

Tibial Fracture: Anterior leg Compartment Pressure Alterations Following reamed and non-reamed Intramedullary Nailing

Authors:

Zakir Ali Shah¹, Nouran AbuGuba¹, Aya Ewida¹, Amqa Saeed², Basma Mohammed Alkubaisi², Juman Jihad Waisi²

¹Specialist Senior Registrar, Rashid hospital, Trauma & Orthopedic Department, Dubai, United Arab Emirates

¹Year 5 MBBS, College of Medicine, University of Sharjah

²Intern Surgery, Mayo Hospital, Lahore, Pakistan

²Year 5 MBBS, College of Medicine, Ajman university

Corresponding Author:

Zakir Ali Shah

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ABSTRACT:

Objectives: To determine the anterior leg compartment pressure changes following closed reamed and non-reamed intramedullary nailing for fracture tibia. **Subjects and Methods:** Patients aged 17 to 65 with a closed tibia fracture were chosen for the study. They were randomly assigned to two treatment groups using a random number table. Group 1 received reamed intramedullary nailing, while Group 2 underwent non-reamed intramedullary nailing. Compartment pressure was measured in both groups before and after surgery, and the changes in pressure (delta P values) were calculated. **Results:** Most patients in both groups were male. The average age was 35.97 years (SD $\pm$ 15.51) in Group 1 and 35.30 years (SD $\pm$ 12.29) in Group 2. After surgery, compartment pressure was 19.60 mmHg (SD $\pm$ 4.36) in Group 1 and 16.37 mmHg (SD $\pm$ 3.79) in Group 2. These differences were not clinically significant. **Conclusions:** Reaming does not significantly contribute to the development of compartment syndrome.

Keywords: Compartment Pressure leg, Compartment Syndrome leg, Intramedullary Nailing

INTRODUCTION:

Compartment pressure refers to the pressure inside a tightly enclosed space in the body, called an osteofascial compartment, which houses skeletal muscles. The rigid boundaries of these compartments, made of bone and connective tissue, don't easily allow excess pressure to escape¹. When the pressure inside these compartments rises above the level needed for normal blood flow in tiny blood vessels, it can lead to compartment syndrome. If left untreated, this condition may cause permanent muscle damage, leading to stiffness and scarring, known as contracture^{1,2}. Tibia fractures often come with blood vessel complications, ranging from mild to severe. Severe cases might involve a complete blockage of blood flow in major arteries like the anterior or posterior tibial artery while milder cases could cause slight toe curling due to reduced blood flow to small foot muscles. While severe complications are usually obvious to orthopedic surgeons, milder ones are often missed and may not significantly affect the patient^{3,4}. Compartment

syndrome is a major issue after trauma and is diagnosed based on symptoms like intense pain, numbness, pale skin, weakness, or lack of pulse. To confirm the diagnosis, doctors measure the pressure inside the compartment⁵. In 1881, Richard von Volkmann first highlighted the problem of ischemic contracture, where reduced blood flow damages muscles. Since then, researchers have studied how high tissue pressure can disrupt tiny blood vessels under various conditions⁶. Over the past 30 years, several methods have been developed to measure compartment pressure, including the Wick catheter, Whiteside's needle injection technique, continuous infusion, and slit catheter methods^{5,6}. The Whiteside technique involves inserting a catheter near the fracture site and injecting a small amount of saline to measure pressure. Normally, compartment pressure ranges from 0 to 8 mmHg. If it exceeds 30 mmHg or if the difference between the patient's diastolic blood pressure and the compartment pressure (delta P) is less than 20 mmHg, immediate

surgery to relieve the pressure is needed. Tools like peripheral oxygen saturation monitors and Doppler ultrasound can also aid in diagnosis⁷. The tibia, a major leg bone, accounts for about 16.95% of all fractures seen in emergency rooms⁸. Tibial shaft fractures carry a high risk of compartment syndrome, with around 45% of compartment syndrome cases involving these fractures. One common treatment for tibial shaft fractures is closed intramedullary nailing, where a metal rod is inserted into the bone's marrow canal, either with or without reaming the canal beforehand⁹. Reaming, which widens the canal, may increase compartment pressure, and some studies suggest it raises the risk of compartment syndrome in tibial fractures¹⁰.

