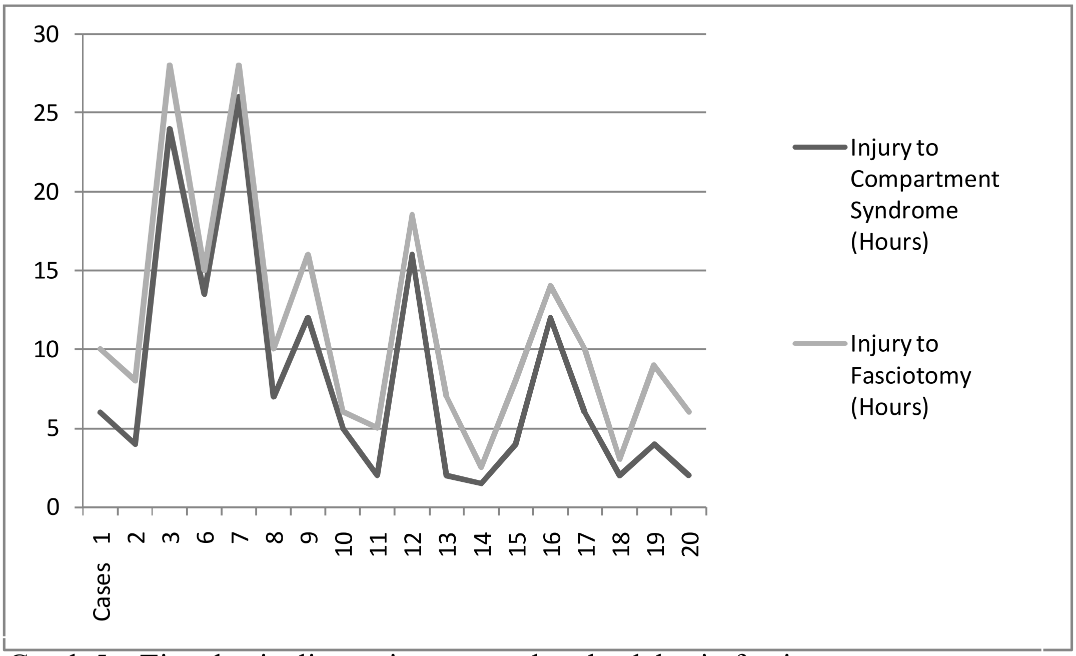
Graph 3- Distribution of bones involved



Graph 4 – Tibial zones involved

Fifteen of the fractures involved Tibia. Of the fifteen Tibia fractures, three involved the Tibial plateau and one involved a proximal Tibia epiphyseal injury and the rest involved tibial diaphysis. Compartment syndrome frequently occurs in Tibia compared to all other sites. Occurrence in Proximal one-third Tibial is the commonest. (Graph 3, 4)

Of the remaining patients, one was a subtrochanteric fracture of the femur. The patient developed compartment syndrome of thigh probably as a consequence of the renal failure he was suffering from. Two were fractures of both bones forearm. One was a fracture around the elbow involving Medial Epicondyle and Olecranon. One patient had additional injuries along with Tibial fracture involving the ipsilateral Femur and Humerus and also compartment syndrome involving the forearm. One patient (case 21) had sustained a D12 compression fracture with altered neurology of both lower limbs, along with a Tibial plateau fracture (internally fixed in an institution outside). When he presented 10 days later, he had the altered neurology and also passive stretch pain with swelling of the affected leg.



Graph 5 – Time lag in diagnosis compared to the delay in fasciotomy

The compartment syndromes were diagnosed by clinical monitoring. The delay in development of Compartment syndrome following injury was 8.3 hours (1.5 hours to 26 hours, excluding case 21). The average delay in performing the fasciotomy after injury was 11.3 hours (2.5 hours to 28 hours).

There was a delay in 2 of the cases (Case 3 and 7) presenting to our institution as they received first aid in an outside institution primarily.

Case 21, a 10 day old missed post-operative compartment syndrome, was not considered in the time of delay, because it was a case of established and missed compartment syndrome, on presentation from a different hospital. The patient's intra-compartmental pressure of all the compartments of the leg was measured using an electronic arterial-pressure monitor by an infusion technique. The ΔP of the involved leg was found to be 10mmHg, indicating the need for fasciotomy. ΔP of the other leg was found to be 40mmHg.

