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A hospital based one year randomised controlled trial to determine optimum height of leg elevation in closed fractures of leg by invasive intra compartmental pressure monitoring

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Abstract
Introduction: Closed fractures of leg are common following RTA, which requires immobilization and leg elevation above heart level to reduce oedema formation and increase of compartment pressure leg elevation is routine in pre operative and post operative period to reduce intra compartment pressure whereas optimum height of elevation has not been standardized till now. Inadvertent elevation of leg decreases venous oedema whereas chances of muscle ischemia increases with prolonged and inappropriate elevation of leg. So determination of appropriate level of leg elevation above heart level by invasive method by white side's method will help reduce muscle ischemia and discomfort to the patient.
Purpose: To determine optimum height of leg elevation above heart level to reduce intra compartmental pressure.
Methods: Patients at KLES Dr. Prabhakar Kore Hospital with closed fractures of leg. Anterior compartment pressure measured with Whiteside's invasive method .Patients were randomly divided into two groups Group A: 15 cm of leg elevation and Group B:30 cm of leg elevation
Results: In this study 60 patients with closed fractures of tibia were selected for intra compartmental pressure monitoring and randomised for different weights of leg elevation i.e., Group A 15 cm above heart level and Group B 30 cm above heart level. The mean age of leg fractures in our study was 40.1 years. Male subjects were 85% (mean = 53) and female were 17% (mean = 7) of total of 60 patients.
The measurement of compartment pressure of normal leg was 9.4 ± 2.5 mm Hg. Pressure were measured within 5 cm of fracture site at 0 hr, 12 hr, 24 hr and 48 hr interval using Whiteside's method. The mean values at 0 hr were 29.17 ± 5.95 mm Hg, at 12 hr interval it was 29.97 ± 5.46 mm Hg, at 24 hr interval it was 23.36 ± 3.8 mm Hg and at 48 hr interval it was in Group A. The mean values at 0 hr were 32 ± 7.8 mm Hg, at 12 hr interval it was 32.33 ±57.65 mm Hg, at 24 hr interval it was 26.48 ± 3.5 mm Hg and at 48 hr interval it was in 25.19 ± 2.56 mm Hg in Group B. In our study 5 patients out of 60 underwent fasciotomy. All patients had differential or delta pressure below 30 mm Hg before fasciotomy.
Conclusion: Tibia fractures are commonest cause of compartment syndrome of leg. Whiteside's method is a reliable and safe method of measuring intra compartment pressure when sophisticated methods are not available. Inappropriate levels of leg elevation causes muscle ischemia. Elevation of leg to 15 cm leads same clinical results as 30 cm with the advantage of avoiding muscle ischaemia. There is further need for evaluation of different heights of leg elevation and review about our practice of leg elevation.

Keywords: RTA, randomised, determine optimum height, pressure monitoring

1. Introduction
Increase in intra compartmental pressure due to oedema and haemorrhage following fractures is inevitable, which may progress to acute compartment syndrome (ACS). Acute compartment syndrome is defined as the elevation of intra compartmental pressure (ICP) to a level and for a duration that without decompression will cause tissue ischemia and necrosis [1]. Compartment syndrome can be a life or limb-threatening emergency [2]. Early diagnosis is important for the prevention of disability [2].
Approximately 40% of all compartment syndromes occur after fractures of the tibia shaft fractures [3]. Following open or closed tibia fractures it is a common practice to immobilize and

elevate the leg above heart or body level in order to decrease tissue oedema and compartment pressure, with the goals of improving venous outflow and preventing the stasis of blood associated with a dependent position.

Elevation is also thought to decrease swelling, patient discomfort, wound complications, as well as the risk of compartment syndrome [6]. However, elevating a limb with increased compartment pressures has been shown to reduce perfusion pressure and contribute to tissue ischemia[6]. Therefore, the practise of leg elevation for a traumatized lower extremity in the peri operative Period remains controversial.

Elevation of leg elevation pre operatively and post operatively to reduce intra compartment pressure is a common practice where as optimum height of leg elevation has not been standardised till now to our best knowledge and search of literature.

The classical clinical features of five Ps (pain, pallor, paralysis, par aesthesia, pulselessness) cannot be always relied upon for early diagnosis of a developing acute compartment syndrome [8, 9]. Early diagnosis of Acute compartment syndrome is necessary to prevent its dismal permanent crippling [10]. Various methods of diagnosing acute compartment syndrome are invasive ICP measurement and non invasive methods [11].

