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ADAM OVIDIU

THE TREATMENT OF FRACTURES OF DIAPHYSAL BONES OF THE UPPER EXTREMITY IN CHILDREN – A COST-EFFECTIVENESS STUDY

ABSTRACT OF THE DOCTORAL THESIS

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CONTENT

GENERAL PART

1. Diaphyseal fractures in children

Described since antiquity, most fractures and dislocations were treated conservatively until the appearance of three major inventions: anesthesia in 1846, antiseptics in 1865 and X-rays in 1895 [1]. In the following years, the surgical treatment of fractures experienced a rapid evolution, most types of osteosynthesis were imagined and put into practice: the osteosynthesis plates by Hansmann in 1886, the external fixator by Parkhill in 1897 and the intramedullary rods by Schöne in year 1913. Also, at the beginning of that century, several types of surgical approach were described and the first fracture osteosynthesis techniques were published [2].

The complexity of diaphyseal fractures encountered in children required the development of minimally invasive pediatric orthopedic surgical techniques taking into account the particularities of the immature bone, so percutaneous osteosynthesis in diaphyseal fractures of the forearm in children and adolescents was firstly reported in 1977 by Perez. The first published study on elastic osteosynthesis, as a new concept in pediatric traumatology, belongs to Firică [3], but minimally invasive osteosynthesis in children is described in detail as a technique and successfully applied by Metaizeau (Metaizeau technique), who describes the aspects related to the biology and peculiarities of immature bone and which used elastic steel rods to stabilize fractures in children, according to the Ender technique, approaching the fracture focus at a distance [4].

Although the conservative management of diaphyseal fractures in children depends on the age and type of fracture, the acceptable degrees of angulation, displacement and rotation, the indications for conservative treatment remain controversial in the specialized literature. Open reduction and osteosynthesis is a therapeutic option indicated in the case of open fractures, with significant comminution, with vascular or nerve damage, unstable fractures with significant displacement or that have moved during orthopedic treatment and fractures with pathological bone displacement [5].

Frequently encountered in pediatric traumatic pathology, the incidence of fractures in children has increased in the conditions of modern life, where road, sports and play accidents occupy the first place and are of particular interest in children [6]. Most fractures in this age group do not pose a real threat to life and can be treated [7,8]. Although there are many pediatric systemic and metabolic diseases that predispose to fractures, most of these pathological bone fractures are secondary to trauma [9]. In children, most pathological fractures are due to bone infections, benign bone tumors or metabolic diseases. However, sometimes the cause can be a malignant condition, such as Ewing's sarcoma, fibrosarcoma, leukemia, bone metastases, which is why clinical or paraclinical suspicion must be followed by special investigations [10,11].

At a national level, there is very few data on the incidence of fractures in children. International specialized studies report that the risk of having a fracture during childhood is around 50% for boys and 30% for girls [12,13].

Depending on the nature of the traumatic agent and the place of action, we can describe in children fractures produced by direct mechanisms and fractures produced by indirect mechanisms. As in the case of adults, the production of a fracture in a child involves the existence of intrinsic or extrinsic factors, capable of determining the interruption of bone continuity, but with the production of injuries specific to the pediatric period determined by the elasticity and plasticity of their developing bones.

2. Pathological anatomy of fractures in children

Although the composition of the bone skeleton is identical to that of the adult, the structure of the bones in children is characteristic, determining particularities and different ways of approach in pediatric orthopedic and traumatic pathology [7].

The presence of growth cartilages, the periosteum, which is much better represented and better vascularized, the lower height and weight, the muscle mass is less represented but with a vascularization not compromised by chronic pathologies coexisting in the adult, the increased porosity and the better represented Haversian canals in the immature bone ensure qualities and particularities of bones in children, unique qualities with practical importance, which implicitly impose a different vision on the therapeutic attitude in pediatric orthopedic and traumatic pathology.

