Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 6 Issue 8 August 2023

Research Article

Diagnostic Technique and Prevention of Compartment Syndrome in Closed Interlocking Intramedullary Osteosynthesis of Tibia

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DOI: 10.31080/ASOR.2023.06.0789

Received: May 31, 2023

Published: July 16, 2023

Abstract

A significant part of the undesirable outcomes or complications after diaphyseal fractures of the tibia is explained either by the somatic condition of the patient or by the mechanism of the injury. However, often the reasons for these outcomes lie in the compartment syndrome. Unfortunately, this complication does not receive proper coverage in the scientific literature, exactly as well as methods of preventing it. The article proposes to deduce the principles of diagnosis and prevention of compartment syndrome based on a significant sample of patients. Diagnosis is reduced to the study of sub-fascial pressure at the slightest clinical sign of the development of compartment syndrome, while prevention consists in carrying out preventive semi-closed fasciotomies. Our studies have shown that compartment syndrome develops in 93% of cases when performing closed locking intramedullary nail of the tibia, fasciotomies from usual approaches to lock the pin were performed as a method of prevention. After performing fasciotomies, the indicators of sub-fascial pressure were re-examined and it showed significant clinical improvements than in patients without performing fasciotomies. The result of the methodology developed by the authors was an algorithm for diagnosing the compartment syndrome and an algorithm for its prevention.

Keywords: Diagnostic; Compartment Syndrome; Interlocking; Intramedullary; Osteosynthesis

Introduction

Compartment-syndrome, also called local hypertension ischemic syndrome (LHIS) is a common complication of fractures in long bones. According to L.N. Ankin frequency of LHIS is up to 35% [1]. Incidence may increase in case of poly trauma and shock, In case of electrical trauma, it is 100%.

In addition, L.N. Ankin (2002), claims that compartment syndrome is a common cause of deterioration in the functional outcome of fracture treatment. Most often, compartment syndrome develops in the lower leg and is the cause of complications that dramatically reduce the functionality of the limb [2]. Basically, at the stage of reversible changes, this syndrome is usually not diagnosed by doctors or is not recorded in medical documentation. At best, it is described in local status, or as an addition to the diagnosis - "swelling, epidermal blisters, scabs etc." [3].

Palpatory determination of the increase in pressure is a subjective method of investigation [4]. A more accurate way to determine the subfacial pressure is to use a Strayker serial device. Contrast enhanced X-ray contrast imaging and computed tomography have also not been used due to the high risk of complications, and are used only in case of suspected damage to the main vessels [5].

In the modern literature, we have not found methods for the prevention and treatment of compartment syndrome that would meet

all modern requirements (specificity, simplicity, non-invasiveness, safety and express diagnosis) [6].

The main reasons for the development of LHIS are ischemia, persistent vasospasm and alternating vascular atony, and a decrease nerve tolerance to hypoxia, which determines the different muscle response to the ischemia at the stage of metabolic disturbance. The dynamics of morphological changes during the simulation of LHIS for 4 hours shows the development of scar-fibrous degeneration of soft tissues, characteristic of this syndrome [7].

There are several theories of the development of compartment syndrome, the most relevant is F. Matsen (1980) Arteriovenous gradient theory - an increase in pressure in the fascial bed levels the difference between arterial and venous pressure, causing impaired blood supply.

Currently, the definition of compartment syndrome is a condition in which high subfascial pressure in the closed osteofascial space reduces muscle perfusion, causing ischemia, necrosis and leads to the formation of ischemic contracture.

The literature also revealed the variability of symptoms and diagnostic criteria for compartment syndrome, but the most common are five symptoms: "syndrome 5 P": pain, paraesthesia, passive stretch (severe pain that occurs when muscles are pulled), pressure is measured either by palpation, or differentially according to the method of T. Whiteside or Whiteside's modified by S. S. Strafun., *et al*., by monitoring of fascial bed pressure from Stryker, Pulselessness [8].

The dominant symptom of compartment syndrome is pain, which increases over time and does not correspond to the severity and nature of the injury. Edema does not appear immediately, occurs from several hours to 2-3 days after injury, is closely associated increasing of pain. Palpation is determined by the tension and soreness of the muscle group corresponding to the localization of the osteofascial beds. Study of the neurological status, paresthesia of the autonomous zones of the innervation of the nerves passing through the osteofascial beds with increased internal pressure is determined. Paresthesia are the first level of nerve damage, followed by hyperesthesia, hypoesthesia, and anesthesia [9].