All patients were clinically monitored for compartment syndrome from time of presentation, and also post-operatively. During the study, two distinct groups of patients were identified.

1. Patients who presented with compartment syndrome following a fracture
2. Patients who developed compartment syndrome after surgical fixation of a fracture (cases 1, 2, 6, 8, 9 and 14)

Compartment Syndrome Following	No. of patients
Fracture	12
Surgical fixation of fracture(s)	6

Table 2 – Grouping of patients with compartment syndrome

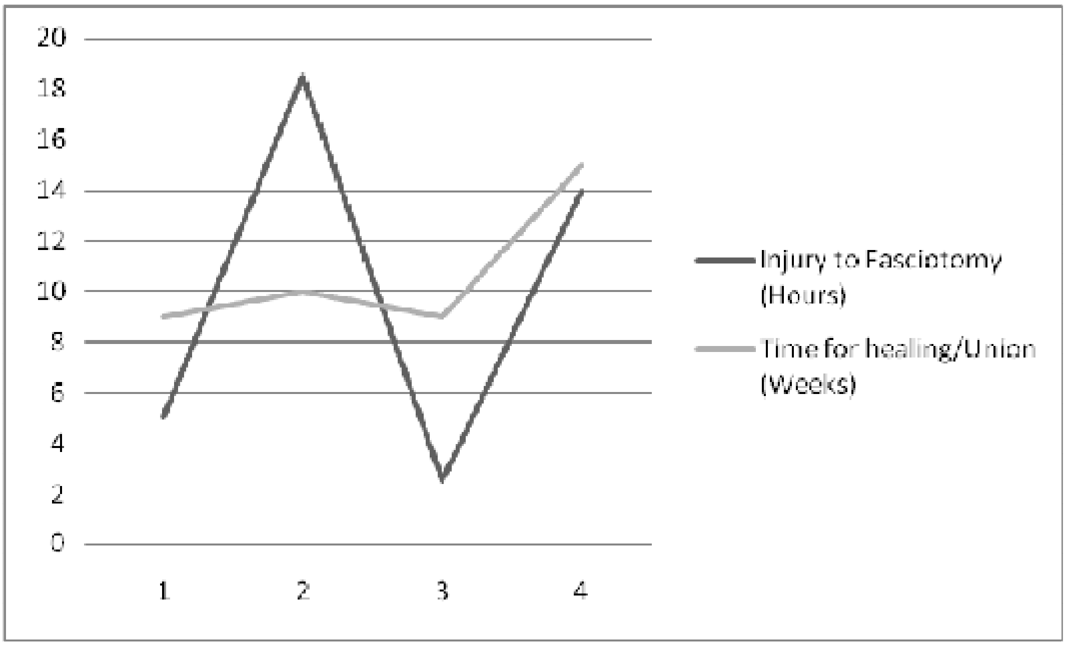
Of the 12 pateints who developed compartment syndrome after a fracture, 7 cases which were monitored from admission developed compartment syndrome. And they were taken up for fasciotomy with appropriate fixation.

Of the 18 cases considered, 6 of the fractures (Cases 1, 2, 6, 8, 9 and 14), 5 tibial diaphyseal fractures and 1 ulna fracture, treated with Intramedullary nailing developed compartment syndrome post-operatively. Pre-operatively, four of the fracture limbs were found to be edematous. All the 6 cases were diagnosed with compartment syndrome post-operatively after intramedullary nailing. The delay in establishing the diagnosis of Compartment syndrome following intramedullary nailing was 8.5 hours (4 hours to 13.5 hours), caused probably by reduction of the fracture prior to intramedullary fixation. And the average delay in fasciotomy after intramedullary nailing was 11.8 hours (8 hours to 16 hours).