METHODS:

The study was designed as a quasi-experimental trial and ran for 18 months. It included 120 patients with closed tibia fractures, split evenly into two groups. Participants were chosen using a convenient, non-probability sampling method.

Study Population and Consent:

Eligible patients were men or women aged 17 to 65 who underwent closed reamed or non-reamed intramedullary nailing for a closed tibia fracture. Patients were excluded if they had open fractures,

Each participant provided written informed consent for inclusion in the study and the use of their data for research purposes.

Study Design and Group Allocation:

Participants were randomly assigned to one of two treatment groups using a random number table to ensure unbiased allocation. Group 1 underwent reamed intramedullary nailing, while Group 2 received non-reamed intramedullary nailing. Both treatment methods were deemed ethical, with no additional risks to patients. To minimize bias, groups were matched for age, sex, fracture type, and fracture duration.

Data Collection:

Demographic details and fracture history were recorded for all participants. A thorough clinical examination assessed the extent of injury and any associated findings. All patients were stabilized following Advanced Trauma Life Support (ATLS) protocols, and diagnoses were confirmed via radiographic imaging. Baseline laboratory tests included complete blood count, blood urea, serum creatinine, prothrombin time (PT), activated partial thromboplastin time (APTT), and blood sugar levels.

Compartment Pressure Measurement:

Compartment pressure was measured 24 hours before surgery and within 4 hours post-surgery using the

Whiteside needle injection technique. At both time points, diastolic blood pressure was recorded, and delta P values (diastolic blood pressure minus compartment pressure) were calculated. Patients were monitored for 24 hours post-surgery for signs of compartment syndrome, including severe pain, numbness, pallor, paralysis, or pulselessness.

Pressure Measurement Technique:

Under strict aseptic conditions, the anterior compartment was prepared with povidone-iodine, and the skin was anesthetized with plain lidocaine (without epinephrine). The needle insertion site was marked within 5 cm of the fracture and 1.5 cm lateral to the anterior tibial crest. A 20 mL syringe, with the plunger set at 15 mL, was connected to a four-way stopcock. An 18-gauge needle was attached to one end of a sterile intravenous (IV) extension tube, and a second IV extension tube was connected to a blood pressure manometer. The needle was inserted into a saline bag, and the stopcock was adjusted to allow saline to fill approximately half the extension tube without air bubbles. The stopcock was then closed to retain the saline during needle transfer. The 18-gauge needle was inserted into the muscle of the anterior compartment to measure tissue pressure. The stopcock was adjusted to create a "T" connection, linking the syringe to both extension tubes and forming a closed system. The syringe plunger was slowly depressed to increase system pressure while observing the saline/air meniscus. As the system pressure exceeded the surrounding tissue pressure, a small amount of saline was injected, causing the meniscus to move. The manometer reading at this point, when the saline column moved, was recorded as the tissue pressure in mmHg.

Data Analysis:

Data collected from the study were entered into SPSS software for analysis. General variables, including demographic details (age, sex), fracture history (type of trauma), and extent of damage assessed through clinical examination, were summarized using descriptive statistics. For numerical variables, means and standard deviations were calculated for each group, and a t-test was used to evaluate statistical significance. Outcome measures were reported as frequencies and proportions. The success or failure of the procedures was evaluated using a scaled observation for comparison between groups. Statistical significance between the two groups was assessed using the Chi-square test for qualitative data. A p-value of 0.05 or less was considered statistically significant.

