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TREATMENT DYNAMICS OF TIBIAL SHAFT FRACTURES IN CHILDREN – THE ROLE OF GENDER, AGE AND TREATMENT METHOD

DINAMIKA LEČENJA PRELOMA POTKOLENICE KOD DECE – ULOGA POLA, UZRASTA I METODA LEČENJA

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Abstract

Introduction. Tibial shaft fractures in pediatric patients pose challenges due to bone growth. This study examined the influence of gender, age, and treatment methods on the duration of hospitalization, total treatment time, and timing of osteosynthetic material removal. **Material and Methods.** We conducted an analysis of 50 pediatric patients treated for tibial shaft fractures at the Institute for Children and Youth Healthcare of Vojvodina between 2016 and 2022. Patients with systemic diseases, neuromuscular disorders, polytrauma, or incomplete medical records were excluded. The cohort comprised 36 boys (72%) and 14 girls (28%), with a mean age of 11.76 years (SD=3.93). The primary mechanisms of injury included falls (38%), traffic accidents (30%), and sports activities (26%). An isolated tibial fracture occurred in 30% of the cases, while 70% of the patients sustained an associated fibular fracture. Statistical analysis were performed using Wilcoxon Rank Sum, Kruskal-Wallis, and Fisher's exact tests in RStudio. **Results.** Boys had a longer hospital stay than girls (11.28 vs. 6.14 days), whereas girls experienced a longer overall treatment duration (330.23 vs. 211.58 days) and a delay in the removal of osteosynthetic material (312 vs. 218.9 days). Adolescents aged 13-17 years exhibited longer hospitalization periods and delayed surgical intervention compared to children under 13 years of age ($p<0.05$). Age did not impact the time to weight-bearing or the total treatment duration. Surgical treatment was associated with a longer overall treatment course compared to conservative management ($p<0.05$). **Conclusion.** Gender and age play a significant role in the management of pediatric tibial shaft fractures, with girls and older adolescents experiencing extended treatment durations. While surgical intervention remains essential in severe cases, it is linked to prolonged treatment duration. These findings highlight the need for personalized treatment plans and call for further research into gender-specific approaches and long-term outcomes.

Key words: Tibial Fractures; Child; Adolescent; Treatment Outcome; Hospitalization; Orthopedic Fixation Devices; Age Factors; Sex Factors

Sažetak

Uvod. Prelomi dijafize tibije kod dece predstavljaju poseban izazov zbog rasta kostiju. Ova studija je ispitivala efekte pola, starosti i metoda lečenja na trajanje hospitalizacije, dužinu lečenja i vreme uklanjanja osteosintetskog materijala. **Materijal i metode.** U Institutu za zdravstvenu zaštitu dece i omladine Vojvodine (2016–2022) ispitano je 50 pedijatrijskih pacijenata sa prelomom tibije. Isključeni su oni sa sistemskim oboljenjima, neuromuskularnim poremećajima, politraumom ili nekompletnom evidencijom. Uzorak je obuhvatio 36 dečaka (72%) i 14 devojčica (28%), prosečne starosti 11,76 godina (SD = 3,93). Najčešći uzroci povreda bili su padovi (38%), saobraćajne nesreće (30%) i sportske aktivnosti (26%). Izolovana fraktura tibije bila je prisutna kod 30% pacijenata, dok je 70% imalo udruženi prelom fibule. U analizi je korišten Vilkoksonov test (*Wilcoxon Rank Sum*), Kruskal-Volisov test i Fišerovi egzaktni testovi u RStudio. **Rezultati.** Dečaci su duže boravili u bolnici od devojčica (11,28 > 6,14 dana), dok je kod devojčica ukupno trajanje lečenja bilo duže (330,23 > 211,58 dana) i odloženo uklanjanje osteosintetskog materijala (312 > 218,9 dana). Adolescenti (13–17 godina) su imali dužu hospitalizaciju i odlaganje operacije u poređenju sa decom mlađom od 13 godina ($p < 0,05$). Starost nije uticala na vreme do oslonca ili ukupnu dužinu lečenja. Hirurško lečenje je dovelo do dužeg ukupnog vremena lečenja u poređenju sa konzervativnim ($p < 0,05$). **Zaključak.** Pol i starost utiču na lečenje preloma dijafize tibije kod dece, pri čemu devojčice i stariji adolescenti imaju duže lečenje. Posle hirurške intervencije, koja je neophodna u teškim slučajevima, lečenje duže traje. Ovi nalazi naglašavaju potrebu za personalizovanim planiranjem lečenja i predlažu dalje istraživanje rodno specifičnih strategija lečenja.