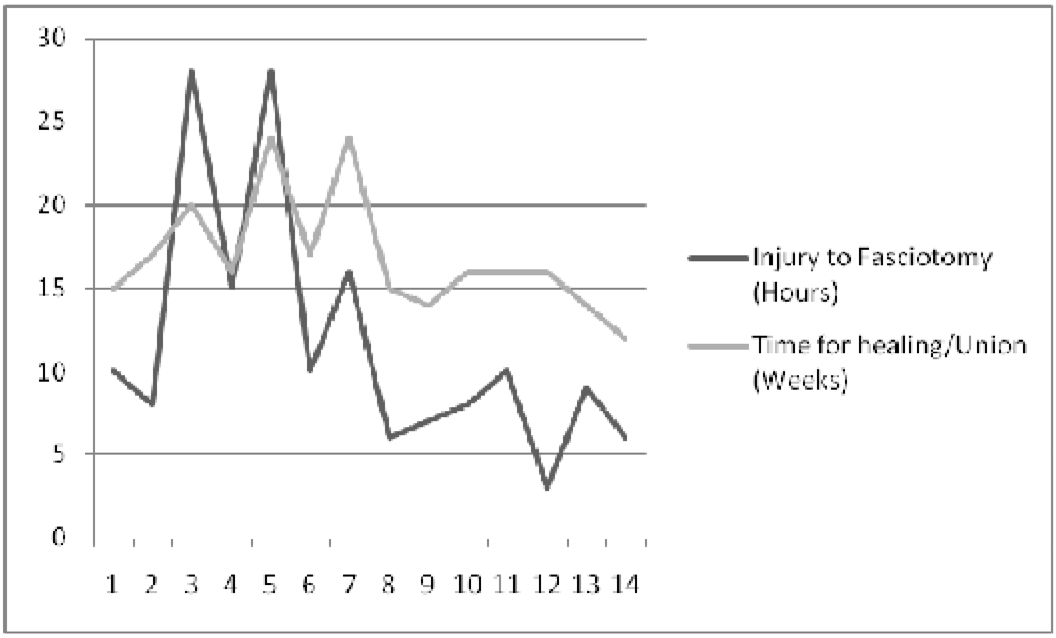
Of the fifteen Tibial fractures, 6 were treated with intramedullary nailing (One-Unreamed nail), 4 were treated with Hybrid fixation, 3 were treated with external fixation and the Proximal Tibia epiphyseal injury (case 20) was treated with cancellous screw fixation. One patient with tibial plateau fracture was treated with Hybrid fixator primarily. (Case 17) The external fixation was converted to internal fixation by means of intramedullary nailing after 3 weeks. One patient underwent internal fixation for Tibial plateau fracture in an institution elsewhere before presenting to us. The subtrochanteric fracture was treated with Dynamic Condylar Screw and one of the forearm fractures was treated with K-wire fixation while the other was treated with Ulna square nail. And the elbow fracture was treated with internal fixation. The time lag in diagnosis, delay in fasciotomy and method of fixation of each case has been detailed in the Master Chart.

Except one, none of the cases had incidence infections or non-union. The patient who developed infection was a case of missed compartment syndrome.

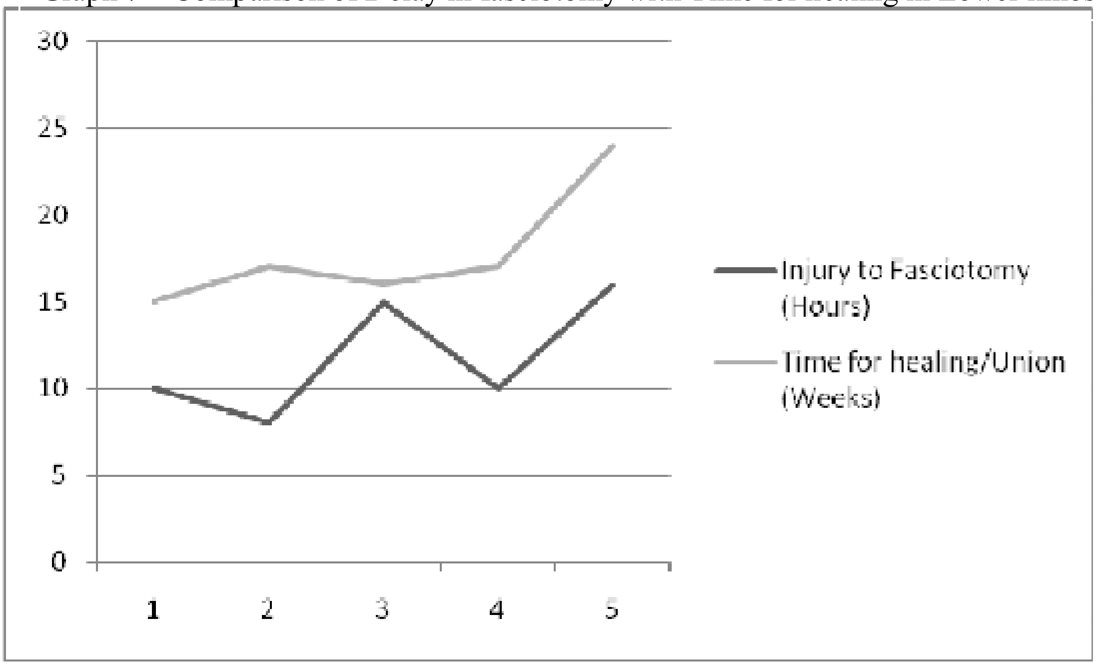
All the patients were reviewed with an average follow-up of 33 months (6 months to 60 months). 2 patients (case 3 and 6) died due to unrelated causes. One patient (case 21) died due to sepsis leading to Multi Organ Failure secondary to a 10 day old missed compartment syndrome.