Interruption of both bone cortices without radiologically highlighting the interruption of the continuity of the periosteum defines the subperiosteal fracture, a well-known entity encountered in pediatric traumatology. In frequent situations, the diaphysis interpenetrates the bone metaphysis, causing a widening of the bone outline, an injury described as a settling fracture. Complete fracture of only one cortex and angulation of the contralateral one without interruption on radiological examination defines the "greenstick" fracture [14,15].

The surgeon's first goal is to identify what Müller called "the essence of the fracture." This is the attribute that gives the fracture its particular identity and allows it to be assigned to a specific type. Each long bone is assigned a number, three segments (proximal, diaphyseal and distal) coded with numbers and classified into types, groups and subgroups according to the morphology of the fracture path. Depending on these aspects, the AO classifies long bone fractures as belonging to simple, mixed comminutive and complex cominutive fractures. The association of the fracture with a solution of the continuity of the skin and the involvement of the overlying structures requires the Gustilo-Anderson classification and, implicitly, the type of appropriate treatment, a classification used at the national level, both in adults and children [16,17].

The production of a fracture determines a chain of physiological and metabolic reactions, which have the role of regenerating the affected bone structure, respectively to reconstitute the original bone structure. Bone healing can be defined as the effective reconstitution of the damaged tissue, to original form, which distinguishes it and makes it different from the healing of other tissues of the body that repair tissue damage through cicatrization or fibrosis mechanisms [18].

Primary healing is achieved if two requirements are met: the interfragmentary space at the level of the fracture must be minimal, and the bone fragments must be anatomically reduced, requirements met by anatomical bleeding reduction and osteosynthesis with an open focus [18]. Secondary or indirect healing involves both membrane ossification and enchondral ossification and is characteristic of fractures treated orthopedically (by cast immobilization) or in the case of those stabilized by external fixation or intramedullary elastic fixation. The repair phase occurs 3-4 days after the fracture, before the completion of the inflammation phase, a phase initiated by mesenchymal cells from the periosteum that migrate to the fracture site and differentiate into osteoblasts, chondrocytes and fibroblasts, cells specialized in the formation of fibrous callus [19].

The evolutionary phases of the fibrous callus follow, which recognize the two types of ossification: membrane ossification and enchondral ossification. It lasts from a few weeks to a few months and results in the appearance of callus at the level of the fracture site, a callus that, due to the particularities of the periosteum in children, will cause an indirect healing, usually with a hypertrophic callus [20].

In the case of fractures in children, the anatomical and histological peculiarities of the periosteum create local conditions (the periosteum easily detaches from the bone structure with very pronounced local bleeding) favorable for indirect healing in the case of conservative orthopedic treatment or in the case of elastic osteosynthesis, indirect healing with a hypertrophic callus most of the time [21].

3. Treatment of fractures in children

The treatment of fractures is based on principles and main objectives aimed at the morphological and functional restoration of the damaged bone, taking into account the particularities of the bone system in children. It is carried out through different bone anatomy reconstruction techniques that involve orthopedic or open reduction procedures and post-reduction immobilization, with the maintenance of the above and underlying joints and muscle groups corresponding to the affected segment in a functional position.

Particular importance is given to conservative orthopedic treatment due to the particular morpho-functional aspects, which determine the ability of rapid healing and remodeling over time of the fractured bone in children, with the secondary correction of some degrees of permissive angulation or rotation in the younger age group [22,23].

Orthopedic treatment in the case of fractures in children must be considered as first-line treatment and consists of orthopedic reduction and cast immobilization. Orthopedic reduction involves the performance of simultaneous, continuous and prolonged extension-counterextension maneuvers along the axis of the fractured bone, supplemented by maneuvers performed at the fracture site. Immobilization with a simple plaster splint, bivalve or even circular device must ensure containment of the fractured fragments, respect the functional position of the affected limb, and not affect the local circulation or the underlying skin [24,25].