Ključne reči: prelomi tibije; dete; adolescent; ishod lečenja; hospitalizacija; ortopedski fiksatori; starost; pol

Introduction

Tibial fractures account for about 15% of long-bone fractures in children and adolescents [1]. Among lower extremity fractures, 47% involve the tibia and fibula, with 26% occurring in the distal segment, 16% in the shaft, and 5% in the proximal segment of the tibia [2]. Tibial diaphysis fractures, commonly referred to as tibial shaft fractures in children, pose a significant clinical challenge due to various injury mechanisms and manifestations that differ according to the patient's age and circumstances. Notably, tibial shaft fractures

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Abbreviations
FIN – flexible intramedullary nailing
ESIN – elastic stable intramedullary nailing
CRIM – Closed Reduction Immobilization

are the second most frequent type of fracture among children affected by abuse, with 26% of these young patients presenting with such injuries. This statistic underscores the importance of considering non-accidental trauma in the differential diagnosis when evaluating pediatric fractures [3].

Treating tibial shaft fractures in children requires a careful approached to avoid potential serious complications, the most severe of which is impaired bone healing. For instance, in type III open tibial fractures, as classified by Gustilo-Anderson, the incidence of healing complications is as high as 60% [4]. Therefore, individualized treatment strategies are essential to achieve optimal outcomes. The treatment of tibial shaft fractures in pediatric patients differs from adults primarily due to the presence of growth plates and the potential for bone remodeling. In children, conservative management with casting or bracing is often favored for minimally displaced fractures, given that their bones have a greater capacity for healing and correcting deformities over time. In contrast, adults typically require surgical intervention, such as intramedullary nailing or plating, due to a lower potential for remodeling and a higher risk of complications like nonunion or malalignment. Additionally, pain management, rehabilitation, and monitoring strategies must be tailored to the child's growth and developmental needs [5].

Most pediatric tibial shaft fractures are managed non-operatively, typically involving closed reduction and immobilization in a plaster cast, leading to favorable long-term outcomes [6]. However, more severe fractures may necessitate surgical intervention. Indications for operative treatment include the inability to maintain proper fracture alignment with non-operative methods, open fractures requiring frequent wound care, fractures complicated by compartment syndrome, and fractures with significant swelling, such as those involving ipsilateral femoral fractures ("floating knee"). Other indications include tibial fractures with an intact fibula, particularly when the fracture line extends from the distal anteromedial to the proximal posterolateral aspect of the tibia, as these tend to drift into varus even in well-molded casts, then comminuted and unstable fractures, and fractures where prolonged immobilization is impractical due to social or activity-related factors [7].

Surgical options include flexible intramedullary nailing (FIN), K-wiring, rigid intramedullary nailing, open reduction with internal (plate and screw) fixation, and external fixation. Studies have consistently demonstrated that titanium elastic nails provide the most effective treatment management with the lowest complication rates, making this technique the preferred option whenever applicable [8, 9]. However, the use of this method is limited by the child's size and the severity of the fracture. In cases of open, complex, or unstable fractures, or when non-operative or other treatments modalities fail, the Ilizarov method is considered a favorable option [10].