Graph 6 – Comparison of Delay in fasciotomy with Time for healing in Upper limbs



Graph 7 – Comparison of Delay in fasciotomy with Time for healing in Lower limbs



Graph 8 – Comparison of Delay in fasciotomy with Time for healing in

Post-Operative Comaprtment Syndrome

The average time of healing in upper limb fractures was 11 weeks (9 to 15 weeks) and in lower limb fractures was 17 weeks (12 to 24 weeks). In two tibial fractures, the delay in healing needed bone grafting. (Graph 6, 7) Healing was relatively delayed in patients who had undergone fasciotomy 10 hours after the injury or internal fixation compared to those who had gone fasciotomy in less than 10 hours, in case of both upper and lower limb fractures. (Graph 6, 7)

3 patients (case 1, 9 and 16) had neurological insult secondary to acute compartment syndrome. One patient (case 1) had weakness (Power 1/5) of the anterior compartment muscles of the leg at the time of diagnosis of compartment syndrome. He went on to recover partially (Power 3/5) over a period of 3 months and then no further. Another patient had weakness (Power 3/5) of Extensor hallucis Longus at time of diagnosis of compartment syndrome and went on to recover in 3 weeks. One other patient (case 16) had developed severe Volksmann Ischemic Contracture of the forearm due to delay in presentation to the hospital and hence delay in fasciotomy. The average delay in fasciotomy following injury in

these 3 cases was 13 hours (10 hours to 16 hours). Though the risk of infection is high, except one, none of our cases had any infection. Severe and extensive muscle necrosis of most of the muscles of the leg was found during fasciotomy of one of the patients (case 21), which ultimately led to sepsis and Above Knee amputation of the limb.

Two of the cases (Case 7 and 9) had no signs of union at the end of 12 weeks both clinically and radiographically. The patients required bone grafting as a secondary procedure at 3 months to induce bony healing. The patient with Volksmann Ischemic Contracture lost functionality of the upper limb, from elbow distally.

Image 6 – An example of Anterolateral and Posteromedial fasciotomy of the leg from the study

Image 7 - Muscle necrosis following missed compartment syndrome (Case 21)

Functional Outcome

Upper Extremity Functional Index (UEFI) and Lower Extremity Functional Scale (LEFS) were used in assessment of the present level of functionality of the patients reviewed.

CASE	AGE (YEARS)	DELAY IN FASCIOTOMY (HOURS)	FUNCTIONAL OUTCOME SCORE	% OF MAXIMAL FUNCTION
1	20	10 hours	72	90
2	52	8 hours	70	88
3	56	28 hours	N/A	N/A
6	78	15 hours	N/A	N/A
7	30	28 hours	67	84
8	55	10 hours	69	86
9	62	16 hours	64	80
10	56	6 hours	75	94
11	8	5 hours	80	100
12	30	18.5 hours	72	90
13	23	7 hours	78	98
14	22	2.5 hours	79	99
15	44	8 hours	72	90
16	19	14 hours	0	0
17	63	10 hours	70	88
18	30	3 hours	72	90
19	37	9 hours	69	86
20	16	6 hours	79	99
21	66	10.2 days	N/A	N/A

Cases 3, 6 and 21 – Lost to follow-up

Table 3 – Functional outcome of the cases

The functional outcome is decreased in patients who had undergone fasciotomy after 10 hours. However, younger patients showed better recovery even if they had undergone fasciotomy after 10 hours, compared to older patients.

