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GROWTH CHANGES OF THE FEMUR AND TIBIA AFTER FRACTURES IN CHILDREN

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Introduction. In contrast to adults, the reparative process in children with fractures has one essential feature: the consolidation of bones tissue runs parallel to further growth and bone formation.
The aim of the study. To determine the frequency of growth changes of different segments of the lower extremities in children, to determine the association of these types of fractures with age and/or method of treatment; to clarify the indications for orthopedic correction or surgical treatment of these deformities in long-term perspective.
Material and methods. Between 2001 and 2014, 306 children with multiple fractures of the lower limbs were treated in the Regional Clinical Emergency Hospital, Barnaul. Fifty six with femoral and tibial fractures of 306 children were re-evaluated in 3–10 years for the long-term results of treatment.
Results and discussion. In the long-term follow-up period, the measuring of the contralateral lower limb segments (tibia and femur) showed that 27 (44.3%) children had marked differences in their length. Three of them had shortening of limb segment and 24 children had lengthening shortening of limb segment. Changes in the growth rate were observed in fractures of the femur in 22 cases and in fractures of the tibia in 5 cases.
Conclusion. The frequency of limb segment elongation after surgical and conservative treatment was approximately the same.

Keywords: treatment of fractures, osteosynthesis, fractures of the femur and tibia in children, limb shortening, limb lengthening.

ИЗМЕНЕНИЯ РОСТА БЕДРА И ГОЛЕНИ У ДЕТЕЙ ПОСЛЕ ПЕРЕЛОМОВ

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Введение. В отличие от взрослых, репаративный процесс у детей при переломах имеет существенную особенность: сращение сломанной кости у ребенка происходит на фоне ее дальнейшего роста и перестройки.
Цель исследования: выяснить, как часто и какие сегменты нижних конечностей у детей подвержены изменениям роста после переломов; определить, оказывает ли влияние на это тип перелома возраст ребенка, способ лечения; уточнить, требуется ли ортопедическая коррекция или хирургическое лечение этих нарушений в отдаленном периоде.
Материал и методы. В период с 2001 по 2014 г. в КГБУЗ «Краевая клиническая больница скорой медицинской помощи» г. Барнаула проведено лечение 306 детей с переломами нижних конечностей при множественной и сочетанной травме. Из них в отдаленный период, в сроки от 3 до 10 лет, осмотрено 56 детей, проходивших стационарное лечение с переломами бедра и голени.
Результаты и обсуждение. В отдаленном периоде при измерении длины контралатеральных сегментов нижних конечностей (голени и бедра) в 27 (44,3 %) случаях отмечено различие в их длине. Из них в трех — укорочение сегментов конечностей, в 24 — удлинение. Изменение темпов роста отмечено при переломах бедра в 22 случаях, при переломах голени — в 5 случаях.
Заключение. Частота удлинений сегментов нижней конечности после переломов бедра и голени у детей составляет 42,3 %, выше при переломах бедренной кости и не зависит от вида проводившегося лечения.

Ключевые слова: лечение переломов, остеосинтез, переломы бедра и голени у детей, разновеликость нижних конечностей.

Introduction

Unlike adults, the reparative process in pediatric patients with fractures occurs when the children are actively growing. As a consequence, various abnormalities in the growth and development of bones may occur, following fractures in pediatric patients, which can either decline or escalate the growth of the affected bone, leading to segment shortening or elongation, respectively. It is considered that the shortening of various bone segments in the extremities, following fractures in pediatric patients, occurs mostly when the epiphyseal growth plates are damaged, while elongation results from the stimulatory effect of reparative processes upon a damaged bone.

While the reasons for bone shortening are not yet discussed among researchers, there are clear differences in opinion considering those resulting in bone elongation. Some authors believe that the main reason for accelerated growth is the treatment method used, in particular, the hyperextension of fragments during skeletal traction [1, 2]. Others, on the contrary, believe that bone elongation is associated with multiple closed manipulations or surgical interventions within the fracture zone [3, 4]. Nevertheless, there is still no convincing scientific evidence to support this point of view [5].