Intra compartmental pressure measurement is a reliable objective method for early and accurate diagnosis of compartment syndrome [11-17]. Anterior compartment is the most commonly involved compartment of the leg in acute compartment syndrome [1]. Invasive methods like Whiteside's method has been a time tested and standardised way of measuring ICP [18]. Various non invasive measurement techniques are also available.

Recent studies using Near infrared spectroscopy (NIRS) in healthy individuals with tourniquet to mimic Acute compartment syndrome in laboratory conditions, oxygen levels were measured in anterior and posterior compartment muscles with leg elevated to different heights above heart levels. Observations were made that as leg was elevated oxygen level dropped linearly with height of elevation above heart level [6, 7].

Few other studies challenged the merits of practice of leg elevation following closed tibia fractures. These studies prompted us to find out appropriate level of leg elevation during peri-operative period to avoid inadvertent injury from inappropriate leg elevation.

According to Arterio-venous (AV) gradient theory increase in local tissue pressure reduces the AV gradient and thus reduce the blood flow [19, 20].

$$LBF = (P_a - P_v)/r$$

Matsen *et al*. presented results on human subjects that elevation of the limb in the presence of raised tissue pressure reduced AV gradient which in turn reduced blood flow which was later supported by studies on healthy individuals [1, 12]

Appropriate treatment in the form of decompression of the compartments has to be initiated at the earliest to prevent any permanent disability [2]. The purpose of this prospective randomised study was to measure and monitor the anterior compartment pressure in leg fractures at different heights of leg elevation to determine optimum height of leg elevation in clinical practise.

2. Materials &Methods

A careful physical examination was carried out to look for the clinical features of compartment syndrome including pain out of proportion with firmness of the compartment, pain on passive stretching of the involved muscles as well as paralysis, paraesthesia and pulselessness. Proper radiographs of the involved extremities were taken. Anterior compartment pressures of the injured extremities were measured using the Whitesides' infusion technique [6]. Whitesides' technique employs the following materials - i) One mercury manometer, ii) Two plastic intravenous extension tubes, iii) Two 18-gauge needles, iv) One 20-cc syringe, v) one three-way stopcock, vi) One bottle of bacteriostatic normal saline. The extremity to be measured is cleaned and sterility prepped. Sterile saline is drawn into the 20 ml syringe, which is attached to the three-way stopcock.

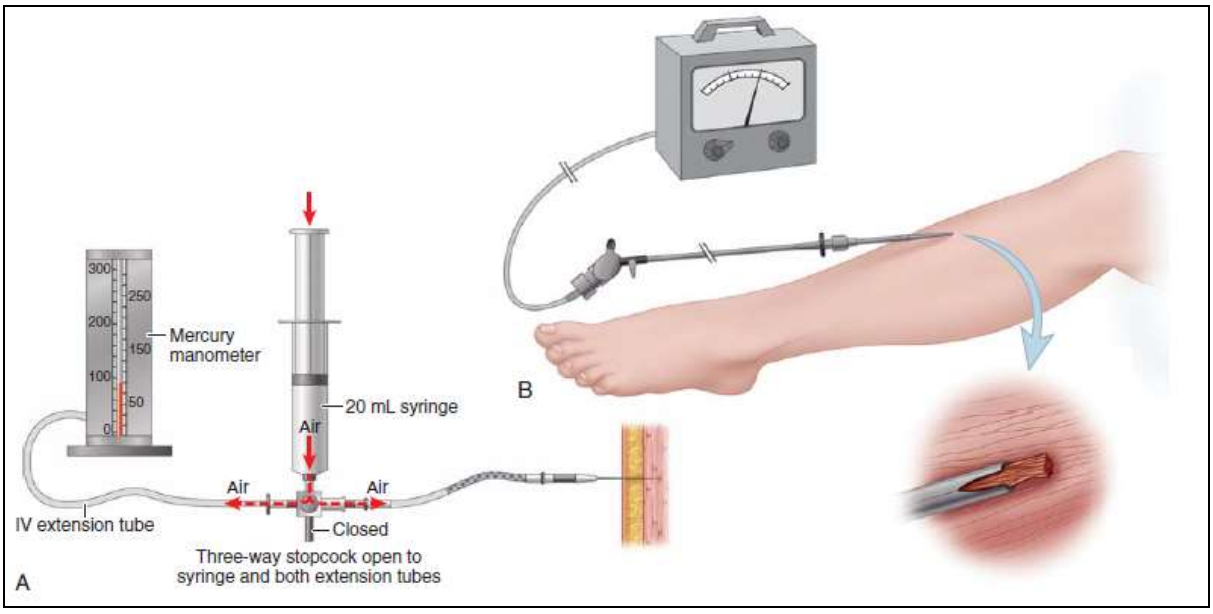

Fig 1: Technique of white side's *et al*. for determination of tissue pressure. A, Tissue pressure is measured by determining amount of pressure within closed system required to overcome pressure within closed compartment and inject minute amount of saline. B, Use of wick catheter for monitoring compartment pressure