In pediatric traumatology, orthopedic surgical treatment is reserved for cases in which orthopedic reduction has failed, in the case of post-reduction unstable fractures, in the case of fractures with large comminution, open fractures and fractures on pathological bone [26].

Open reduction and osteosynthesis is based on the principle of opening the fracture site, evacuating the post-fracture hematoma, preparing the fractured bone ends and reducing the fracture, which will be maintained and stabilized, usually rigidly, by using osteosynthesis materials [27].

Osteosynthesis can be internal or centromedullary, by using Kirschner pins, Küntscher rods inserted centromedullary through the fracture focus, or external by mounting the osteosynthesis material outside the fractured bone by using cerclages, neutralization or compaction plates with screws, drills, screws compression or external fixator.

Minimally invasive osteosynthesis in children is described and successfully applied by Metaizeau, using elastic steel rods according to the Ender technique, for osteosynthesis of femur and tibia diaphyseal fractures in adolescents. Healing is achieved by an indirect mechanism, similar to the healing of fractures treated conservatively, with a usually hypertrophic callus [5].

The European studies are the ones that discuss the age and weight limit, so that minimally invasive osteosynthesis with elastic titanium rods is not indicated under the age of 5 and after the age of 16. The same authors contraindicate osteosynthesis with elastic titanium rods in children weighing more than 60 kilograms [28,29].

Recent reports in the specialized literature about the benefits of osteosynthesis with elastic titanium rods in adults and the elderly with polytraumas or associated stiffness, in which classic osteosynthesis could increase the anesthetic and operative risk, demonstrate the applicability of the technique to the 16-18-year-old age group, regardless of weight [30].

The existence of soft tissue injuries (hematomas, lacerations, solutions of tegumentary continuity) at the level of the insertion region of the osteosynthesis material may constitute a contraindication, if the osteosynthesis mounting can only be practiced in one way (retrograde or anterograde).

The identification of traumatic nerve or vascular injuries (absence of the radial pulse after orthopedic reduction, radial nerve paresis in humerus fractures) requires classical surgical exploration and the presence in the operative team of colleagues from the specialties of plastic surgery and vascular surgery.

SPECIAL PART

4. The general purpose and objectives of the paper

The choice of the research theme for obtaining the title of doctor in medical sciences was based on my own medical career. With an experience of over 25 years in pediatric surgery, I chose the current research topic entitled "Treatment by minimally invasive methods of limb fractures in pediatric orthopedic and traumatological practice". Although at the national level, minimally invasive osteosynthesis is applied in few university centers, the surgical technique and the specific instrumentation being known, there are controversies related to the surgical treatment of fractures in children at an international level, which motivated me even more to research and bring innovations in this field. Thus, during the study period regarding in the data found in the present paper, three full-length articles published in journals with an impact factor were published, two of which are published as the first author [31,32] and one as a co-author [33] .

Bone healing after osteosynthesis with elastic titanium rods occurs through an indirect mechanism, osteosynthesis with elastic rods determining a healing comparable to that obtained by conservative treatment, the particularities of this treatment method consisting in healing with hypertrophic callus in the initial phase due to the preservation of the post-fracture hematoma , non-detachment of the periosteum at the level of the fracture focus and due to the permissive micromovements, existing at the level of the early postmobilization fracture focus. In the case of the young organism, in the growth period, the physiological process of bone remodeling is much more accentuated and remodels the focus with the removal of the bone callus formed in excess and, frequently, with the correction of the degrees of angulation or rotation.

Reviewing the specialized literature, we found that there are no studies aimed at measuring costs and efficiency in the case of fractures treated with the minimally invasive method, nor studies that would compare the costs or efficiency of this method with the classic approach.

In order to achieve the proposed objectives, we carried out a research of the specialized literature in order to calculate the incidence of fractures of the upper limb among children, the calculation of hospitalization costs in the case of the minimally invasive treatment approach and the comparison with the hospitalization costs for cases treated by the classical method.

