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MEASURE THE INTRACOMPARTMENTAL PRESSURE CHANGES IN INTRAMEDULLARY NAILING OF TIBIA: A CROSS SECTIONAL STUDY

Orthopaedics

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ABSTRACT

Background: Tibial shaft fractures are common in orthopedic trauma, and intramedullary nailing (IMN) is a standard treatment. However, compartment syndrome remains a serious complication. This study aimed to evaluate intracompartmental pressure (ICP) changes during IMN of tibial fractures. **Material & Methods:** A cross-sectional observational study was conducted among 35 adult patients with traumatic tibial diaphyseal fractures who underwent IMN. ICP measurements were taken preoperatively, intraoperatively, and postoperatively using a Stryker pressure monitor. Delta pressure (ΔP) calculations were used to assess ischemic risk. **Results:** The study revealed significant fluctuations in ICP across surgical phases ($p < 0.05$). Females experienced a progressive increase in compartment pressure (CP) from preoperative to postoperative phases (39.8 mmHg to 49.2 mmHg), whereas males exhibited an initial increase followed by a slight decrease postoperatively (37.1 mmHg to 42.0 mmHg). Sex-based differences in postoperative CP trends were notable ($p < 0.05$). Preoperative delta pressure (ΔP) correlated with intraoperative and postoperative CP fluctuations. All patients had intact neurological and vascular function postoperatively. **Conclusion:** This study highlights the importance of individualized perioperative ICP monitoring strategies, particularly for high-risk patients. Sex-based differences and mechanism of injury influence ICP changes, and understanding these variations can help prevent compartment syndrome and ischemic complications. The findings contribute to refining perioperative management protocols in orthopedic trauma surgery. Delta pressure.

KEYWORDS

Intracompartmental pressure, Intramedullary nailing, Tibial fractures, Compartment syndrome

INTRODUCTION

Tibial shaft fractures represent approximately 37% of all long adult bone fractures, with a total frequency of 17–21 per 100,000 people, with the highest prevalence in males aged 10–20.[1,2] Fractures can come from high-energy or low-energy causes and are frequently caused by falls, auto accidents, or injuries sustained in sports.[3,4] The about 24% prevalence of open diaphyseal fractures is mostly explained by the tibial shaft's subcutaneous position and restricted soft tissue covering. Devastating and linked to significant bone and soft-tissue damage, high-energy open tibial shaft fractures significantly raise the risk of infection, nonunion, and wound complications.[5] Taking into consideration particular patient characteristics, fracture features, and concurrent injuries, appropriate treatment decisions for certain fracture forms are multifactorial. Intramedullary nail fixation remains the treatment of choice for unstable and displaced tibial shaft fractures in the adult.[1] By avoiding rupturing the soft tissue surrounding the fracture, intramedullary nailing preserves the blood supply with minimal surgical dissection.[3] Compartment occurs when excessive pressure develops within a compartment, a group of muscles, nerves, and blood vessels enclosed by a firm, non-expandable membrane called fascia. This increased pressure compromises blood flow, oxygen delivery, and nutrient supply to the tissues within the compartment, leading to ischemia. Compartment syndrome is associated with significant pain and requires prompt attention.[6-9] Acute Compartment Syndrome is triggered by trauma, fractures, injuries, or burns. Chronic Compartment Syndrome is caused by repetitive stress from activities such as running or cycling.[10] Acute compartment syndrome is considered as a surgical emergency requiring immediate intervention, chronic compartment syndrome is typically managed conservatively with lifestyle modifications and non-surgical treatments.[11,12] This study aimed to address the gap in knowledge by systematically measuring ICP changes throughout the IMN procedure, both intraoperatively and in the immediate postoperative period.

MATERIALAND METHODS

A Cross sectional observational Study was conducted among 35 **a**dult patients (ages18–65) with traumatic tibial diaphyseal fractures who were indicated for IMN between periods of 1 year (1 August 2023 to 31 July 2024) at Department of Orthopaedics, 'Rohilkhand Medical College and Hospital', Bareilly. Criteria for exclusion included patients that were having open fractures tibia Gustilo Anderson type III, previous lower extremity surgeries, or known contraindications to compartment pressure monitoring (e.g., allergies to materials used in measurement devices), patients having fractures that were treated with other methods, such as plates, external fixture. Patients with closed fracture of shaft of tibia were included in the study. Approval from Institutional ethics committee was taken. Written as well as informed consent was taken before. Patients' clinical status was closely monitored before, during, and after surgery to diagnose compartment syndrome based on clinical signs, symptoms, and pressure monitoring device readings. In unresponsive patients, visible signs such as a swollen leg with tense skin and areas of pallor were indicative of compartment syndrome. When fasciotomy was performed, compartment pressures were measured to examine the relationship between clinical status and pressure values. In uncertain cases, pressure monitoring continued for 24 hours. Regular evaluations of pain, paresthesia, and mobility were conducted every six hours to ensure timely detection and management of potential complications. The Stryker hand-held pressure monitoring device was used by attaching the needle to the chamber stem, filling the chamber with normal saline, and connecting it to the device. After removing extra air, the needle was held at a 45-degree angle. The device was zeroed by pressing the zero button for 2 seconds, and then 0.3mL of solution was injected into the compartment to measure the pressure, which was displayed on the device.