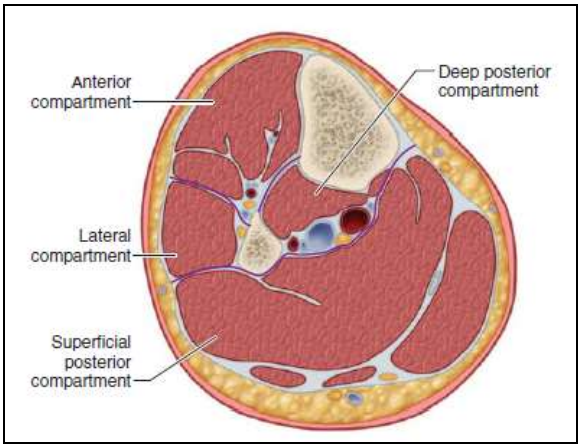

Fig 2: Four compartment of leg: transverse section through middle portion of left leg.

A single intravenous extension tube is attached to the stopcock and a second 18-gauge needle is attached to its other end. The third unused portion of the stopcock is closed off temporarily. The 18-gauge needle at the end of the extension tube attached to the stopcock is then inserted into the bottle of the saline. Saline is then aspirated without the bubbles into approximately half the length of the extension tube. The three-way stopcock is turned to close off this tube so that the saline is not lost during transfer of the needle. The second extension tube is then connected to the three-way stopcock at its remaining open part and its other end is connected to the manometer. The saline-containing needle is then inserted into the muscle of the extremity to be tested. The stopcock is then turned so that the syringe is opened to both extension tubes, forming a T-connection with a free column of air extending from behind the column of saline into the syringe as well as into the manometer. Pressure is increased in the system gradually by slowly depressing the plunger of the syringe while watching the column of saline. As the plunger is depressed, the saline meniscus will be altered from a convex configuration to a flat configuration, when the air pressure in the system equals the interstitial pressure in the patient's examined tissue. The manometer reading at this time is the tissue pressure in mm Hg. Precautions were taken not to depress the syringe plunger too rapidly or placing 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. Pressure measurements were taken at the level of fracture and at 5 cm and 10 cm away from the fracture site proximally and distally. Differential pressures were calculated by subtracting the absolute tissue pressure from the patients' diastolic blood pressure. Patients with high absolute tissue pressure (>50 mm Hg) were subjected to repeat measurements after one or two hours. The diagnosis of impending compartment syndrome was made when the differential pressure was less than 30 mm Hg.

3. Results

In this study 60 patients with closed fractures of tibia were selected for intra compartmental pressure monitoring and randomised for different weights of leg elevation i.e., Group A 15 cm above heart level and Group B 30 cm above heart level. The mean age of leg fractures in our study was 40.1 years. Male subjects were 85% (mean = 53) and female were 17% (mean = 7) of total of 60 patients.

The measurement of compartment pressure of normal leg was 9.4 $\pm$ 2.5 mm Hg. Pressure were measured within 5 cm of fracture site at 0 hr, 12 hr, 24 hr and 48 hr interval using Whiteside's method. The mean values at 0 hr were 29.17 $\pm$ 5.95 mm Hg, at 12 hr interval it was 29.97 $\pm$ 5.46 mm Hg, at 24 hr interval it was 23.36 $\pm$ 3.8 mm Hg and at 48 hr interval it was in Group A. The mean values at 0 hr were 32 $\pm$ 7.8 mm Hg, at 12 hr interval it was 32.33 $\pm$57.65 mm Hg, at 24 hr interval it was 26.48 $\pm$ 3.5 mm Hg and at 48 hr interval it was in 25.19 $\pm$ 2.56 mm Hg in Group B.In our study 5 patients out of 60 underwent fasciotomy. All patients had differential or delta pressure below 30 mm Hg before fasciotomy