Following a review of the existing literature, we found only a limited number of studies devoted to the topic of bone growth disorders following the treatment of fractures in pediatric patients. The lower extremities of a human represent a closed biokinematic chain; changes in one link will inevitably lead to a reaction across the entire musculoskeletal system. Naturally, the growth disorders in one segment will result in general disorders in the function of support and motion [6].

This study aimed to: determine the segments of the lower extremities in pediatric patients that are subject to changes in growth, and for how long after fracture; determine whether the age of a child or the method of treatment affects this type of fracture; and clarify whether orthopedic correction or surgical treatment of these disorders is required in the long-term.

Material and methods

Between 2001 and 2014, 306 pediatric patients with fractures of the lower extremities, with multiple and concomitant injuries, were treated at the Regional Clinical Hospital of Emergency Medical Care in Barnaul, a krai government-owned and publicly-funded health care institution. Of these, 56 pediatric patients who underwent in-patient treatment for fractures of the thigh and lower leg were examined in the long-term period, from 3 to 10 years.

Both conservative and surgical methods were used for treatment. In the absence of fragment displacement, stable fractures, and after a single-step manual reposition, the preferred method was plaster immobilization. In the presence of displacements where we could not use single-step repositioning or plaster cast retainment, we used alternative methods such as skeletal traction, external fixation devices (EFD), and internal osteosynthesis.

For external osteosynthesis, we used EFDs manufactured by the Experimental Plant of the Academician G.A. Ilizarov Russian Research Center "Restorative Traumatology and Orthopedics." For internal osteosynthesis, we used products from Synthes (Switzerland), such as intramedullary locking rods, titanium elastic nails (TEN), angle stable plate (LCP), and cannulated screws. Following osteosynthesis, we did not perform external immobilization with plaster casts.

During hospital treatment and after repositioning the fragments and fixing the fragments of the damaged bone, we measured the lengths of the segments in the lower extremities. All pediatric patients treated for fractures of the lower extremities were observed for 1 year, and even longer. Observations were carried out in the readmission office at the hospital; we also measured the length of the lower extremities and ordered restorative treatment if required.

All patients were recalled for examination within a 3 year period after injury. Of the total cases of patients treated, 56 patients were identified with 61 fractures of long tubular bones in the lower extremities. The patients, or their representatives, voluntarily signed informed consent forms in order to participate in the study. Three groups were formed: Group 1 included patients whose primary and final treatment method was osteosynthesis with EFD

(11 pediatric patients), Group 2 included patients treated with internal fixation methods (35 pediatric patients), while Group 3 included patients treated with conservative methods (10 pediatric patients).

During the repeated examination, we measured the length of the lower extremities in all patients with a measuring tape fixed to a device known as a Zuccarelli "leg-meter" type. When different sizes were identified, we carried out an X-ray study of the lower extremities using the full-leg full-spine rack. We used the Pediatric Comprehensive Classification of Long-Bone Fractures (PCCF) system to determine the severity of fracture localization [7].

Data was analyzed by creating a frequency diagram. The median of the series and the interquantile range (25th and 75th percentiles) were determined. To evaluate the statistical significance of differences, we calculated the $\chi 2$ criterion with Yates' correction and the Bonferroni method was used for multiple comparisons. While testing the null hypotheses, the critical significance level of the differences was assumed to be less than 0.05 [8].

Results and discussion

Table 1 indicates the number of fractures and their localization across different groups of pediatric patients. The total number of hip fractures was more than twice that of lower leg fractures. The ratio of thigh to lower leg fractures within the different groups was 2:1, 3:1, and 3:2 for Groups 1, 2, and 3, respectively. This indirectly indicated a more severe case of patients in Group 1 and Group 2. Additionally, half of the patients in Group 1 had multisegmental fractures of the lower extremities, which also indicated the severity of the trauma involved. Nevertheless, these samples were representative; there were statistically significant differences in the number of patients and fractures between groups ($p > 0.05$).

In the long-term, we noted differences in terms of length measurements of the contralateral segments of the lower extremities (lower leg and thigh) in 27 (44.3%) cases out of the 56 patients examined. In 3 of these cases, shortening of segments in the extremities was observed, while in 24 cases, we observed elongation. Changes in growth rates were noted with thigh fractures in 22 cases, and in 5 cases involving lower leg fractures.

