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Original Article

Quantitative measurement of intra-compartmental pressure of the leg in acute traumatic injury: As a routine trend

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ABSTRACT

Background: Experience and literature regarding complications of lower extremity compartment syndrome led us to hypothesize that delayed diagnosis and limb loss are potentially preventable events. Clinical examination does play a role, but quantification of compartment pressure reading serves as confirmation and determines the need for surgical intervention and provides the only objective data in case of conflict.

Methods: We performed a prospective study of all cases of closed tibial fractures presenting to our trauma centre over a 3-year period (January 2009–June 2012). Variables reviewed included intra-compartmental pressure readings, location of the fracture and development of subsequent compartment syndrome requiring fasciotomy. Patients were divided into (1) Group A – proximal tibial fracture, (2) Group B – diaphyseal fracture and (3) Group C – Pilon fracture. Values of the injured and uninjured leg were taken and the data analyzed using SPSS version 22.

Results: 168 (41 females and 127 males) cases were analyzed. Mean pressure readings of the fractured limb were higher in Group A compared to the other groups. The mean difference in pressure values between the injured and uninjured limb recorded were of 15.1 mm Hg (Group A), 13.8 mm Hg (Group B) and 13.3 mm Hg (Group C). Patients who eventually underwent fasciotomy were 5 (10.8%) in Group A, 8 (10.3%) in Group B and 3 (6.8%) in Group C, and had initial baseline pressure difference of >18.5 mm Hg.

Conclusion: These data underscore the importance of routine recording of initial intra-compartmental pressure and relation of difference in compartmental pressure between injured and uninjured limb to eventual development of compartment syndrome requiring fasciotomy.

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Table 1 – Distribution of mode of injury in the study group.

Mode of injury	Number of patients
1. RTA	140 (83.3%)
2. Fall from height	18 (10.7%)
3. Assault	4 (2.3%)
4. Sports injury	6 (3.7%)
Total	168 (100%)

1. Background and Introduction

The most dreaded sequelae an orthopaedic surgeon expects in an injury to the leg is the development of compartment syndrome. Though early recognition and prompt treatment is the objective, diagnosis is usually delayed even after high suspicion and careful clinical evaluation, and by the time it is diagnosed, a considerable amount of physiological damage has already occurred before the frank development of pallor, pulselessness and so on.³

Measurement of compartment pressure continuously generally serves as an adjunct to clinical evaluation, but it is not available in most settings in our country² and has a limited use in patients with a low GCS (Glasgow Coma Scale) score or with an altered mental status.

Baseline elevations in compartments' pressure after the simple occurrence of a fracture before a clinical compartment syndrome develops are not defined. If such data exist it has the potential to influence the ultimate treatment outcome and provide better understanding and interpretation of pressure elevations during continuous pressure monitoring.¹

Approximately 40% of all compartment syndromes occur after fractures of the tibial shaft.²

Anterior compartment is the most commonly involved compartment of the leg in acute compartment syndrome.

Sheridan et al.,⁴ Gershuni et al.⁵ and McQueen et al.⁶ reported consistent involvement of the anterior compartment in tibial fractures complicated by acute compartment syndrome. As such they stated that monitoring of all four compartments is cumbersome and it seems unlikely that the anterior compartment will not be involved in an acute compartment syndrome. They recommend routine monitoring of anterior compartment and other compartments need to be investigated only if there is clinical suspicion of involvement. We intended to measure the level of the anterior compartment pressure and differential pressure in injured and uninjured leg and analyze the data for any prognostic or causative significance.

2. Materials and methods

168 (41 females and 127 males) patients presenting to MMIMSR trauma centre over a 3-year period (January 2009–June 2012) were included in this study. Patients included had unilateral closed tibial fracture presenting within 6 h of injury. Patients who were excluded were with soft tissue injury to the contralateral side of the fractured tibia, with compound fractures of tibia/fibula, having life threatening injuries, polytrauma, associated with comorbidities and altered mental status. A prospective analysis of compartment pressure measurements was performed in the tibial fractures with the opposite leg as the control. Consent was obtained for the measurement of normal compartmental pressures of anterior compartment of injured and contralateral uninjured legs. Approval was obtained from the Maharishi Markandeshwar University Teaching Hospital, Research and Ethical Committee. Variables reviewed included:

1. Intra-compartmental pressure readings of both limbs.
2. Pressure difference between injured and uninjured limb.
3. Location of the fracture.

Fig. 1 – Distribution of mode of injury in the study group.

Table 2 – Distribution of side of injury in the study group.

Side of the injury	No. of patients
Right	100
Left	68

Table 3 – Age and sex distribution in the study groups A, B and C.

Age group (years)	Number of patients (%)	Sex distribution	Group		
			A	B	C
1–10	0	M = 0 F = 0	–	–	–
11–20	1 (0.5%)	M = 1 F = 0	–	1	–
21–30	69 (41.1%)	M = 52 F = 17	19	21	12
31–40	78 (46.43%)	M = 58 F = 20	14	29	15
41–50	13 (7.73%)	M = 10 F = 3	4	4	2
51–60	7 (4.16%)	M = 5 F = 2	2	–	3
Total	168		51	78	39

4. Development of subsequent compartment syndrome requiring fasciotomy.

Patients who were diagnosed with proximal tibial fracture were allocated to Group A, those with diaphyseal fracture and Pilon fracture to Group B and Group C, respectively.