5. The study of the incidence of fractures of the upper limb in the pediatric population in Romania and in the Western region: comparing these data with the data obtained from the specialized literature through the method of systematic review of the literature

Fractures are common in children, accounting for 10% to 25% of all pediatric injuries [10]. Distal forearm fracture is the most common type of fracture in childhood and adolescence. Approximately one third of all children sustain at least one fracture before the age of 17 [34]. The most frequent mechanism of fractures is represented by falls [35].

The objective of the systematic review of the literature was to obtain the most recently published data in the specialized literature regarding the incidence of fractures at the level of the upper extremity in children. Thus, to capture the incidence data published in the last five years in the scientific literature regarding the incidence of upper extremity fractures in children, we performed a systematic search on January 27, 2020, using the Medline database (via PubMed). The search was limited to papers in English published in the last five years (2015 - 2020). No geographic restrictions were applied to provide as comprehensive a picture of fracture incidence as possible. We used a search strategy based on keywords and relevant synonyms.

Using ICD-10-AM, 3rd edition diagnosis codes as keywords, we performed a search of the National Hospital Centralized Database. The database contains anonymized continuous hospitalization data. The incidence of upper limb fractures at regional and national level was calculated. The search was limited to the year 2018 and to the pediatric population (age below 18 years). Patients of both sexes were included. ICD-10 codes were used to identify arm fractures.

Following the search, we identified 132 studies, and a number of 119 studies were excluded by screening the titles and abstracts. One study was not in English and was therefore excluded, leaving 12 relevant studies [36-48]. An overall incidence including all ICD-10 codes used by the healthcare system was also calculated, representing the combined incidence for fractures of the arm, forearm and upper limb (not otherwise specified). The 2018 census results were used as national and regional population data; incidence values were calculated per 100,000 persons/year.

Following the systematic review of the literature, 5 studies were identified that reported data on the incidence of humerus fractures. Three studies reported data on proximal humerus fractures, two studies on diaphyseal humerus fractures, one study on distal humerus and three studies on humerus fractures without specifying a more precise location. One study (Naranje et al., [36]) reported data on humerus fractures without specifying a more precise location.

We also identified 9 studies that reported data on the incidence of forearm bone fractures with different locations. Three studies reported data on distal radius fractures, one on radius/ulna fractures, one study on diaphyseal fractures of the ulna, one study on diaphyseal fractures of the radius and six studies on forearm fractures.

Finally, there were 2 studies that reported data on the incidence of upper limb fractures without specifying the exact location.

The incidence of arm fractures is shown in Table 1. The incidence was calculated per 100,000 persons/year. Thus, it can be seen that the incidence is higher in the Western region compared to the national average.

Table 1. The incidence of humerus fractures in Romania and the Western Region

Fractures of the arm	**Total (National)**	**Western Region**
Number of cases	2012	201
Population	3,669,563	310,254
Incidence	54.83	64.79

The incidence of forearm fractures is shown in Table 2. The incidence was calculated per 100,000 persons/year. Thus it can be seen that the incidence is higher in the Western region compared to the national average.

Table 2. The incidence of radial and ulnar fractures in Romania and the Western Region

Fractures of the forearm	**Total (Național)**	**Western Region**
Number of cases	5,129	433
Population	3,669,563	310,254
Incidence	145.72	175.02

In Romania and in the Western region of Romania, the calculated incidence of fractures of the upper extremity (not otherwise specified) in children was 11.41 / 100 000 persons/year and 16.76 / 100 000 persons/year, respectively. The incidence was calculated at 100,000 people/year. Thus, it can be seen that the incidence is higher in the Western region compared to the national average.

Thus, it can be stated that in Romania and in the Western Region of Romania, the incidence of arm fractures in children was 54.83 / 100,000 people/year and 64.79 / 100,000 people/year, respectively. The incidence of forearm fractures was 139.77 / 100 000 persons/year and 139.56 / 100 000 persons/year, respectively. The incidences of upper extremity fractures (not otherwise specified) were 11.42 / 100,000 persons/year and 15.79 / 100,000 persons/year, respectively.