Determination of the severity of compartment syndrome according to the classification proposed by S. S. Strafun., 1991

- **Mild**: The distal segment is warm, the pulse is preserved, paresthesia or hypoesthesia of the fingers, subfascial pressure is 30-40 mm Hg less than diastolic.
- **Moderate**: The temperature of the distal segment is reduced, the pulse is weak, hypoesthesia or anesthesia of the fingers, subfascial pressure at the level of diastolic.
- **Severe**: Violation of the patency of the main arteries, pulseless, anesthesia of the fingers, subfascial pressure exceeds diastolic pressure.

Due to circulatory disorders, C. T. Holden indicates the existence of two different types of ischemia

- **Type 1** - proximal artery injury leads to ischemia of the distal segment;
- **Type 2** - direct injury leads to ischemia directly at the site of injury.

Most often, differential diagnosis of LHIS is carried out with diseases such as myositis (Clostridial or non-Clostridial), arterial damage or thrombosis, and nerve damage.

The aim of study

To develop diagnostic, preventive and therapeutic measures aimed at preventing the development of compartment syndrome during closed interlocking osteosynthesis of the tibia.

- **Area of research:** compartment syndrome in fractures of the tibial shaft.
- **Subject of research:** semi-closed fasciotomy of the lower leg, carried out through incisions for implantation of interlocking nail in osteosynthesis of the tibia.

Research methods

- Chief complaints, history of life and illness, objective examination data.
- Standard laboratory tests.
- Instrumental - radiography, determination of subfascial pressure (using a commercially available device from Stryker).
- Statistical processing for small samples (reliability), mathematical analysis.

The study is based on the results of treatment of 93 patients with diaphyseal fractures of the tibia on whom closed interlocking nail was done in the orthopedic and trauma department of the State Budgetary Healthcare Institution of the Crimea Republic "Emergency Hospital No. 6, Simferopol". In most of the cases, we used ChM hardware (81 patients - 87.10%), in 11 cases (11.83%) we used Bliskunov's fixator, in 1 case (1.07%) Stryker hardware between 1992 to 2015. Surgical interventions were carried out in the orthopedic and traumatology department of the State Budgetary Healthcare Institution of the Crimea Republic "Emergency Hospital No. 6, Simferopol".

We should admit that this procedure is associated with the need to measure the pressure of each case, a slip is possible when the needle is inserted into the fascial bed next to it, the obturation of the needle, the placement of the needle tip in the fascia, ligament, tendon, outside the fascial bed.

The use of decompressive fasciotomy of the shin during osteosynthesis was performed in 27 cases (29%), in 66 cases (71%), the osteosynthesis was performed according to the classical technology.

Fasciotomy can be performed in three ways - open, semi-closed and closed. Open fasciotomy was not performed in our cases. This method is not preventive, but therapeutic and is used only in the presence of moderate and severe local hypertensive ischemic syndrome.

According to our proposed method, the dissection was carried out in two ways, semi-closed and closed. Semi-closed fasciotomy was performed in the anterior and anterolateral compartments from the incision for the implantation of an intramedullary device. Decompression of the rear surface and deep fascial beds was carried out as closed.

When performing semi-closed prophylactic fasciotomy of the tibia, no changes are made to the method of closed intramedullary osteosynthesis of the tibia. Fasciotomy of all four sheaths are performed through the operating approaches for the implantation of the device.

Results and Discussion

In our studies, 47 patients were diagnosed with compartment syndrome in the postoperative period. The severity was assessed as mild. No moderate or severe degree compartment syndrome was diagnosed in any of the clinical cases of observation. In 23 cases, verification of the diagnosis was confirmed by the monitoring of subfascial pressure using a serial device from Stryker.

The research was carried out in several stages. The first stage is before the start of surgery. The second - after processing the bone for the implantation of an intramedullary fixator. At this stage, the preperation of the bone marrow cavity was not a prerequisite. The third stage is after the implantation of an intraosseous device. The fourth - after the completion of surgical treatment, suturing of skin wounds. The fifth study - one day after surgery.

The studies were carried out using the "classical" intra medullary nailing. In this case, preventive fasciotomy of the cases were excluded.

Data without fasciotomy in intramedullary nail of tibia is below in a table 1.

