

ORIGINAL PAPER

Clinical patterns of knee fractures in children: a single-center case series

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ABSTRACT

Introduction: Fractures around the knee joint in pediatric patients are not the most common causes of hospitalization, but they should be considered. Most cases require invasive treatment to minimize adverse consequences of the injuries sustained. The aim of this study is to present the epidemiology of fractures in the knee joint area among pediatric patients who present to the Emergency Department due to knee joint injuries.

Material and methods: Data were analyzed for all pediatric patients treated in the Emergency Department and subsequently hospitalized due to knee joint injuries in a tertiary referral hospital 2018–2023, according to codes S72.4, S82.0, S82.1, corresponding to fractures around the knee joint, including distal femoral, proximal tibial, and patellar fractures.

Results: Among the qualified first-time patients, 23 were boys and 8 were girls. The largest portion of the group consisted of children aged 14–16 years. A predominance of patients with fractures of the proximal tibia was noted (27/31) compared to the distal femur (4/31). No patellar fractures were identified. Within the proximal tibia, the majority (12/27) suffered from an avulsion fracture of the anterior cruciate ligament (ACL), followed by tibial tubercle fractures (9/27), epiphyseal fractures (3/27), mixed tubercle and avulsion fractures of the ACL (2/27), and one fatigue fracture (1/27).

Conclusions: In summary, the most common pediatric knee fractures are proximal tibial fractures, mainly ACL avulsion and tibial tubercle fractures. High-energy sports-related trauma are the leading cause, contributing to more severe fracture types. The findings align with global trends showing a rise in complex, sports-induced injuries in youth. This highlights the importance of prevention, early diagnosis, and proper treatment strategies.

KEY WORDS:

fractures, pediatrics, knee injuries.

INTRODUCTION

The frequency of knee intra- and periarticular fracture injuries in pediatric patients are rare, nevertheless should be kept in mind. At the very beginning, it is worth mentioning that in this still growing pediatric population, leg grows 23 mm/year, with most of that coming from the knee, which is 9 mm/year from distal femur and 6 mm/year from proximal tibia [1]. Another important

aspect is the muscles, ligaments which insertions surround the knee joint, as well as the ligaments and fibrous structures like menisci localized inside. The continuous increase in youth sports participation as well as single sports specialization engage greater force generation of muscles of the bone, which contribute to a significant risk factor for the kind of injuries we are describing. These factors cause more high-energy trauma. Specifically, the knee fracture injuries can be divided into anterior

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cruciate ligament (ACL) avulsion, tibial tubercle and epiphyseal bone fractures. Anterior cruciate ligament avulsion fracture can be caused by 3 different mechanisms such as non-contact twisting, hyperextension and contact mechanism, where direct blow can cause to knee either hyperextend or valgus stress. Among them, contact and twisting non-contact are the most common ones [2, 3]. Such mechanisms are seen in falling from height, bike or motor vehicle accidents and pivot-shifting sports like skiing or football and basketball [3]. Three mechanisms are also described in tibial tubercle fractures. First is concentric contraction of quadriceps muscle during the phase of flight in jumping (straight of the knee). Second – eccentric contraction of quadriceps muscle as during sudden passive flexion of the knee (phase 1 and phase of landing in jumping) and as during sudden braking like in running [4]. The third one is disproportion between strong muscle development contributed to insufficient ossification of tibial tubercle. This one is seen in quick sports specialization and imposed loading [5]. Mainly high-energy trauma like jumping seen in basketball or football are common in this injury, but there are also seen low-energy trauma such as in running, where there seems to be a strong relation with low bone density, high body mass index and hyperglycemia [5, 6]. It is important to notice that still increase of obese children is a significant risk factor for low-energy injuries. In physeal injuries, distal femur and proximal tibia are engaged. Distal femoral physeal injuries can be caused by a valgus force or a hyperextension force, or can occur by direct impact to the area [7]. The most frequent mechanism of femoral fractures is falls, except in adolescents, in whom motor vehicle accidents contribute cause most fractures [8]. When it goes about proximal physical tibial injuries, there are also three mechanisms. What is interesting, the mechanism depends on the age. In prepubescent children aged 4–9, typically low-energy trauma with varus or valgus forces are observed, among which the valgus force is more frequent. That occurs most commonly while using a trampoline which results in a meta-

physeal fracture. Especially jumping others people with a weight difference [9]. In the juvenile group aged 10–12, a high energy extension force occurs most often while riding a bicycle, especially when attempting to brake suddenly with the ipsilateral foot striking the ground. And in the adolescent group, aged more than 13 years old, the high energy flexion-avulsion mechanism is observed especially in boys playing basketball. This mechanism may result in a simple apophyseal fracture of the tibial tubercle or, depending on skeletal maturity, they may combine with a physeal injury of the proximal tibia, resulting in a type of triplane fracture [10].