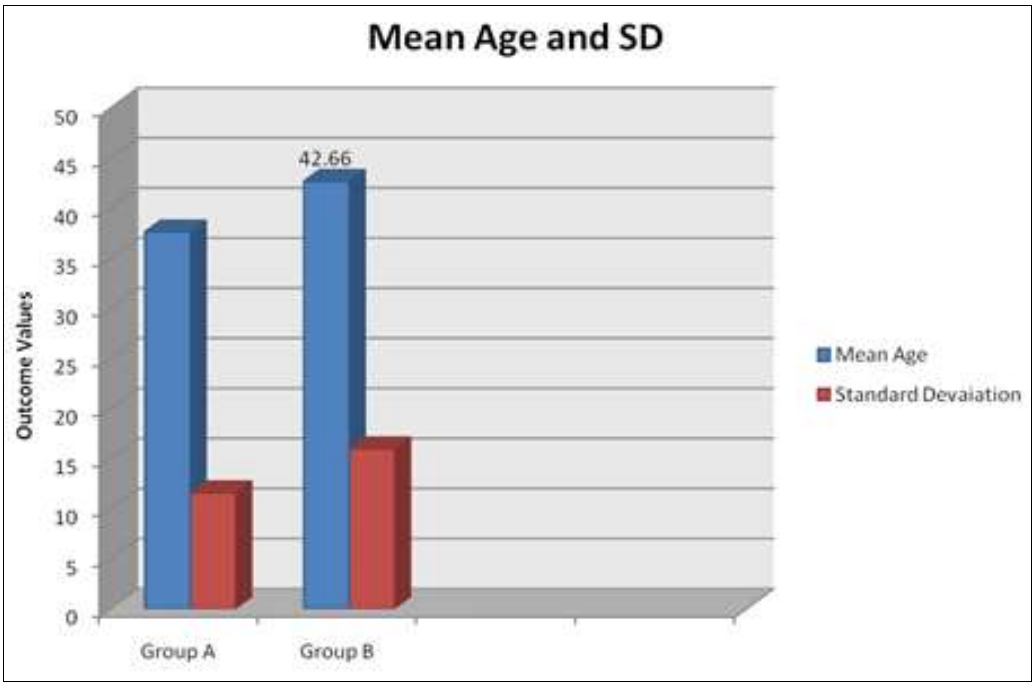

Chart 1: Age distribution in group A and B ranged from 18-61 yrs, with mean age of group A was 37.6 yrs SD of 11.5 years. Majority of patients were in third and fourth decades.

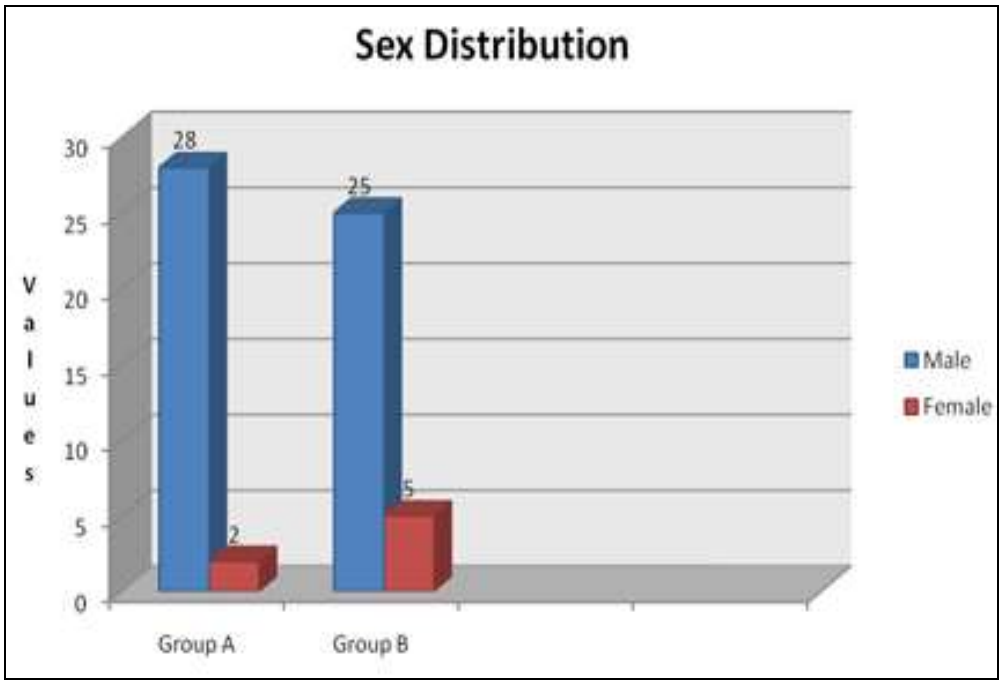

Chart 2: In group A there were 28 male subjects and two female subject. In group B there were 25 males and five females.