Types	Compartments of lower leg			
	Anterior-lateral	lateral	Superficial posterior	Deep Posterior
Before implantation of the rod	7 ± 0,3	6 ± 0,3	7 ± 0,3	6 ± 0,3
After processing of cavity for an implantation	9 ± 0,7	9 ± 0,8	7 ± 0,3	7 ± 0,2
After implantation	17 ± 0,5	15 ± 0,5	7 ± 0,2	7 ± 0,2
Finishing surgery	18 ± 0,3	17 ± 0,3	8 ± 0,2	8 ± 0,2
Next 24 hours after implantation	21 ± 0,7	22 ± 0,8	11 ± 0,3	12 ± 0,3

Table 1

Analyzing the data obtained, it can be noted that using the standard method, an increase in subfascial pressure in the shin fascial beds is noted.

The use of preventive closed fasciotomy for intramedullary nail allowed us to avoid clinical manifestations of compartment syndrome in the early postoperative period. In all cases, there were no complications.

Thus, preventive decompression of the anterolateral and lateral fascial beds is a prerequisite for tibia osteosynthesis.

This surgical technique allows decompression of the fascial beds, however, accurate verification of the fascial case and the availability of special instrumentation "fasciotomes" are required in order to ensure adequate decompression.

It should be noted that according to the obtained data of subfascial pressure (Table 1), decompression of the posterior superficial and posterior deep cases is not a prerequisite for preventing the development of compartment syndrome, since the results correspond to the borderline indicators.

Data using fasciotomy in intramedullary nail of tibia is below in table 2.

Before implantation, the tissue pressure figures were identical to those in the control group and amounted to 6–7 mm Hg.

After the formation of the intramedullary canal for the implantation of the intramedullary fixator, the level of subfascial pressure

Types	Compartments of lower leg			
	Anterior-lateral	Lateral	Superficial posterior	Deep Posterior
Before implantation	7 ± 0,3	6 ± 0,3	7 ± 0,3	6 ± 0,2
After proccessing of cavity for an implantation	9 ± 0,5	9 ± 0,6	7 ± 0,2	7 ± 0,2
After implantation	12 ± 0,5	11 ± 0,5	7 ± 0,2	7 ± 0,2
Finishing surgery	12 ± 0,3	11 ± 0,3	8 ± 0,2	8 ± 0,2
Next 24 hours after implantation	13 ± 0,6	13 ± 0,7	9 ± 0,3	10 ± 0,3

Table 2

also did not differ in the two study groups and ranged from 7 mm Hg, up to 9 mm Hg.

After implantation of the fixator, there is a significant differences in subfascial pressure in the group of patients using fasciotomy and in the control group. Thus, in the study group, no differences were observed in the posterior superficial and posterior deep fascial beds of the tibia. In the anterolateral, the average subfascial pressure corresponded to 12 ± 0.5 mm Hg against 17 ± 0.5 mm Hg in the control group. Considering that up to 14 mm Hg can be considered the normal, the indicated data did not go beyond its border. In the lateral fascial bed of the shin, the subfascial pressure level corresponded to 11 ± 0.5 mm Hg, compared with the control group (15 ± 0.5 mm Hg) was 4 mm Hg. below and did not go beyond the normal.

After 24 hours, as in the control group, there was an increase subfascial pressure in all four shin fascial beds. It should be noted that no clinical symptoms of LHIS were observed in any case, and also no significant increase in level of pain was observed. The degree of increase in subfacial pressure was also within the normal range: anterolateral sheath 13 ± 0.6 (21 ± 0.7) mm Hg, lateral 13 ± 0.7 (22 ± 0.8) mm Hg, posterior superficial 9 ± 0, (11 ± 0.3) mm Hg, posterior deep 10 ± 0.2 (12 ± 0.3) mm Hg.

Considering the above, it is possible to conclude about the effectiveness of the fasciotomy of the tibia fascial beds during the intramedullary nail in order to prevent compartment syndrome.

Conclusions

As a result, using of preventive fasciotomies through operating approach for the implantation of interlocking intramedullary nail, an effective method for the prevention of compartment syndrome has been found.

- The main method for diagnosing compartment syndrome is the use of a commercially available device for measuring subfascial pressure from Stryker.
- The chances of LHIS while performing osteosynthesis of tibia is 93.7%, compartment syndrome of mild and moderate degree mostly appeared.
- An increase of subfascial pressure during nailing of tibia is observed mainly in two compartments - anterolateral and lateral.
- Preventive fasciotomy of the shin through incisions for the implantation of the interlocking nail allows to prevent the development of compartment syndrome.

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