Patient Groups	Average Functional outcome
Compartment syndrome after a Fracture	85%
Compartment syndrome after Fracture fixation	86%

The average functional outcome score of the cases, excluding those lost to follow-up is 68 and percentage of maximal function is 85%. The decrease in functional outcome score was due to the dysfunctional status of the affected limb in case 16. The percentage of maximal function increased to 91% on excluding case 16. The average percentage of maximal function of cases with post-operative compartment syndrome (Cases 1, 2, 8, 9) was 86%, compared to the 85% in cases primarily diagnosed with compartment syndrome (93% on excluding Case 16). No significant difference was found in the functional outcome of both the group of patients.

A Case of Tibial Plateau Fracture

A Case of Tibial Plateau Fracture (Contd…)

A Case of Tibial Plateau Fracture (Contd…)

MASTER CHART

S No	Age, Sex	Mode of Injury	Injury	Diagnosis Time Lag	Fasciotomy Delay (Hours)	Surgical procedures done	Time for healing/Union (Weeks)
1	20,M	RTA	Right Leg - Tibia Upper 1/3	6 hours (Post IM nailing)	10 hours	IM Nailing Fasciotomy SSG	15 weeks
2	52,M	RTA	Right Leg - Tibia Upper 1/3	4 hours (Post IM nailing)	8 hours	IM Nailing Fasciotomy SSG	17 weeks
3	56,M	Trivial fall K/C/O SHT with ARF	Right Thigh Subtrochant-eric fracture of Femur	24 hours (First aid taken outside)	28 hours	Fasciotomy Skeletal Traction Biological DCS & SSG	20 weeks
4	48,F	Industrial Crush Injury	Right Forearm (No Fractures)	2 hours	4 hours	Fasciotomy	n/a
5	20,M	Industrial Crush Injury	Right Forearm (No Fractures)	2 hours	6 hours	Fasciotomy	n/a
6	78,M	RTA	Left Leg - Tibia Upper 1/3	13.5 hours (Post IM nailing)	15 hours	IM Nailing Fasciotomy SSG	16 weeks
7	30,M	RTA	Left Leg - Tibia Lower 1/3	26 hours (First aid taken outside)	28 hours	Fasciotomy External Fixation SSG	24 weeks Required Bone grafting

S No	Age, Sex	Mode of Injury	Injury	Diagnosis Time Lag	Fasciotomy Delay (Hours)	Surgical procedures done	Time for healing/Union (Weeks)
8	55,M	RTA	Right Leg - Communited Tibia Middle 1/3	7 hours (Post IM nailing)	10 hours	IM Nailing Fasciotomy SSG	17 weeks
9	62,M	RTA	Right Leg - Tibia Upper 1/3	12 hours (Post IM nailing)	16 hours	IM Nailing Fasciotomy SSG	24 weeks Required Flap cover and Bone grafting
10	56,M	RTA	Right Leg - Tibia Middle 1/3 Communited and segemental	5 hours	6 hours	Fasciotomy External Fixation SSG	15 weeks
11	8,M	Fall from height	Right Forearm - Both bones proximal 1/3	2 hours	5 hours	Fasciotomy K-wire Fixation	9 weeks
12	30,F	Bus Runover	Right Elbow - Medial epicondyle & Olecranon	16 hours	18.5 hours	Fasciotomy Internal fixation SSG	10 weeks
13	23,M	RTA	Left Leg - Tibia Middle 1/3 Communited	2 hours	7 hours	Fasciotomy with Unreamed nailing	14 weeks
14	22,M	Industrial Injury	Right Forearm - Radius Segmental & Ulna Proximal 1/3	1.5 hours (Post IM nailing)	2.5 hours	Square nailing of Ulna Fasciotomy SSG	9 weeks

S No	Age, Sex	Mode of Injury	Injury	Diagnosis Time Lag	Fasciotomy Delay (Hours)	Surgical procedures done	Time for healing/Union (Weeks)
15	44,M	RTA	Right Leg - Tibia Middle 1/3 Communited and segemental	4 hours	8 hours	Fasciotomy Hybrid Fixation SSG	16 weeks
16	19,M	RTA	Right Humerus Mid shaft Right Femur Middle 1/3rd Right Tibia Grade IIIB Middle 1/3	12 hours	14 hours	External Fixation Fasciotomy AK amputation Right forearm reconstructi on	15 weeks
17	63,M	RTA	Right leg - Tibia Proximal 1/3 Segmental	6 hours	10 hours	Fasciotomy Hybrid Fixation SSG IM Nail conversion	16 weeks
18	30,M	Fall from height	Right Leg - Tibial Plateau Schatzker Type VI	2 hours	3 hours	Fasciotomy Hybrid Fixation SSG	16 weeks
19	37,M	RTA	Right Leg - Tibial Plateau SChatzker Type IV	4 hours	9 hours	Fasciotomy Hybrid Fixation Cancellous screw fixation SSG	14 weeks
20	16,M	RTA	Right Leg - Proximal Tibia Epiphyseal Injury	2 hours	6 hours	Fasciotomy Cancellous screw fixation SSG	12 weeks