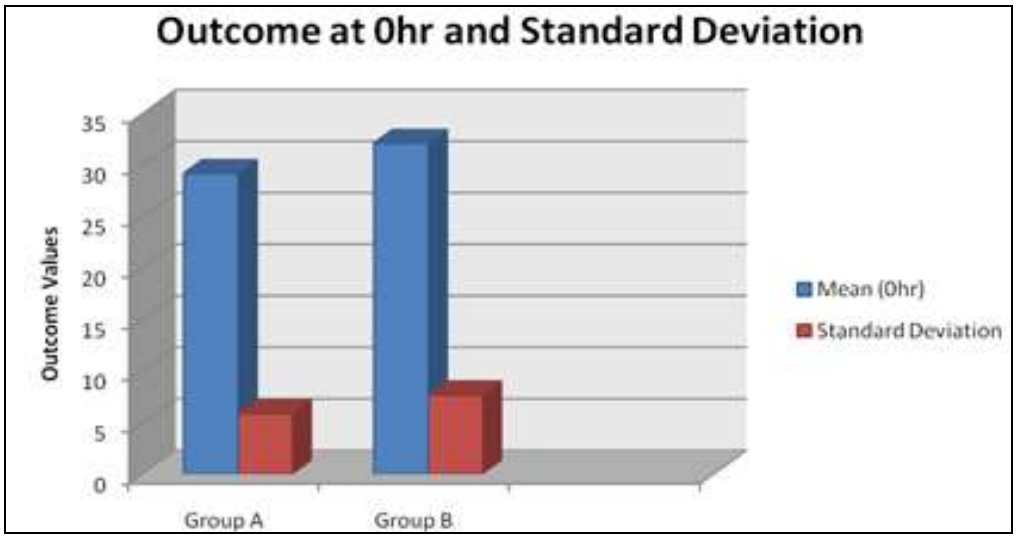

Chart 3: Intra compartment pressure at the time of immobilisation in group A was 29.16 mmHg with SD of 5.85 mmHg. In Group B mean values at the time of immobilisation was 32.1 mmHg with SD of 7.66 mmHg.

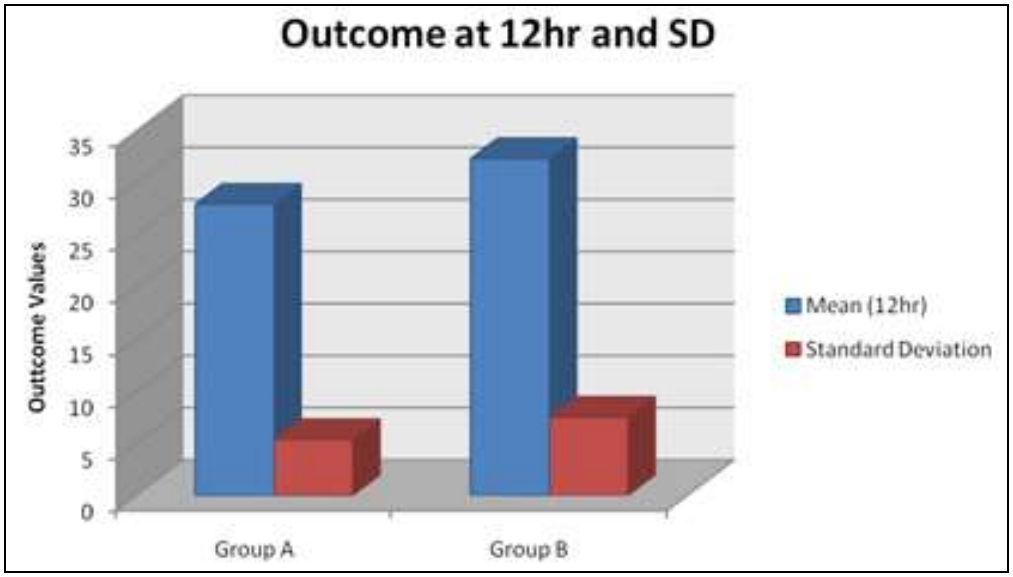

Chart 4: Intra compartment pressure at the time of immobilisation in group A was27.9 mmHg with SD of 5.39Hg. In Group B mean values at the time of immobilisation was 32.3 mmHg with SD of 7.5 mmHg.