In terms of gender distribution in general, it has been observed that the male gender is more frequently affected by fractures of the upper limb among children. Subunit values show studies reporting more girls than boys and are quite rare, being described in two studies, that of Jacobsen et al. and that of Christoffersen et al. [45,49]. Both studies showed these subunit ratios when it came to arm fractures. The maximum value of the ratio of boys to girls was described by Yang et al. (8.7) regarding hand fractures [48]. The maximum value of the proportion in relation to total upper limb fractures was observed by Wang et al. (7.4) in their study of child collisions producing fractures [12].

In the database of the "Louis Țurcanu" Children's Hospital, 181 patients were included, of which 135 were boys and 46 were girls, resulting in a B/F ratio of 2.93, similar to what we find in the literature from online databases.

As necessary as the discussion of age groups is, it is also complicated given the heterogeneity of data in the literature. There is no consensus in establishing specific age groups. Thus, in many studies, 2 major groups could be observed: the ages between 0 and 9 years and the ages between 10 and 18 years. In the database of the "Louis Țurcanu" Children's Hospital, separating the age groups into two equal parts, we obtained results similar to those in the literature regarding upper limb fractures, as follows: 0-9 years: 26.52%, 10-18 years: 73.58%.

Minimally invasive osteosynthesis in children is described and successfully applied by Metaizeau, using elastic steel rods according to the Ender technique, for osteosynthesis of femur and tibia diaphyseal fractures in adolescents. Titanium elastic rods are part of the range of stable elastic intramedullary rods (ESIN). This method provides for the introduction of 2 elastic rods through the metaphysis into the medullary canal, advancing them through the fracture site and impacting them into the opposite metaphysis. Titanium, which has a higher elasticity compared to steel, is the material of choice in case of diaphyseal fractures that require a higher elastic reaction force [50].

It is also possible to observe the short duration of hospitalization of patients treated with titanium rods, lasting less than a week on average. The same thing was similar among the patients hospitalized in the "Louis Țurcanu" Children's Hospital, most of them benefiting from 3-4 days of hospitalization. Regarding postoperative complications, no significant differences could be detected between TEN (3/51) and non-TEN (16/130) patients, at a p value= 0.318.

6. Comparison of the economic efficiency of the three treatment methods: comparison of costs and cost versus reimbursement of the treatment of diaphyseal fractures in children and using minimally invasive methods with titanium elastic rod (TEN) versus kirschner pin treatment and closed reduction of fractures with cast immobilization

Forearm fractures are the most common childhood fractures. For any medical system cost is a major issue in the decision to adopt a particular treatment option over another [52]. In the case of TEN versus other options for the treatment of long bone fractures in children, cost is also an important issue. Only a few publications have focused on the financial aspects of using TEN in children, and most of them have focused on long bone fractures of the lower limbs [52].

Thus, we evaluated the costs of using TEN versus other therapeutic means in the treatment of forearm fractures in children by conducting a retrospective longitudinal study on 173 consecutive patients with forearm fractures treated in a single institution during 2017. The study was carried out at the Children's Hospital "Louis Țurcanu", Timisoara, Romania.

Cost per patient was calculated by summing direct costs (drugs, surgical materials) and indirect costs calculated at the aggregate level (overhead, diagnostic costs, hospital management, equipment service and maintenance, and medical staff salaries).

The hospital's revenue data were obtained from the DRG database, which includes all patients treated during 2017. The revenue for each patient received by the hospital from the Single National Social Health Insurance Fund (FNUASS) was calculated by multiplying the index case-mix (CMI) with the weighted case rate (TCP). The cost of the Kirschner pin and the TEN are covered by the National Trauma Health Program, for this reason when calculating the reimbursement for each patient we added the direct costs of the TEN ($71 / TEN) and those of the K-wire ($1.2) separately from the reimbursement received from the national program. The cost calculation was performed in the local currency (RON) and the values were converted into US dollars at the exchange rate of the National Bank of Romania (1 USD = 4.2268 RON on 23.04.2019).