The surgical procedure followed standard steps, with the patient positioned supine and the injured leg flexed at 90 degrees without skeletal traction or preoperative ischemia. Intramedullary reaming was performed to a diameter 1mm larger than the calculated nail size, and triple distal and double proximal locking screws were inserted as indicated. Compartment pressure was measured using a Stryker slit catheter. Pressures were measured in the anterior and deep posterior compartments of both the uninjured and fractured legs at specific intervals: before surgery, during intramedullary nail insertion, and immediately after surgery. Measurements were taken at the point of maximum deformity or soft-tissue tension in the fractured leg and compared to the uninjured leg. Delta P values were calculated by correlating the measurements with mean blood pressure. Additionally, qualitative data including fracture type, age, gender, side of injury, and mechanism of injury were recorded. Patients diagnosed with compartment syndrome underwent immediate fasciotomy to decompress all four compartments. The incisions were left open, and follow-up assessments were conducted every 48 hours in the surgical room. Wound closure was attempted over several days, and if necessary, free skin grafts were used to facilitate healing. The surgical technique involved: General or spinal anesthesia with patients in a supine position. Infrapatellar (IP) or suprapatellar (SP) approach for intramedullary nailing based on surgeon preference. Fracture reduction and nail insertion under fluoroscopic guidance. Minimal soft tissue handling to reduce trauma. Postoperative monitoring included

Continuous ICP monitoring for 24 hours, with attention to high-risk patients. Evaluation for compartment syndrome if ICP exceeded 30mmHg or delta pressure was <30mmHg. Postoperative complications were also collected. Statistical analysis was performed using SPSS version 23.0, with a p-value <0.05 considered significant.

RESULTS

Table1: Demographic Distribution Of Patients

AGE GROUP	SEX	Counts
18-30	F	0
	M	12(33.3%)
31-40	F	1(2.8%)
	M	11(30.6%)
41-50	F	1(2.8%)
	M	5(13.9%)
>50	F	3(8.3%)
	M	3(8.3%)

Males predominated in younger age groups (18-40 years). In patients older than 50 years, the sex distribution was more balanced, with equal representation of males and females (8.3% each) Chi-square test showed statistically significant variations in age and sex distribution ($p < 0.05$).

Table 2: Preoperative CP, Intraoperative CP and Postoperative CP

	PRE-OPCP	INTRA-OPCP Settled	POST-OPCP
Mean	39.8	45.4	49.2
	37.1	43.1	42.0
SD	10.3	7.80	10.9
	11.5	7.80	11.5

Compartment pressure (CP) trends showed distinct differences between males and females throughout the surgical phases. Females experienced a progressive increase in CP from preoperative to postoperative phases (39.8 mmHg to 49.2 mmHg), whereas males exhibited an initial increase followed by a slight decrease postoperatively (37.1 mmHg to 42.0 mmHg). Statistical analysis confirmed significant differences in CP between phases and notable differences between male and female trajectories ($p < 0.05$).

Table 3: Postoperative Pressure Trends Across Compartments

	SEX	PRE-OPCP	INTRA-OP CP settled	POST-OPCP
Mean	F	39.8	45.4	49.2
	M	37.1	43.1	42.0
Standard deviation	F	10.3	7.80	10.9
	M	11.5	7.80	11.5

The study revealed distinct compartment pressure (CP) trends between females and males across surgical phases. Females experienced a steady increase in CP from 39.8 mmHg preoperatively to 49.2 mmHg postoperatively, whereas males showed an initial increase from 37.1 mmHg preoperatively to 43.1 mmHg intraoperatively, followed by a slight decrease to 42.0 mmHg postoperatively. These sex-specific differences in postoperative trends were notable, and repeated measures ANOVA confirmed significant changes in CP across phases and between sexes ($p < 0.05$).

Table 4: Correlations Between Preoperative Delta P, Intraoperative Delta P And Postoperative Delta P

	PRE-OPDELTA P	INTRA-OPDELTAP	POST-OPDELTAP
Mean	40.2	33.3	34.3
SD	9.96	6.53	10.3

Delta P values showed significant variation across different phases, with a preoperative mean of 40.2 mmHg (SD = 9.96) indicating high variability, decreasing to 33.3 mmHg (SD = 6.53) intraoperatively with more consistency, and then increasing to 34.3 mmHg (SD = 10.3) postoperatively with greater variability. Statistical analysis using repeated measures ANOVA confirmed significant differences between phases ($p < 0.05$).