Table 2 indicates the distribution of patients across groups in terms of segment shortening in the lower extremities. In the long-term, two patients showed shortening of the thigh, and one patient showed shortening of the lower leg. All cases involving shortening were seen in pediatric patients who had been treated surgically; Group 1 included two patients, whereas Group 2 included only one patient. One of the patients from Group 1 had a shortening of 2 cm following an open multifragment fracture of the distal epiphyseal cartilage of the thigh (33-E/2.2). The second patient from Group 1 had a shortening of 1 cm following an open multifragment fracture of both bones of the lower leg (41-E/2.2) in the proximal region. The patient in Group 2 had a shortening of 1 cm following complete intraarticular fracture of the distal epiphysial cartilage of the thigh with a transition to the diaphysis (33-E/4.2), after osteosynthesis with a nail DFN. In all cases, the shortening of the extremity segment was not clinically significant; patients were able to use ordinary footwear, and the changes in extremity length did not require correction by orthopedic footwear, insoles, or other orthopedic products.

Table 1

Localization of fractures in the long bones of the lower extremities across different patient groups

Localization of fracture	Group 1 (n = 11)	Group 2 (n = 35)	Group 3 (n = 10)	Total (n = 56)
Thigh	10* (66.7 %)	27* (77.1 %)	6* (60 %)	43* (70.5 %)
Lower leg bones	5* (33.3* %)	8* (22.9 %)	4* (40 %)	17* (29.5 %)
Total	15* (100 %)	36* (100 %)	10* (100 %)	61* (100 %)

Note: *the number of bone fractures within groups

Table 2

Shortening of segments in the lower extremities across different patient groups

Extremity segment	Group 1 (n^* = 15)	Group 2 (n = 35)	Group 3 (n = 10)	Total
Thigh	1	1	-	2
Lower leg	1	-	-	1
Total	2	1	-	3

Note: n^* represents the number of thigh and lower leg fractures

Within 1 year of trauma, shortening was observed in one patient from Group 1 with an open multifragment fracture of both bones of the lower leg (41-E/2.2) due to a posttraumatic defect of the shinbone. All patients with extremity shortening were adolescents belonging to the older age group (15–18 years) at the time of fracture. These patients were reexamined 7, 8, and 10 years after injury. At the time of examination, all epiphyseal plates within the growth zones of the lower extremities were completely closed.

Table 3 indicates the distribution of patients across groups in terms of segment elongation in the lower extremities. Elongation was observed in 24 segments: 60% of these were found in patients from Group 1, 34.3% in patients from Group 2, and 60% of patients from Group 3. Elongation of the thigh was noted more frequently (46.5%) than that of the lower leg (23.5%). There was no statistical significance in the frequency of elongations in different segments when compared between groups ($p > 0.1$). In general, elongation of the lower extremities was observed in patients with diaphyseal fractures of the thigh and lower leg bones, such as 32-D/4.1, 32-D/5.1, 32-D/5.2, 42-D/4.1, 42-D/5.1, and 42-D/5.2. Within 1 year of trauma, and after consolidation completion, elongation was noted in two cases from Group 3 with fractures of the thigh, treated by skeletal traction. In 22 cases, elongation of an extremity segment was detected for a longer time period after injury, ranging from 3 to 7 years. All patients with elongation of the extremities at the time of fracture were classified in either the younger or middle age group (from 3 to 12 years of age).

Table 4 indicates the frequency and magnitude of elongation in the segments of the lower extremities (cm). Most of these elongations reached 2 cm (62.5% of cases), those that reached 1 cm were scarce (29.2%), and elongations longer than 2 cm were rarely observed (8.3%). Notably, in fractures of the lower leg bones, the elongation was less than or equal to 1 cm in most cases.

Table 3

Frequency of segment elongation in the lower extremities across different patient groups

Extremity segment	Group 1 ($n^* = 10/5$)	Group 2 ($n^* = 27/8$)	Group 3 ($n^* = 6/4$)	Total ($n^* = 43/17$)
Thigh	5 (50%)	10 (37%)	5 (83.3%)	20 (46.5%)
Lower leg	1 (20%)	2 (25%)	1 (25%)	4 (23.5%)
Total	6 (60%)	12 (34.3%)	6 (60%)	24 (40%)

Note: n^* represents the number of thigh fractures within each group, the denominator represents the number of lower leg fractures.