Between January 1 and December 31, 2017, a total of 173 patients (45 girls and 128 boys) with forearm fractures were admitted and treated in our hospital. The age of the patients varied between 3.3 and 19.5 years (on average 12.1 years). There were 66 fractures of the radius, 1 fracture of the ulna, and 106 cases that had combined fractures of the radius and ulna (Table 3). Closed reduction with cast immobilization was used in 46 patients, closed or open reduction with Kirschner pin application was used in 82 patients, and closed or open reduction with TEN was used in 44 patients. Postoperative cast immobilization was used in all patients treated with Kirschner Wire, in 5 patients treated with 1 TEN, and none of the patients treated with 2 TEN.

Table 3. Treatment methods

<table>
<tr><th>Procedure</th><th>Radius
N= 66</th><th>Ulna
N= 1</th><th>Radius + ulna
N= 106</th><th colspan="2">Total
N= 173</th></tr>
<tr><td>Closed reduction + cast</td><td>30</td><td>0</td><td>16</td><td colspan="2">46</td></tr>
<tr><td>1 K-wire</td><td>29</td><td>0</td><td>52</td><td>81</td><td rowspan="2">82</td></tr>
<tr><td>2 K-wire</td><td>7</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1 TEN</td><td>7</td><td>1</td><td>2</td><td>10</td><td rowspan="2">44</td></tr>
<tr><td>2 TEN</td><td>0</td><td>0</td><td>34</td><td>34</td></tr>
<tr><td>Post operatory cast immobilization</td><td>29</td><td>1</td><td>53</td><td colspan="2">83</td></tr>
</table>

N: number of patients; TEN: titanium elastic nail;

The average duration of hospitalization was 3.43 days (1-8 days): 3.57 days (1-7 days) for TEN patients, 3.55 days (1-7 days) for patients with Kirschner pin and 3.09 days (1-6 days) for patients with closed reduction and cast immobilization. Only 3 polytrauma patients were admitted to the intensive care unit.

The mean cost for treatment of forearm fractures was US$520.09 (US$337.43–US$455.53)/patient (Table 4). The mean cost for TEN insertion was greater than Kirschner pin insertion (mean difference, $131.80) and greater than closed reduction with cast immobilization (mean difference, $182.42). The cost of Kirschner Wire treatment was also higher than closed reduction with immobilization (mean difference, $50.70; $p = 0.03$).

Table 4. Costs and Reimbursement in Continuous Hospitalization

Procedure	Spending Mean (min;max)	Reimbursment Mean (min;max)	TEN/ K-wire removal Mean (min;max)	Reimbursment of removal Mean (min;max)
TEN	632.76 (471.16; 1073.00)	497.88 (443.03; 514.01)	462.84 (385.30; 672.54)	1066.61 (512.76; 1867.47)
K-wire	499.50 (372.36; 1095.82)	364.64 (162.16; 455.53)	424.71 (365.05; 636.01)	1044.32 (107.31; 1867.47)
Closed reduction + cast	451.30 (337.43; 699.25)	150.03 (107.31; 372.06)	-	-
Total	520.09 (337.43; 455.53)	309.51 (107.31; 455.53)	439.52 (365.05; 672.54)	1043.91 (107.31; 1867.47)

All values are in USD; min: minimum value; max: maximum value; TEN: titanium elastic nail

Reimbursement per patient was higher in patients treated with TEN versus Kirschner Wire; $497.88 versus $364.64 per patient (mean difference, $131.16) and greater than for patients treated with closed reduction and immobilization (mean difference, $343.92). The benefit-cost balance was negative for all three treatment methods. The average loss per patient was similar (p>0.05) for TEN patients; $133.26 ($16.29 – $700.94) and K-wire patients; $132.62 ($0.87–$722.58) per patient and was higher (mean difference, $178.61) for closed reduction and cast patients; $311.91 ($146.01– $591.93).