Table 5: Outcome Distribution Based on Neurological and Vascular Status

	SEX	Count
NEROLOGICALSTATUS(Intact)	F	5
	M	31
VASCULAR STATUS(Intact)	F	5
	M	31

The study found that all 36 participants (5 females, 31 males) had intact neurological and vascular function postoperatively, indicating uniformly positive outcomes across both sexes. This suggests that effective intraoperative and postoperative management strategies successfully prevented neurological and vascular compromise.

DISCUSSION

The demographic distribution of the patients in this study reflects age and sex- specific trends that are crucial for understanding variations in injury patterns and clinical outcomes. The dominance of male patients across all age groups, particularly in the younger age brackets, is consistent with findings from P Tornetta III et al.[13] and Zelle BA et al.[2], where younger males were the most affected due to higher exposure to risk factors such as occupational hazards and high-energy trauma. The absence of female representation in the 18–30 years age group in this study contrasts with Hansen EN et al.[14], where a more balanced distribution was noted, suggesting regional and lifestyle differences in injury mechanisms. The increasing representation of females in the >50 years category aligns with Xia L et al.[15], which found a higher occurance of fractures in postmenopausal women, likely due to osteoporosis-related fragility fractures. The statistically significant variation in age and sex distribution ($p < 0.05$) suggests that demographic factors are essential considerations in the treatment of the fracture of tibia. mThe study found significant differences in compartment pressure (CP) trends between females and males across the surgical timeline. Females experienced a progressive increase in CP from preoperative (39.8 mmHg) to postoperative (49.2 mmHg), whereas males showed an initial increase from preoperative (37.1 mmHg) to intraoperative (43.1 mmHg), followed by a decline postoperatively (42.0 mmHg). The statistically significant changes ($p < 0.05$) highlight the dynamic nature of CP and suggest the need for sex-specific postoperative monitoring strategies to optimize patient care. These findings are persistent with Tian S et al.[16], who reported a sustained increase in compartment pressures postoperatively, particularly in female patients, potentially due to differences in muscle perfusion and vascular compliance. However, the results contrast with Hendrickx LAM et al.[17], where CP values stabilised postoperatively in both sexes without significant increases. The postoperative pressure trends across compartments demonstrate distinct trajectories between sexes, reinforcing the dynamic nature of intraoperative and postoperative pressure fluctuations. Females exhibited a continuous increase in CP from 39.8 mmHg preoperatively to 45.4 mmHg intraoperatively and 49.2 mmHg postoperatively, whereas males experienced arise from 37.1mmHg preoperatively to 43.1mmHg intraoperatively, followed by a decline to 42.0 mmHg postoperatively. The statistical significance ($p < 0.05$) of these changes aligns with Ho KLK et al.[18], who observed similar intraoperative CP increases, but contrasts with Duckworth AD et al.[1]4, where compartment pressures remained stable postoperatively. The outcome distribution based on neurological and vascular status demonstrates uniformly positive recovery in both sexes, with all patients maintaining intact neurological and vascular function. These findings are consistent with Zelle BA et al.[2], who reported high rates of neurological and vascular integrity in patients undergoing intramedullary nailing, emphasizing the effectiveness of surgical and perioperative interventions. The correlations between preoperative, intraoperative, and postoperative delta pressure (ΔP) illustrate significant fluctuations in compartmental pressures throughout the surgical timeline. The mean ΔP decreased from 40.2mmHg preoperatively to 33.3 mmHg intraoperatively, before slightly increasing to 34.3mmHg postoperatively. This trajectory aligns with findings from Tian S et al.[17], who identified intraoperative decreases in compartment pressures due to fracture reduction and stabilization, followed by mild postoperative increases attributed to post-surgical edema. The statistical significance of these changes ($p < 0.05$) reinforces the findings of Von Keudell AG et al.[19], who emphasized the importance of continuous postoperative monitoring to avoid compartment syndrome. The study contributes to the evolving understanding of perioperative pressure variations, underscoring the need for refined clinical protocols that integrate preoperative ICP risk assessment, intraoperative modulation strategies, and individualized postoperative management for optimizing patient outcomes.

CONCLUSIONS

This study provides valuable insights into the dynamic changes in

intracompartmental pressure (ICP) associated with intramedullary nailing of tibial fractures. The findings emphasize the importance of perioperative monitoring, sex-based differences in postoperative compartment pressure trajectories, and the predictive value of delta pressure in identifying patients at risk for compartment syndrome.

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