Table 4

The length of elongation in segments of the lower extremities

Extremity segment	Up to 1.0 cm	Up to 2.0 cm	Over 2.0 cm
Thigh	4 (20%)	14 (70%)	2 (10%)
Lower leg	3 (75%)	1 (25%)	–
Total	7 (29.2%)	15 (62.5%)	2 (8.3%)

Table 5

Frequency of segment elongation in the lower extremities depending upon treatment method in patients across different groups

Method of treatment	Fracture of thigh	Fracture of lower leg bones	Total
Osteosynthesis with EFD	5 (20.8 %)	1 (4.2 %)	6 (25 %)
Osteosynthesis with TEN	5 (20.8 %)	1 (4.2 %)	6 (25 %)
Bio-Oss	4 (16.6 %)	1 (4.2 %)	5 (20.8 %)
Osteosynthesis with LCP plates	1 (4.2 %)	–	1 (4.2 %)
Osteosynthesis with screw with a channel	–	–	–
Skeletal traction	4 (16.6 %)	1 (4.2 %)	5 (20.8 %)
Plaster cast	1 (4.2 %)	–	1 (4.2 %)
Total	20 (83.2 %)	4 (16.8 %)	24 (100 %)

As shown in Table 5, the frequency of elongations was quite similar for both surgical and conservative methods of treatment and did not differ significantly ($p > 0.1$).

The frequency of elongation in extremity segments depending upon patient age is shown in Table 6.

Table 6

Frequency of elongation in segments of the lower extremities across different age groups

	1–3 years	4–7 years	8–11 years	12–14 years	15–17 years	Total
Total with fracture of the thigh	3	14	10	5	11	43
Sub-group showing elongation of the thigh (%)	3 (100 %)	6 (42.8 %)	7 (70 %)	2 (40 %)	2 (18.2 %)	20 (46.5 %)
Fracture of the lower leg bones	3	5	2	4	4	18
Sub-group showing elongation of the lower leg (%)	1 (33.3 %)	1 (20 %)	1 (50 %)	1 (25 %)	0 (0 %)	4 (22.2 %)

As shown in Table 6, the most frequent elongation was observed in pediatric patients of the early age groups, in particular, preschool and primary school age, during periods of intensive growth. Moreover, among the pediatric patients examined over the long-term period, all patients in the younger age group showed elongation of various segments. In the adolescent group, however, the percentage ratio of thigh elongation to the number of fractures was relatively small and amounted to only 18.2%.

In most cases, elongation of the extremities was not clinically significant and the pediatric patients were able to use ordinary shoes. Only two patients, were required to use insoles in ordinary shoes while walking; this applied to patients with a size difference in the lower extremities of slightly greater than 2 cm.

Thus, the shortening of segments in the lower extremities over a long period of time mostly occurred with metaepiphysial fractures and was the result of damage to the epiphyseal growth plates. Elongation, however, was caused by the general reaction of the body to reparative regeneration of the broken bone, which developed predominantly in pediatric patients of younger age groups.

Conclusion

The disorders of growth rate in the lower extremities in the cases of fractures in pediatric patients were seen in 27 (44.3%) cases, and the majority of these involved elongations owing to fractures of the thigh. More often, shortening of segments in the lower extremities developed after epimetaphyseal fractures, which intersected the epiphyseal growth plate. In contrast, elongation of the extremities developed following fractures of the diaphysis. Shortening of extremity segments was observed in adolescents (15–18 years old), while elongation was noted in patients of preschool and primary school age (4–11 years). The frequency of elongation in extremity segments in groups of patients receiving surgical and conservative treatment was approximately the same. Over the long-term period and in patients with different sizes of segments in the lower extremities following growth termination, corrective methods using orthopedic products were only required in cases where the difference in length was 2.0 cm or more. None of our patients required surgical treatment for different leg sizes.

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Conflict of interest

The authors declare no obvious and potential conflicts of interest related to the publication of this article.

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