RESULTS:

The study enrolled 120 patients, evenly divided into two groups. Group 1 included 60 patients with tibial shaft

fractures treated with reamed intramedullary nailing, while Group 2 comprised 60 patients treated with non-reamed intramedullary nailing for tibial fractures. In Group 1, 50 patients (83%) were male, and 10 (17%) were female. In Group 2, 52 patients (87%) were male, and 8 (13%) were female. The age of patients in Group 1 ranged from 20 to 50 years, with a mean of 35.97 ± 15.51 years, while in Group 2, ages ranged from 23 to 47 years, with a mean of 35.30 ± 12.29 years. In both groups, the largest age group was 17–27 years, with 12 patients (40%) in each group. The average hospital stay for Group 1 was 10.47 ± 5.01 days, while for Group 2 it was 10.40 ± 5.05 days. In Group 1 (n=60), 90.0% (54 patients) were injured due to road traffic accidents, 3.0%

(2 patients) from falls from stairs or height, 3.0% (2 patients) from a heavy weight falling on both legs, and 4.0% (2 patients) from fights. In Group 2 (n=60), 93.0% (56 patients) were injured due to road traffic accidents, 7.0% (4 patients) from falls from stairs or height, and no patients were injured from a heavy weight falling on both legs or from fights. Road traffic accidents were the primary cause of injury in both groups. Fractures of the middle third of the tibial shaft occurred in 18 patients (60%) in Group 1 and 21 patients (70%) in Group 2, while fractures of the distal third of the tibia were observed in 10 patients (33%) in Group 1 and 7 patients (23%) in Group 2 (Chart 1).

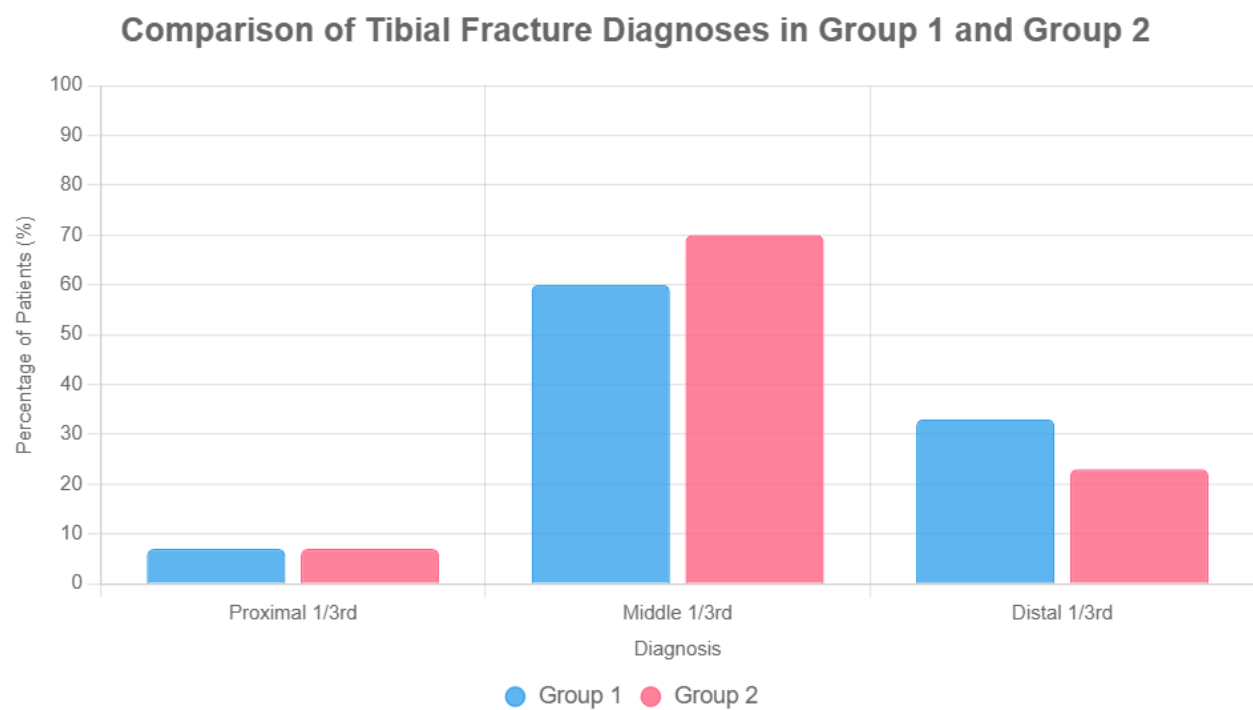


Chart 1. Different diagnosis of patients in both groups (n=120)

This chart displays the percentage of patients with fractures in the proximal, middle, and distal thirds of the tibia for both groups. Group 1 is represented in blue, and Group 2 in red, with percentages on the y-axis and diagnosis types on the x-axis.