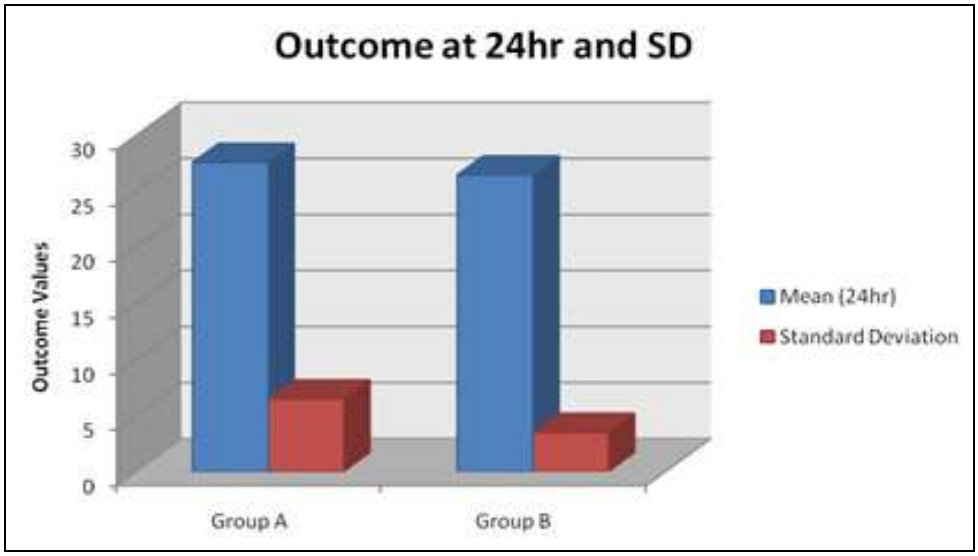

Chart 5: Intra compartment pressure at the time of immobilisation in group A was 27.6 mmHg with SD of 6.45 mmHg. In Group B mean values at the time of immobilisation was 26.4 mmHg with SD of 3.4 mmHg.

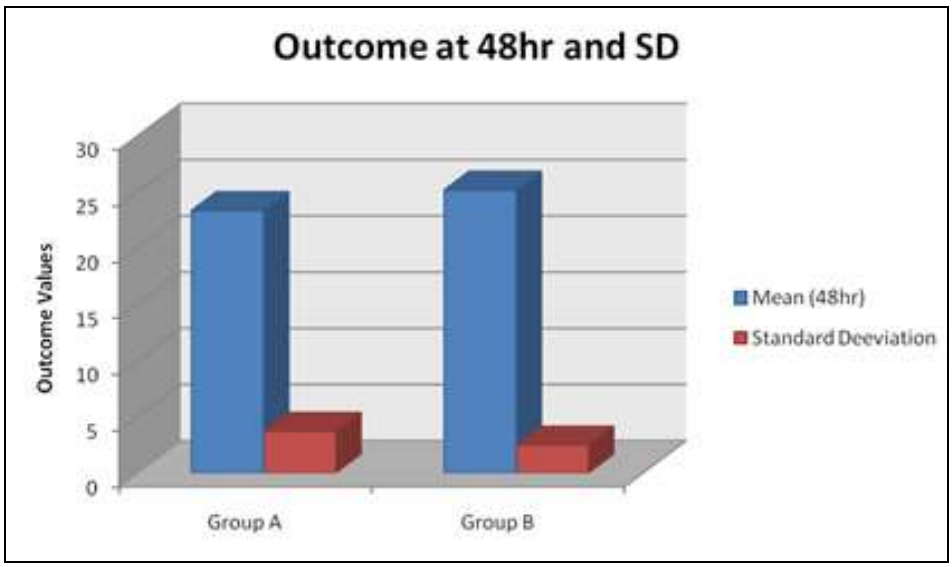

Chart 6: Intra compartment pressure at the time of immobilisation in group A was 23.3 mmHg with SD of 3.7 mmHg. In Group B mean values at the time of immobilisation was 25.1 mmHg with SD of 2.5 mmHg.