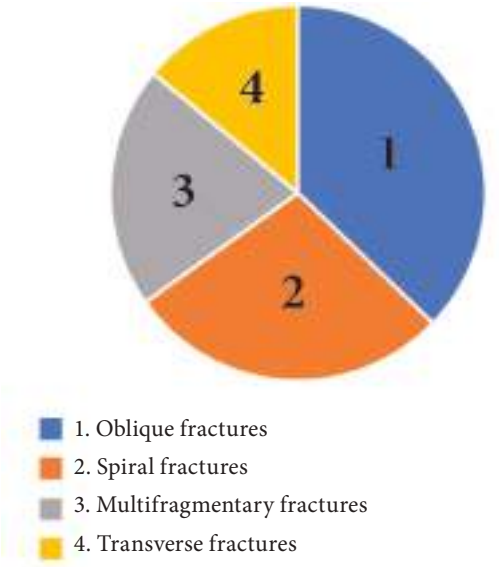
Over the past two decades, flexible intramedullary nailing has become increasingly popular for treating shaft fractures in children aged 4 to 15 years. Known as elastic stable intramedullary nailing (ESIN), this technique evolved from flexible rodding methods developed in Nancy, France. ESIN offers numerous benefits, including minimal invasiveness, shorter hospital stays, early mobilization, and fewer complications. ESINs differ from other flexible nail systems, such as Ender nails, which lack the necessary elasticity for pediatric fractures and can alter the natural bone curvature. ESIN is widely accepted for length-stable femoral fractures, such as transverse and short oblique patterns, particularly in children weighing under 60 kilograms, reducing the risk of complications like femoral head osteonecrosis and premature greater trochanteric epiphysiodesis with rigid intramedullary techniques. Nonetheless, the application of ESIN in unstable fractures remains a topic of debate due to concerns over a higher incidence of angular and rotational deformities [11–13].

Once bone healing and remodeling are complete, the implants are removed in a secondary surgery. This procedure is crucial to prevent complications such as chronic infections, interference with surrounding soft tissues, and long-term issues with fracture healing [14]. The procedure, however, carries risks [15] including tendon rupture, infections, neurovascular injury, and granuloma formation, highlighting the need for careful evaluation the optimal timing for osteosynthetic implant removal.

This study aimed to evaluate the influence of factors such as gender, age, and treatment methods on hospitalization duration and overall treatment length in pediatric patients treated over a five–year period in a single institution. It also sought to compare the length of therapy between operated and non-operated patients to identify any significant differences in outcomes based on the chosen treatment approach.

Material and Methods

The study received approval from the Ethics Committee of the Institute for the Health Care of Children and Youth of Vojvodina. It was conducted



Graph 1. Prevalence of different fractures based on the type of fracture line

retrospectively from 2016 to 2022, involving fifty participants of both sexes aged 0 to 17 years with tibial shaft fractures who consented to participate in the research. Exclusion criteria included the presence of systemic diseases, neuromuscular disorders, polytrauma, and incomplete medical documentation. Among the 50 subjects, 36 were male (72%) and 14 were female (28%). The average age of the patients was 11.76 years (SD=3.93), with 7 (14%) in the 0-6 years age group, 18 (36%) in the 7-12 years group, and 25 (50%) in the 13-17 years group. Injuries to the left leg were recorded in 46% of cases, while the right leg was affected in 54% of cases. The most frequent mechanism of injury was a fall, reported by 19 patients (38%), followed by traffic accidents in 15 patients (30%), sports-related activities in 13 (26%), and other causes in 3 patients (6%).

A total of 30% of patients presented with an isolated tibial fracture, whereas 70% had an associated fibular fracture. Among the 35 patients with an accompanying fibula fracture, 28 underwent surgical treatment. In contrast, out of the 15 patients with an isolated tibial fracture, 14 required surgical intervention. Although there was a seemingly higher rate of surgical treatment in the group with isolated tibial fractures, this difference was not statistically significant based on the data provided.

Based on the fracture line orientation, the distribution of fractures was classified as follows: oblique fractures 37.2%, spiral fractures 27.9%, multifragmentary fractures 20.95%, and transverse fractures 13.95% (as illustrated in **Graph 1**).