Preoperative compartment pressure was 11.87 ± 3.45 mmHg (range: 5–20 mmHg) in Group 1 and 12.43 ± 3.53 mmHg (range: 8–18 mmHg) in Group 2 (**Data table 1**).

Data table 1. Preoperative compartment pressure comparison in mmHg between two groups (n=120)

	Group 1 (n=60)	Group 2 (n=60)	P value
Mean ± SD	11.87±3.45	12.43±3.53	P >0.05

Postoperative compartment pressures were 19.60 ± 4.36 mmHg (range: 10–25 mmHg) in patients treated with reamed intramedullary nailing and 16.37 ± 3.79 mmHg (range: 8–22 mmHg) in those treated with non-reamed intramedullary nailing. This difference was statistically significant ($p < 0.05$) (**Data table 2**).

Data table 2. Postoperative compartment pressure comparison in mmHg between two groups (n=120)

	Group 1 (n=60)	Group 2 (n=60)	P value
Mean $\pm$ SD	19.60 $\pm$ 4.36	16.37 $\pm$ 3.79	P <0.05

Preoperative diastolic blood pressure was 78.77 $\pm$ 8.37 mmHg (range: 65–95 mmHg) in Group 1 and 77.50 $\pm$ 7.28 mmHg (range: 65–90 mmHg) in Group 2. Postoperative diastolic blood pressure was 77.13 $\pm$ 9.05 mmHg (range: 60–95 mmHg) in Group 1 and 80.97 $\pm$ 10.37 mmHg (range: 50–110 mmHg) in Group 2 (**Data table 3**). The postoperative difference between groups was statistically significant ($p < 0.05$).

Data table 3. Preoperative and Postoperative diastolic blood pressure comparison in mmHg between two groups (n=120)

	Mean $\pm$ SD (Group 1)	Mean $\pm$ SD (Group 2)	P value
Preoperative diastolic blood pressure	78.77 $\pm$ 8.37	77.50 $\pm$ 7.28	P >0.05
Postoperative diastolic blood pressure	77.13 $\pm$ 9.05	80.97 $\pm$ 10.37	P <0.05

Preoperative delta P values (diastolic blood pressure minus compartment pressure) were 66.90 $\pm$ 9.67 mmHg (range: 65–85 mmHg) in Group 1 and 65.07 $\pm$ 7.27 mmHg (range: 55–80 mmHg) in Group 2. Postoperative delta P values were 57.53 $\pm$ 10.67 mmHg (range: 40–85 mmHg) in Group 1 and 64.53 $\pm$ 10.18 mmHg (range: 35–88 mmHg) in Group 2 (**Data table 4**). The postoperative difference between groups was statistically significant ($p < 0.05$). No patients in either group exhibited signs or symptoms of compartment syndrome.

Data table 4. Preoperative delta P and Postoperative delta P comparison in mmHg between two groups (n=120)

	Mean $\pm$ SD (Group 1)	Mean $\pm$ SD (Group 2)	P value
Preoperative delta P	66.90 $\pm$ 9.67	65.07 $\pm$ 7.27	P >0.05
Postoperative delta P	57.53 $\pm$ 10.67	64.53 $\pm$ 10.18	P <0.05

DISCUSSION:

The development of acute compartment syndrome (ACS), where elevated pressure in a closed muscle compartment impedes arterial blood flow, can lead to permanent, disabling ischemia. Preventing the resulting soft tissue dysfunction necessitates early diagnosis and decompression. While early closed intramedullary nailing is a well-established method for treating tibial fractures, it carries a potential risk of increasing soft tissue swelling and inducing ACS. This risk underpins recommendations by some to delay surgery for up to seven days until acute swelling diminishes. Accurate measurement of compartment pressure enables diagnosis of impending or early ACS before irreversible changes set in. This study examines the changes in compartment pressure during both reamed and non-reamed intramedullary nailing procedures for tibial fractures. The mean ages in the two study groups (35.97 $\pm$ 15.51 years and 35.30 $\pm$ 12.29 years) closely resemble those