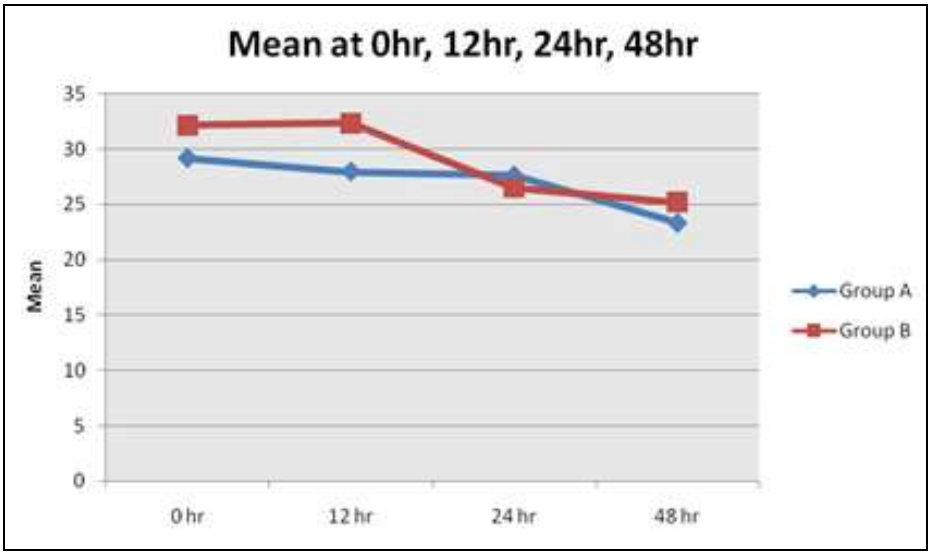

Chart 7: Mean of Intra compartment pressure showing fall in pressure is maximum at 24 hours of immobilisation which is below 30 mmHg in group A. In group B fall in Intra compartment pressure was noted at 24 hours and further fall in both groups were not significant with continued elevation. Rate of fall is comparable in both groups.

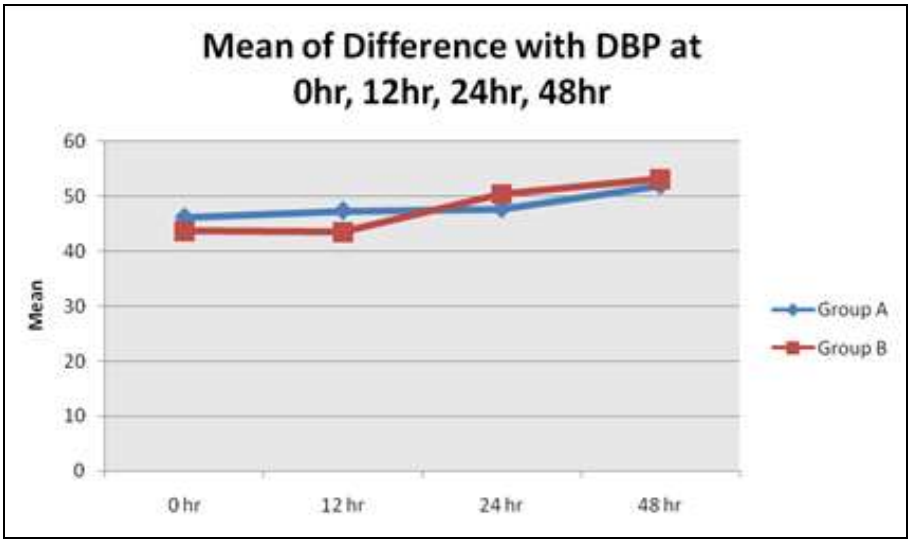

Chart 8: The delta pressure was above 30 mmHg from first reading and at 24 hours delta pressure raise was found and sustained till 48 hours of immobilisation. Seven patients who underwent fasciotomy had delta pressures below 30 mmHg.

4. Discussion

Acute Compartment Syndrome is a condition in which increased pressure within a limited space compromises the circulation and function of the tissues within that space [7, 10]. Approximately 40% of all Acute Compartment Syndrome occur after fractures of tibia shaft [5].

In this randomised control trial, 60 patients with closed tibia fractures were included, 30 patients in Group A and Group B. Serial measurement of ICP using Whiteside's method was done with different heights of leg elevation above heart level. Fall in intra compartmental pressure was noted. This study was significant as very few studies are carried out to signify optimum and safe height of leg elevation in trauma and assess merits and demerits of leg elevation in raised compartment pressure.

In our study out of 60 patients 53 patients were male and 7 patients were female.