The average time from injury to treatment was 4.28 days, and the average duration of hospitalization was 9.84 days. Forty (80%) patients were treated surgically, while the remaining 10 patients (20%) underwent closed reduction and immobilization with a plaster cast (Closed Reduction Immobilization – CRIM). The average period of cast immobilization was 62.54 days.

All surgical procedures and follow-up treatments were carried out by the same surgeon, with detailed documentation maintained during each follow-up visit. Statistical analysis was performed using RStudio software, employing the Wilcoxon Rank Sum Test, Kruskal-Wallis test, and Fisher's exact test to analyze the data.

Results

For the 36 male patients, the average treatment duration was 211.58 days, with osteosynthetic material removal occurring after an average of 218.91 days. For the 14 female patients, the average treatment duration was 330.23 days, with the removal of osteosynthetic material taking place after an average of 312 days. There is a statistically significant difference in the treatment duration based on the patient's ($p<0.01$), as well as in the time to osteosynthetic material removal ($p<0.05$). On average, male children spent 11.28 days in the hospital, compared to female children, who spent an average of 6.14 days there, as detailed in **Table 1.**

There was a statistically significant difference in the hospitalization duration between sexes ($p<0.05$). However, gender did not have a statistically significant impact on the average time to begin weight-bearing in these patients.

Table 1. Treatment and hospitalization duration depending on gender

	Boys	Girls
Duration of hospitalization	11.3 days	6.1 days
Duration of presence OS material	219 days	312 days
Duration of treatment	212 days	330 days

Table 2. Hospitalization duration depending on age

Age (years)	0-6	7-12	13-17
Average duration of hospitalization in days	3.4	4.6	13.2

Graph 2. Period from hospitalization to surgery in days

The overall average hospitalization duration for the patient cohort was 9.8 days. Patients aged 0-6 years had an average hospitalization period of 3.4 days, those aged 7-12 years averaged 4.6 days; and patients aged 13-17 years had an average stay of 13.2 days **(Table 2)**. There was a statistically significant difference in the length of hospitalization depending on age group ($p<0.05$), with post-hoc tests indicating that patients aged 13-17 years differed significantly from the other two age groups. The average time from hospitalization to intervention for the entire sample was 5.1 days. For the age group 0-6 years, it was 1 day; for the 7-12 years group, it was 3 days; and for those aged 13-17 years, it was 7.8 days (as illustrated in **Graph 2**). This age-based difference in the period from hospitalization to surgery was statistically significant ($p<0.05$), with post-hoc tests again confirming that the 13-17 years age group differed significantly from the other two groups.

The average time from injury to initiation of weight-bearing on the injured leg was 64.72 days, and the total treatment duration for both surgically and conservatively treated patients averaged 229.22 days. For surgically treated patients, osteosynthetic material was removed after an average of 249.54 days. Statistical analysis revealed no statistically significant difference in the time to begin weight-bearing, the duration of osteosynthetic material presence, or the overall treatment length when stratified by age.

The mean treatment duration for surgically treated patients was 258 days, while non-surgically treated patients had shorter average treatment period of 137 days, demonstrating a statistically significant difference ($p<0.05$) based on whether the patient underwent surgery.

Discussion

In adults, tibial shaft fractures account for about 1.9% of all fractures [16], whereas in pediatric population, they represent approximately 2.5% of all pediatric fractures [17]. Similarly to adult cases, these fractures are observed to be two to three times more common in males [16, 17]. Our study's findings align with this sex ratio.

Among the 35 patients with a combined fibula fracture, 28 (80%) underwent surgery, while 14 (93.3%) of the 15 patients with an isolated tibial fracture also received surgical treatment. This data indicates a higher proportion of patients receiving surgical intervention in the group with isolated tibial fractures, corroborating the assertion that isolated tibial fractures often warrant surgical intervention [7].

Regarding the fracture line orientation, oblique fractures were the most frequent type in this study, occurring in over 37% of cases. This observation differs from the studies conducted by Stenroos et al. [18] and Ho et al. [19], where spiral fractures were the predominant type (57-62%). Nonetheless, both studies ranked oblique fractures as the second most common type after spiral fractures.