S No	Age, Sex	Mode of Injury	Injury	Diagnosis Time Lag	Fasciotomy Delay (Hours)	Surgical procedures done	Time for healing/Union (Weeks)
21	66,M	RTA	Left Leg - Tibial Plateau Schatzker Type VI (Internal fixation in a different institution 10 days back)	10 days (Missed CS)	10.2 days	Fasciotomy Amputation (Death due to ARF, Cardiac arrest)	n/a

n/a - Not Applicable

Table 1 – Patients list with time lag in diagnosis, delay in fasciotomy, surgical procedures underwent and time of healing

DISCUSSION

DISCUSSION

Compartment syndrome has been extensively studied. But difficulty and delay in diagnosis of the condition is the major problem encountered. The management of fractures associated with compartment syndrome also does not have fixed guidelines.

The study analyses nearly all the issues involved in management of the compartment syndrome and the associated fractures.

The study shows that compartment syndrome commonly occurred in physiologically young males, similar to all other studies.[1, 21, 25, 37] And high velocity injuries were also identified as the major cause of compartment syndrome as in most studies.[1, 21, 25, 37] Compartment syndrome of leg was the most common followed by that of forearm. And tibial fractures were the major cause of compartment syndrome of leg. McQueen et al showed that 36% of compartment syndromes follow tibial diaphyseal fractures.[22] Of all tibial fractures, proximal tibial fractures were most commonly involved. The higher incidence of compartment syndrome in proximal tibial fractures has been attributed to the vulnerable blood supply of the popliteal artery and the posterior tibial artery, due to the vessel bifurcation and enclosing tight osseofascial canal.

Six of our cases developed compartment syndrome after the associated fracture was treated by surgical stabilization. McQueen et al found an incidence of 5.5% compartment syndrome in fractures treated by reamed nailing compared with 12.2% in externally fixed fractures.[22] The cause of compartment syndrome in post-operative cases has been postulated to be the sudden decrease in compartment size following reduction of the fracture prior to intramedullary fixation.

All diagnoses of compartment syndrome were made clinically. One patient was diagnosed with compartment syndrome 10 days after internal fixation of a tibial plateau fracture. The compartment syndrome was missed due to the spinal injury sustained by the patient and altered neurology below the thoracic level. All patients with tibial and forearm fractures were monitored clinically, for stretch pain and out of proportion pain, preoperatively from admission and also postoperatively.

Cases at risk of developing compartment syndrome were identified and monitored. Measurement of intra-compartmental pressure was done only for patients under nerve blocks, with altered state of consciousness, with spinal cord injury and children who are not able to express themselves. In other patients, intra-compartmental pressure was measured only when clinical signs are inconclusive and to determine the need for fasciotomy. McQueen emphasized in numerous studies that diagnosis of compartment syndrome can be made only by continuous monitoring of the intra-compartmental pressure.[4, 21, 22, 23, 24] Continous intra-compartmental monitoring is preferred to a single reading. However, Twaddle and Amendola stressed that continuous monitoring of all patients is not feasible due to the need for equipment and manpower. They advised clinical monitoring to diagnose compartment syndrome and to measure intra-compartmental pressure in a specified group of patients as mentioned above. And they observed that the judicious use of monitoring is required to prevent over diagnosing compartment syndrome.

Turen proposed that skeletal stabilization of fractures was needed immediately after fasciotomy to aid in the healing of soft-tissues which was also concurred by Twaddle and Amendola.[36, 37] Georgidas and Hak et al observed that, closed fractures and uncontaminated open fractures, presenting with compartment syndrome, can be treated with primary internal fixation following fasciotomy, as there are low or negligible risks of infection and non-union .[9, 11] And this treatment protocol simplifies the bony and soft tissue management. During primary internal fixation, some soft tissue cover must be obtained to cover the implant and fracture site.