The TEN was removed in 36 patients and the Kirschner pin in 53 patients. The mean cost for TEN removal was higher than for K wire removal (p = 0.002). Reimbursement for TEN removal and Kirschner pin removal was similar (p > 0.05), and revenue-cost differences were positive for both TEN removal and Kirschner pin removal: $621.15 ($22.09 - $558.99) for TEN and $619.61 ($504.85 - $1496.88) for removal of the Kirschner pin.

Complications occurred in 17 patients; 1 patient treated with TEN, 13 with Kirschner Broche and 3 treated with closed reduction, followed by cast immobilization, these having no impact on the cost (p> 0.05). Three patients suffered multiple injuries and were admitted to the intensive care unit. This had a direct impact on costs (mean difference, $247.89, p = 0.01).

It is a known fact that TEN stabilization of upper limb fracture has a better medical and functional outcome, the efficiency and advantages of this method being proven in several studies [53-55]. Thus, we come to discuss the main disadvantage of the method, namely the involvement of costs. Here, like all international studies, we can note the high price of the rods compared to the K brooches [56-59].

7. Discussion of the effects of the SARS-CoV-2 pandemic on costs related to the treatment of upper limb fractures in children

SARS-Cov-2 (Severe Acute Respiratory Syndrome Coronavirus 2) infection was initially identified in December 2019 in the Wuhan region of China and quickly spread to the rest of the world, being declared a pandemic by the WHO. Romania reported the first case of the disease (COVID-19) in February 2020, and approximately 1.5 million cases have been documented as of October 2021. COVID-19 is a respiratory disease caused by the SARS-CoV-2 virus, which is more more severe than seasonal influenza, with approximately 5% of diagnosed patients requiring hospitalization in the ATI ward and with a mortality of approximately 3% [60-62].

Thus, a comparative study is in progress between the year 2019, pre-pandemic, and the year 2021, with maximum restrictions, regarding the modification of the data regarding the application of upper limb fracture treatments in children and the associated costs within the "Louis Țurcanu" Children's Hospital ", Timisoara. So, it can be seen that following the processing of the statistical data, there is an association between the number of hospitalized cases and the pandemic situation in our hospital, with the year 2021 seeing fewer hospitalizations than the year 2019. Also, changes in the treatment methods used can be observed. Although the number of titanium rod insertions did not change significantly, the number of K-wire operations decreased in favor of orthopedic treatment by closed reduction of fractures with cast immobilization.

Although there is no statistically significant difference between the average losses, as demonstrated by the Student's t test, there is a total net gain between the two years of $628.03, representing a decrease of 0.33%. Thus, even if there was a change in the treatment method used due to the pandemic situation, this did not have a significant impact on financial expenses.

Conclusions

Minimally invasive osteosynthesis is a treatment method of great interest due to the many advantages it possesses, but also due to personal experience in the operating room. After exhaustively studying the specialized medical literature, we came to the conclusion that there are still controversies within the proposed research theme. Thus, I have come to the conviction that I can make contributions to research in the field that will live up to my own expectations and hopes and that will be of real use in current practice.

The complexity of diaphyseal fractures encountered in children required the development of minimally invasive pediatric orthopedic surgical techniques taking into account the particularities of the immature bone. Among the first techniques of this kind successfully applied to children is the one described by Metaizeau, a technique that bears his name, using elastic steel rods after the Ender technique. Fractures are frequently encountered in pediatric traumatic pathology, and the incidence of fractures in children has increased in modern life conditions, representing even a quarter of all pediatric traumatic injuries.

Fractures of the upper limb in children have many causes, but the most frequently involved mechanism is the fall. Various variable factors participate in this major cause, such as where the incident occurred, season, gender, age group, or activity performed before the incident.