The average period from hospitalization to surgery in our study was 5.1 days, which is slightly longer than 3.9 days reported in the study by Gamal et al. [20]. According to our data, we notice that both hospitalization period and time to surgery in the 13-17 age group were significantly longer compared to younger age groups. One plausible explanation is that our pediatric surgery clinic typically has ESIN nails available for patients up to 16 years of age. For those older than 16 years, rigid intramedullary nails are used, which may take additional time to acquire. This factor likely contributed to the slightly longer average period from hospitalization to surgery compared to Gamal et al. study [20].

Our study revealed that male patients had a significantly longer hospital stays than female patients. This finding contrasts with the results reported by Pogorelić et al. [21], where no gender-based differences in hospital stay duration were noted. This discrepancy might be due to age distribution in our study, where 19 out of 36 male patients (52.8%) were over 12 years of age, compared to only 6 out of 14 female patients (42.8%) falling into this older age group. Given our findings that older patients tend to have longer hospital stays, the higher proportion of older males in our sample might account for the observed difference in hospitalization duration between genders. Future research should aim for a more balanced age and gender distribution to better understand these dynamics.

Although nonoperative treatment is by far the most common method of treatment in most studies [3, 5, 18, 19, 22], only 20% of our patients were treated conservatively. This can be explained by the fact that the data were collected from a tertiary care facility that primarily manages severe cases, which usually require surgical treatment.

In our study, osteosynthetic material was extracted after an average of 249.54 days, considerably sooner than in the studies by Stenroos et al. [18] and

Goodwin et al. [23], where extraction was performed after an average of one year. It should be noted that their studies mainly included open fractures, which are usually the most severe and require later extraction of osteosynthetic material.

Statistical analysis of this study indicates longer treatment duration for surgically treated patients compared to conservatively treated patients, aligning with the findings by Kinney et al. [24]. This difference can be explained by the fact that surgical intervention is usually reserved for the most severe cases that are expected to have a poor outcome with nonoperative treatment, thus necessitating extended postoperative follow-up.

No instances of refracture, remanipulation, or repeat surgery were recorded in our study, which is consistent to the findings of O'Brien et al. [25].

While this study provides valuable insights into management of pediatric tibial shaft fractures, several limitations must be acknowledged. The retrospective design limits control over confounding variables and may introduce biases due to its reliance on previously recorded data. The small sample size of 50 patients restricts the generalizability of the findings and may reduce the statistical power, particularly in subgroup analyses. As the study was conducted at a single institution, the results may not be applicable to other populations. Additionally, the absence of long-term follow-up data leaves gaps in understanding the full scope of functional recovery and complications. Given that 80% of patients underwent surgery, insights into non-operative management remain limited. Furthermore, the study does not thoroughly explore the relationship between injury mechanisms and outcomes, and the lack of functional outcome measures restricts the assessment of the injury's overall impact on quality of life. These limitations highlight the need for cautious interpretation of the results and further research.

Conclusion

Based on the analysis of the results from this study and a review of the literature, several conclusions can be drawn regarding diaphyseal tibial fractures in children. Firstly, these fractures are observed to be two to three times more prevalent in males than in females. In terms of treatment outcomes, girls demonstrated a statistically significant increase in both treatment duration and the time until the extraction of osteosynthetic material ($p<0.05$), while boys experienced significantly longer hospitalization periods.

Additionally, adolescents aged 13 to 17 years exhibited a statistically significantly longer hospitalization duration and an extended period from admission to surgery when compared to patients younger than 13 years ($p<0.05$). However, no significant differences were noted regarding the time to onset of weight-bearing, the duration of osteosynthetic material presence, or the overall length of treatment based on age.

It is also notable that patients who underwent surgical intervention had significantly longer treatment duration than those treated nonoperatively. This finding can be attributed to the fact that surgical intervention is typically reserved for the most severe cases, whereas milder fractures are managed without surgery.

Future research can build on these findings to further enhance management strategies for pediatric tibial fractures, aiming to improve outcomes and reduce the treatment burden on young patients.

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