Twaddle and Amendola observed that the stabilization technique used depends on the location and character of the fracture and the skill of the surgeon, but should minimize operative trauma to a limb that may already have had its circulation compromised. Therefore, if possible, intramedullary nailing to stabilize the bone (and hence the soft tissues) is recommended. After the osteosynthesis has been completed, soft tissue coverage over the bone should be attempted.[37]

All the fractures in our study were stabilized after fasciotomy by external fixation or internal fixation. Following fasciotomy, the fracture was considered to be an open one.

In metaphyseal and metaphyseal-diaphyseal fractures, we used external fixation as the method of choice for primary stabilization. We used external fixation as the primary method of stabilization in 9 of the 15 tibial fractures. For juxta-articular fractures, we used external fixators or hybrid fixators. Hybrid fixators with interfragmentary screw fixation were used in 4 cases of which 2 were tibial plateau fractures. The integrity of the articular surface was maintained by means of the hybrid fixators. The advantages of external fixation are the safety and ease of application, less devitalization of soft tissues and decreased operating time. Difficulties were faced in early mobilization of the patient and wound care.

Of the 6 tibial diaphyseal fractures, 5 were treated primarily by means of external fixation. External fixation was used in diaphyseal fractures, when there was a delay in fasciotomy and the viability of the muscles were in doubt and in cases without adequate soft tissue cover following fasciotomy. One of the cases treated with external fixator was taken up for intramedullary nailing at the earliest. The intramedullary conversion increased patient compliance. One tibial diaphyseal fracture was primarily treated with unreamed intramedullary nailing. Wound management was found to be easier after the internal fixation and the patient was also mobilized early. Early mobilization, easy accessibility to the fasciotomy wounds for wound care, considerable decrease in the bulk of the implant and patient compliance are the advantages of intramedullary internal fixation.

Plate osteosyntheis was never considered in any of the tibial fractures, as the risk of devitalizing the already compromised soft tissues and infection were high.

Bony healing was delayed in all cases irrespective of method of stabilization. Time of bony healing did not differ much from that of post-operative compartment syndromes. In both the groups of patients, those who presented with compartment syndrome following an injury and those who developed compartment syndrome after internal fixation, the fracture was considered to be open. Both the groups had delayed bone healing. The average time of bone healing was nearly the same in both groups. And the functional outcome of both the groups of patients was nearly the same. Acute complications encountered in our study were neurological insult in three of the patients who underwent delayed fasciotomy. Of the three, one patient recovered completely, another patient had incomplete recovery, while the third patient had no neurological recovery. Incomplete recovery or total absence of recovery is due to the development of myonecrosis during the compartment syndrome and consecutive fibrosis of the muscles.[27, 29]

Delay in diagnoses is primarily due to delay in presentation to our centre.

Infection of the fasciotomy wounds and fracture sites are expected. Fracture site is exposed during fasciotomy and the fasciotomy wound is left open for secondary closure increasing the chances of infection. In our study, none of the cases developed infection at the fracture site or fasciotomy wound.

All the cases in our study, including the cases that developed compartment syndrome post-operatively, had delayed bone healing. This is probably due to loss of fracture haematoma during fasciotomies. But bone healing was further delayed in patients who underwent fasciotomy after 10 hours compared to those who underwent fasciotomy earlier. Similar results were also observed by Mullet.[27] Court-Brown and McQueen found that complication rates decreased to 4 % from 54% with early fasciotomy.[4]

Functional outcome was decreased in our patients who had undergone fasciotomy after 10 hours. Younger patients showed better functionality. The functional outcome of patients who had post-operative compartment syndrome was no different from those who had presented with compartment syndrome. The functional outcome of any case is determined mainly by the delay in fasciotomy followed by age than any other factor. Mullet et al found that younger patients had better functional outcome. This was attributed due to change in the muscle-fiber composition and decreased muscle regeneration due to age.[27]

Shortcomings of the study are the limited of number of patients, the absence of a control group and also the analysis being done retrospectively. The chance of developing compartment syndrome has decreased considerably due to the early intervention following injury and advancement in monitoring patients early. In spite of these limitations, the factors influencing the outcome of the fractures associated with compartment syndrome were identified.

Orthopaedic surgeons must remain vigilant to identify compartment syndromes, both in in-patient and out-patient settings. Future development is likely to center around non-invasive methods of diagnosing acute compartment syndrome is being examined, like near infrared spectroscopy, which measures the amount of oxygenated haemoglobin in muscle tissues transcutaneously.