Proper radiographs of the involved extremities were taken. Anterior compartment pressures of the injured extremities were measured using the Whitesides' infusion technique.⁷ Precautions were taken not to depress the syringe plunger too

rapidly or place the needle into the tendon, as these may give a false high reading. A new needle was used for each measurement in order to assure accuracy and sterility.

Pressure measurements were taken at the level of fracture and not exceeding 5 cm away from the fracture site proximally and distally as compartment pressures have been found to be highest at the level of the fracture.⁸

Patients who were treated with fasciotomy had developed $\Delta x = \leq 30$ mm Hg pressure ($\Delta x =$ diastolic pressure – intra-compartmental pressure) and there is enough experimental and clinical work suggesting a pressure difference or delta pressure of ≤ 30 mm Hg should be considered diagnostic.^{6,9–11}

ΔP was calculated and was defined as difference in compartment pressure values of injured and uninjured leg.

McQueen and Court-Brown studied 116 patients with tibial diaphyseal fractures who underwent continuous pressure monitoring of the anterior compartment for 24 h. The use of Δx of ≤ 30 mm Hg as a threshold for fasciotomy led to no missed cases of compartment syndrome, no unnecessary fasciotomies and no complications in any patients.¹⁰ Patients who underwent fasciotomy had difference in pressure between the injured and uninjured leg noted and analyzed.

It should be noted that pressure readings were taken as part of a routine protocol for all the patients and only initial readings were used for this study and patients were then monitored continuously.

Statistical analysis was performed with SPSS software (version 14.0; SPSS, Chicago, IL).

3. Results

Road traffic accident was the commonest mode of injury and accounted for 83.3% of the cases in our series. Other modes of injury included fall from height (10.7%), sports injury (2.3%) and assault (3.7%) (Table 1; Fig. 1).

The mean anterior compartment pressures in Group A were 5.96 mm Hg (uninjured limb) and 20.84 mm Hg (injured

Fig. 2 – Distribution of side of injury in the study group.

Fig. 3 – Distribution of age groups in the study group.

limb). In Group B, uninjured limb mean pressure was observed to be 6.89 mm Hg and that of injured limb was 20.70 mm Hg. In Group C, mean anterior compartment pressures in the uninjured leg were 6.54 mm Hg and in the injured leg it were 19.79 mm Hg (Tables 4 and 5; Figs. 4 and 5).

100 patients (60%) had an injury to the right limb, with those in the age group of 31–40 forming the major proportion of patients (46.4%) (Tables 2 and 3; Figs. 2 and 3).

It was observed that all patients who presented to the emergency with an initial compartment pressure value of >30 mm Hg eventually had to undergo fasciotomy irrespective of the group they were assigned to. But the fact that should not be overlooked in these patients was that all these patients had an initial ΔP in the range of 21–25 mm Hg (Table 6).

We found that a ΔP of ≥ 18.5 mm Hg was the threshold for designating a patient as a high-risk candidate for development of compartment syndrome (Table 6).

No patient developed sequelae or required surgery related to an unrecognized compartment syndrome during a minimum 1-year follow-up.

Table 4 – Analysis of compartment pressure values recorded.

Group	Mean pressure in the injured limb (mm Hg)	Mean pressure in the uninjured limb (mm Hg)	Mean difference in pressure (mm Hg)
A	20.84	5.96	15.1
B	20.70	6.89	13.8
C	19.79	6.53	13.3

4. Discussion

The objective of this study was to determine the prognostic value of ΔP in patients for subsequent fasciotomy. We measured pressure values in both the limbs and found that compartment pressure in the uninjured limb was within the spectrum of normal values. Normal leg values differed significantly from the injured leg and were invariably lower. Our results provide compelling preliminary evidence for the prognostic ability of ΔP in patients with fracture in the leg and at risk of developing compartment syndrome. A statistically significant difference in pressure measurements was noted between the patients who eventually underwent fasciotomy and initial ΔP of ≥ 18.5 mm Hg.

Pressure values were higher in Group A than that of Group B and Group C. Although (continuous) pressure measurements

Table 5 – Analysis of compartment pressure values of the injured limb and eventual fasciotomy.

Pressure readings of the injured leg (mm Hg)	Group A	Group B	Group C	Fasciotomy
0–5	–	–	–	–
6–10	–	–	01	–
11–15	4	5	06	–
16–20	20	38	18	1
21–25	23	26	07	2
26–30	2	06	07	8
31–35	2	03	–	5
36–40	–	–	–	–

Fig. 4 – Distribution of age in the designated groups A, B and C.

Fig. 5 – Distribution of compartment pressure reading across the three groups.

Table 6 – Analysis of ΔP (compartment pressure in the injured limb – compartment pressure of the uninjured limb) and eventual fasciotomy.

ΔP (mm Hg)	Group A	Group B	Group C	Fasciotomy
0-5	1	–	–	–
6-10	4	17	13	–
11-15	22	42	15	–
16-20	20	12	08	4
21-25	4	07	03	12
26-30	–	–	–	–
31-35	–	–	–	–
36-40	–	–	–	–

are the trend to monitor the pressure and diagnose the syndrome as early as possible, we do not use or advocate routine pressure monitoring.

5. Conclusion

A clear relationship was shown between the differences in pressure, which is early elevation of compartment pressure in the injured leg from the normal level and was found to be ΔP of ≥ 18.5 mm Hg.

We assert to the fact that our results should be interpreted with caution, because further studies are needed and are underway.

Conflicts of interest

The authors have none to declare.

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