reported by McQueen, Christie, and Court-Brown¹¹. The mean age of enrolled patients was 31 years, reflecting a population segment typically engaged in high activity levels. A significant male predominance was observed (Group 1: 83%; Group 2: 87%), mirroring the findings of Awais et al., who reported 76.6% males in their cohort¹². This gender distribution may be attributable to socioeconomic factors: males in this setting generally experience greater exposure to outdoor environments through occupational necessity, livelihood activities, and recreational pursuits, while females are predominantly engaged in domestic responsibilities with lower outdoor exposure. Road traffic accidents constituted the primary etiology of injury in both groups.

Group 1: 90%

Group 2: 93%

These findings correspond with epidemiological reports, such as data from the year 2000 documenting one million global road fatalities, of which 75% occurred in

developing nations and approximately 50% within Asia¹³. Key factors contributing to the increased incidence of road traffic injuries include rapid motorization, inadequate enforcement of traffic safety regulations, substandard road and vehicle conditions, and insufficient public health infrastructure^{14,15}. Group 1 had a mean hospital stay of 10.47 ± 5.01 days, while Group 2 averaged 10.40 ± 5.05 days. This is consistent with data published by Mirza and Khan¹⁶. These findings are consistent with the study by Tornetta and French, who reported a mean postoperative compartment pressure of 13.8 mmHg during non-reamed tibial nailing and concluded that the procedure did not elevate the risk of acute compartment syndrome¹⁷. These findings correspond with Nassif et al.'s data demonstrating absence of compartment syndrome in reamed and non-reamed nailing cohorts. Their study further documented that mean compartment pressures decreased rapidly to <30 mmHg postoperatively in all cases¹⁸. The study showed the mean preoperative delta P values [diastolic blood pressure) (compartment pressure)] were 66.90 ± 9.67 mmHg in group 1 patients and 65.07 ± 7.27 mmHg in group 2 patients and mean postoperative delta P values in group 1 patients were 57.53 ± 10.67 mmHg and in group 2 patients were 64.53 ± 10.18 mmHg. The delta P values were greater than thirty millimeters of mercury preoperatively as well as postoperatively in both groups. The results match with the study done by Nassif, Gorczyca, Cole, Pugh and Pienkowski. In their study also the delta p values were greater than thirty millimeters of mercury in both the reamed and undreamed groups.¹⁸ According to international studies delta p value less than 30mmHg is supportive of compartment syndrome^{19,20}. While isolated international reports, including Mawhinney et al²¹ documenting three cases of acute compartment syndrome (ACS) following reamed tibial nailing, exist, our findings supported by the majority of literature demonstrate no association. Crucially, no patient in either cohort developed ACS or exhibited compartment pressures exceeding critical thresholds necessitating fasciotomy.

CONCLUSION:

Comprehensive pressure monitoring and clinical outcome data indicate that intramedullary nailing, whether reamed or non-reamed, does not increase the risk of acute compartment syndrome in tibial fracture management. Reamed nailing shows a slight, transient pressure elevation compared to unreamed techniques (mean difference <5 mmHg in our cohort), but these levels remain well below critical thresholds (<30 mmHg) and resolve spontaneously without clinical consequences. Both methods are deemed safe for maintaining compartmental integrity. We suggest further

research into the incidence of fat embolism within our socioeconomic context to better assess systemic risks associated with reaming.

DECLARATIONS:

Ethics Approval:

All procedures involving human participants in this study were performed in accordance with the ethical standards and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to Participate:

Informed consent was obtained from all subjects and/or their legal guardian(s) for publication of identifying information/images in an online open-access publication. For participants under the age of 16 or those unable to provide consent, written assent was obtained from their parent/legal guardian. Participants were informed of the study's purpose, procedures, and their right to withdraw at any stage without consequence. A copy of the informed consent is available for review by the Editor-in-Chief of this journal.

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Competing interests:

We (authors) declare that we do not have competing interests.

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