CONCLUSION

CONCLUSION

- ✓ A high suspicion of compartment syndrome must be maintained for all cases
- ✓ The early diagnosis and treatment within 12 hours is critical to reduce morbidity and prevent any long term sequale
- ✓ Compartment syndrome causes delay in bone healing
- ✓ Risk of infection is not increased
- ✓ External fixation is the method of choice in metaphyseal and metaphyseal-diaphyseal fractures and fractures without adequate soft tissue cover, when associated with compartment syndrome
- ✓ Hybrid fixators with intrafragmentary screw fixation are used in juxta-articular fractures with communition
- ✓ As bony healing is not compromised in any way, use of intramedullary fixation is not contraindicated in diaphyseal fractures associated with compartment syndrome

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ANNEXURE

SCORING INSTRUCTIONS

The columns on the scale are summed to get a total score. The maximum score is 80.

Interpretation of scores

- The lower the score the greater the disability
- The minimal detectable change is 9 scale points
- % of maximal function = Score/80*100

Performance

- The potential error at a given point in time was +/-5.3 scale points
- Test-retest reliability was 0.94

The Upper Extremity Functional Index (UEFI)

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your upper limb** problem for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, *do you* or *would you* have any difficulty at all with:

	Activities	Extreme difficulty or unable to perform activity	Quite a bit of difficulty	Moderate difficulty	A little bit of difficulty	No difficulty
1	Any of your usual work, housework, or school activities	0	1	2	3	4
2	Your usual hobbies, recreational or sporting activities	0	1	2	3	4
3	Lifting a bag of groceries to waist level	0	1	2	3	4
4	Lifting a bag of groceries above your head	0	1	2	3	4
5	Grooming your hair	0	1	2	3	4
6	Pushing up on your hands (eg from bathtub or chair)	0	1	2	3	4
7	Preparing food (eg peeling, cutting)	0	1	2	3	4
8	Driving	0	1	2	3	4
9	Vacuuming, sweeping or raking	0	1	2	3	4
10	Dressing	0	1	2	3	4
11	Doing up buttons	0	1	2	3	4
12	Using tools or appliances	0	1	2	3	4
13	Opening doors	0	1	2	3	4
14	Cleaning	0	1	2	3	4
15	Tying or lacing shoes	0	1	2	3	4
16	Sleeping	0	1	2	3	4
17	Laundering clothes (eg washing, ironing, folding)	0	1	2	3	4
18	Opening a jar	0	1	2	3	4
19	Throwing a ball	0	1	2	3	4
20	Carrying a small suitcase with your affected limb	0	1	2	3	4
	Column Totals:					

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE: _____ / 80**

Source: Stratford et al (2001): Development and initial validation of the upper extremity functional index. Physiotherapy Canada 53 (4): 259-67
Minimum detectable change (90% confidence): 6 points.

Lower Extremity Functional Scale (LEFS)

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your lower limb problem** for which you are currently seeking attention. Please provide an answer for each activity.

Today, *do you* or *would you* have any difficulty at all with:

Activities	Extreme difficulty or unable to perform activity	Quite a bit of difficulty	Moderate difficulty	A little bit of difficulty	No difficulty
1. Any of your usual work, housework or school activities.	0	1	2	3	4
2. Your usual hobbies, recreational or sporting activities.	0	1	2	3	4
3. Getting into or out of the bath.	0	1	2	3	4
4. Walking between rooms.	0	1	2	3	4
5. Putting on your shoes or socks.	0	1	2	3	4
6. Squatting.	0	1	2	3	4
7. Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
8. Performing light activities around your home.	0	1	2	3	4
9. Performing heavy activities around your home.	0	1	2	3	4
10. Getting into or out of a car.	0	1	2	3	4
11. Walking 2 blocks.	0	1	2	3	4
12. Walking a mile.	0	1	2	3	4
13. Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
14. Standing for 1 hour.	0	1	2	3	4
15. Sitting for 1 hour.	0	1	2	3	4
16. Running on even ground.	0	1	2	3	4
17. Running on uneven ground.	0	1	2	3	4
18. Making sharp turns while running fast.	0	1	2	3	4
19. Hopping.	0	1	2	3	4
20. Rolling over in bed.	0	1	2	3	4
Column Totals:	0	1	2	3	4

Source: Binkley JM, Stratford PW, Lott SA, Riddle DL. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther.* 1999 Apr;79(4):371-83.