In our study age of patients ranged from 18 – 61 years. Mean age in Group A being 37.6 years and 42.6 years in Group B. Majority of patients with tibia fractures were in third and fourth decades of life.

In our study we measured ICP using Whiteside's method. Whiteside's method is an accepted method with minimal inter observer variability.

Johnson O Ogunlnsi, Lawrence N. Oginni *et al* in their study of compartmental pressure in adults with tibia fractures recommended that apparatus for Whiteside's method is simple, easily available in any hospital and most importantly inexpensive. It can be assembled within 10 minutes and is easy to measure compartmental pressure in patients that are considered to be at risk of developing compartment syndrome and Whiteside's method is of great value in the accurate diagnosis of ACS especially in developing countries where sophisticated devices are not available [74].

In our study we measured Intra Compartmental Pressure at 0, 12, 24, 48 hours interval using Whiteside's method and recorded the values with leg elevated to 15cm from heart level in Group A and 30 cm from heart level in Group B.

In Group A, the mean value at the time of immobilization were 29.17 $\pm$ 5.95mm Hg, at 12 hour it was 27.97 $\pm$ 5.46mm Hg, at 24 hour, 23.36 $\pm$ 3.80 mm Hg , 48hour 28.19 $\pm$ 2.56mm Hg. In Group B, the mean values at the time of immobilization were 32.10 $\pm$ 7.80 mm Hg, at 12 hour 32.33 $\pm$ 7.65 mm Hg, at 24 hour 26.48 mm Hg $\pm$ 3.56 mm Hg and at 48 hours 25.19 $\pm$ 2.56 mm Hg. The P - values were at 0.1068 at 0 hour, 0.0136 at 12 hour, 0.4377 at 24 hour and 0.0420 at 48 hour showing no significant difference in values between Group A and Group B.

5. Conclusion

In this randomised control of 60 patients with closed tibia fractures 30 patients in Group A and Group B underwent serial measurements of ICP using Whiteside's method with 15 cm and 30 cm of elevation affected leg above heart level. The overall incidence of compartment syndrome undergoing fasciotomies was 5 out 60 (8.3%).

Age of all the patients in this study ranged from 18 to 61 years. Average age in this study was 37.6 years in Group A and 42.6 years in Group B.

In our study 50 patients we males and 7 patients were females out of total 60 subjects. In our study we used Whiteside's method to measure intra compartmental pressure and we have chosen anterior compartment to measure in all patients with closed tibia fractures. Site of measurement is at the site of fracture or within 5 cm from the fracture site as feasible clinically. In our study we gave posterior above knee slab and immobilised leg to 15 cm above sternum or pubic symphysis as a reference level in Group A and 30 cm above sternum or pubic symphysis as a reference level in Group B.

At the time of first measurement of ICP we measure pressure in normal leg anterior compartment and pressures ranged from 3 – 18 mm Hg with a mean pressure of 8.65 $\pm$ 2.56mm Hg. In our study we measured differential pressures or delta pressure i.e. difference between diastolic blood pressure and intra compartmental pressure. In patients who underwent fasciotomy had delta pressure of average 17.2 mm Hg and highest pressure recorded who did not require fasciotomy was 44 mm Hg in Group A and 49 mm Hg in Group B with differential pressure 36 mm Hg and 41 mm Hg respectively?

In our study decision for fasciotomy was determined by delta pressure. Any values below 30 mm Hg will be an indication for fasciotomy. Clinical signs of 5 P's pulselessness, pallor, pain, paraesthesia, paralysis are not completely reliable for diagnosing early compartment syndrome. Compartment syndrome can exist in presence of pulse in the limb.

Invasive measurement to avoid late diagnosis and extensive

muscle ischemia is recommended in high suspicion cases. In our study we didn't find statistically significant difference in fall of ICP in two groups at 24 hours. Post immobilization both of them had comparable fall and thus unnecessary elevation to 30 cm is not useful and harmful.

6. Summary

In our study, 60 patients with closed tibia fractures were involved to determine appropriate height of leg elevation by measuring fall of Intra compartment pressure using Whiteside's method at 15 cms and 30 cms of leg elevation.

In our study we found rate of fall of ICP at 15 cms is comparable to 30 cms of leg elevation and hence we conclude based on results of decrease in ICP, 15 cms of leg elevation in tibia fractures is appropriate and optimum compared to 30 cms of leg elevation. Further studies to study different heights of elevation and different methods of ICP measurement are necessary.

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