Orthopedic treatment in the case of fractures in children must be considered as first-line treatment and consists of orthopedic reduction and cast immobilization. Sometimes two or even three orthopedic reduction sessions may be necessary. Bleeding osteosynthesis is based on the principle of opening the fracture site, evacuating the post-fracture hematoma, preparing the fractured bone ends and reducing the fracture, which will be maintained and stabilized, usually rigidly, by using osteosynthesis materials. Osteosynthesis can be centromedullary, by using Kirschner pins or Küntscher rods, inserted centromedullary through the fracture focus, or external by mounting the osteosynthesis material outside the fractured bone by using cerclages, neutralization or compaction plates with screws, drills, screws compression or external fixator. Minimally invasive osteosynthesis in children is described and successfully applied by Metaizeau, using elastic steel rods according to the Ender technique, for the osteosynthesis of femur and tibia diaphyseal fractures in adolescents, but the use of this method has also become popular among other long bones, these being also made of titanium.

Bone healing after osteosynthesis with elastic titanium rods occurs through an indirect mechanism, osteosynthesis with elastic rods determining a healing comparable to that obtained by conservative treatment, the particularities of this treatment method consisting in healing with hypertrophic callus in the initial phase due to the preservation of the post-fracture hematoma , non-detachment of the periosteum at the level of the fracture focus and due to the permissive micromovements, existing at the level of the early postmobilization fracture focus. Thus, a much more pronounced bone remodeling results, the remodeling of the focus with the removal of the bone callus formed in excess and, frequently, with the correction of the degrees of angulation or rotation.

Thus, in Romania and in the Western Region of Romania, the incidence of arm fractures in children was 54.83 / 100,000 people/year and 64.79 / 100,000 people/year, respectively. The incidence of forearm fractures was 139.77 / 100 000 persons/year and 139.56 / 100 000 persons/year, respectively. The incidences of upper extremity fractures (not otherwise specified) were 11.42 / 100,000 persons/year and 15.79 / 100,000 persons/year, respectively. These values are similar or even lower than those recorded internationally.

Using TEN, the main advantage of the method is the minimal invasiveness that results in closed reduction and preservation of the fracture hematoma. Postoperative cast immobilization can be avoided so that early mobilizations become possible. The flip side of the coin is an increased direct cost: TEN rods costing $71, while K wires cost $1.2/pc. To see a difference between the treatment methods (TEN, Kirschner pin and nonsurgical orthopedic treatment), we performed a retrospective longitudinal study on 173 consecutive patients with forearm fractures treated in a single institution during 2017 and recorded the costs of the treatments , including data such as the direct cost of surgical materials, hospitalization, drugs, service, salaries, but also the income reimbursed by the Single National Fund for Social Health Insurance. There were 66 radius fractures, 1 ulna fracture, and 106 cases that had combined fractures. Closed reduction with cast immobilization was used in 46 patients, closed or open reduction with Kirschner pin application was used in 82 patients, and closed or open reduction with TEN was used in 44 patients.

Thus, in the study population, treatment of fractures using TEN was more expensive than using K-wire stabilization or non-surgical treatment. Mean treatment costs were $632.76 for TEN, $499.50 for K-wire, and $451.30 for closed reduction and cast immobilization. In our series, there is a negative balance reimbursement relative to expenses for each treatment method, with the average loss being similar ($130 - $130) for TEN and Kirschner pin and higher for patients treated with closed reduction and cast immobilization (≈ $300). There is a positive balance ($600 - $600) per patient for the removal of both TEN and K-wires on an ongoing basis, covering most of the financial shortfall since the implants were placed. The financial shortfall could not be recovered for patients treated by closed reduction and cast immobilization.

Based on these facts, we can state that, in Romania, there are cost differences in the treatment of forearm fractures with TEN versus K wire, but there are no differences in the financial burden for the hospital of one treatment method versus the other.

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