MATERIAL AND METHODS

According to ICD-10 codes of S.72.4 (distal femur fracture), S.82.0 (patella fracture), S82.1 (proximal tibia fracture) there we have analyzed data concerning all patients treated initially in the emergency department and subsequently hospitalized due to knee injuries in the Department of Orthopedics and Pediatric Orthopedics of the Children's Central Clinical Hospital in Lodz in 2018–2023. We focused on the number of patients, number of injuries, sex, age, way of treating, coexisting injuries and types of fractures based on Meyers-McKeever, Ogden and Salter-Harris classifications. The lacking information was filled out based on available diagnostic files.

RESULTS

35 admissions were qualified, including 31 first-timers and 4 revisions. Among 31 qualified primary patients 23 were boys and 8 girls. The biggest age group were children aged 14–16 years (17/31). There were 19/32 left legs and 13/32 right legs involved, of which one patient had both legs involved. A domination of proximal tibia fractures in relation to distal femur fractures was observed. The exact number of individual fractures after first-time injury is listed in Table 1. Among 4 revision patients, all were boys. There were 3 right legs and 1 left leg involved.

TABLE 1. Frequency of knee joint fractures after first-time injury

Injury	Total, <i>N</i> (%)	Female, <i>n</i> (%)	Male, <i>n</i> (%)
Overall	31 (100)	8 (26)	23 (74)
Tibial fractures	27 (87)	5 (63)	22 (96)
ACL avulsion	12 (44)	5 (42)	7 (58)
Tibial tubercle	9 (33)	0	9 (100)
Epi- and metaphyseal	3 (11)	0	3 (100)
Mixed (tibial tubercle + epiphyseal)	2 (7)	0	2 (100)
Stress fracture	1 (4)	0	1 (100)
Femoral fractures	4 (13)	3 (38)	1 (4)
Patella fractures	0 (0)	0	0

ACL – anterior cruciate ligament

TABLE 2. Anterior cruciate ligament avulsion fractures (Meyers-McKeeever classification)

Type	Total, N (%)	Female, n (%)	Male, n (%)
Total	12 (100)	5 (42)	7 (58)
Type I	1 (8)	0	1 (14)
Type II	4 (33)	1 (20)	3 (43)
Type IIIA	2 (17)	2 (40)	0
Type IIIB	1 (8)	1 (20)	0
Type IV	4 (33)	1 (20)	3 (43)

TABLE 3. Tibial tubercle fractures (Ogden classification)

Type	Total
Total	9
Type I	1
Type II	4
Type III	3
Type IV	1

2 revision surgeries were in ACL avulsion fractures, 1 in tibial tubercle fracture and 1 in distal femoral physeal fracture.

Among 9 tibial tubercle fracture patients, 10 legs in total were involved. There was no dominance of leg sides. All patients were boys. The age bracket was 14–17, with median 16. The activity during fracture is as follows: 2 cases during football, and 1 case each during dancing, basketball, rugby, kids play, fall from stairs, in 1 case there were no data available. The Ogden classification is presented in Table 2. There were no additional injuries. 8/9 patients underwent surgery and 1/9 was conservatively treated in a cast. The last decision was made because of not shown bone fragments. In surgery treatment 7/8 patients underwent open reduction internal fixation, and 1/8 underwent closed reduction internal fixation (CRIF). The patient treated conservatively presented with type I, and the patient treated with CRIF – type IV. The latter patient had both legs involved. After the primary surgery, 1/9 had a revision surgery. It was the patient, who primarily had type IV according to Ogden classification and was treated with CRIF. The cause of revision was no possibility of reattaching the bone fragment presented in RTG the day after. The decision was to operatively refix the rectal apparatus with soft tissues. Among 12 ACL avulsion fracture patients, 12 legs in total were involved. The left leg predominated in 8/12 compared to the right leg in 4/12. The age bracket was 8–15, with the median 12. The activity during fracture presents as follows: 3 cases was during school sports classes, 3 cases during skiing, 2 cases on biking, 1 case during trampoline jumping, 1 case during football, 1 case at the quad accident, 1 case after slip. The Meyers-McKeeever classification is presented in Table 3. 5 patients presented with additional injuries, of whom every had lateral meniscus (LM) tear,

1/5 had in addition medial meniscus (MM) tear and 1/5 also had MM and osteochondral fracture of medial tibial plateau (MTP). The additional injuries were presented in type II (2/5 patients) and type IV (3/5 patients), of which in type II there were only LM tears, and in type IV – 1 case with only LM tear, 1 case with both LM and MM tear and 1 case with LM, MM tears and MTP fracture. In total 1/12 patient was conservatively treated in a cast and 11/12 patients underwent arthroscopy with suturing the ACL avulsion fragment. While 6/7 meniscal tears were sutured, the 1/7 which was MM was stable on examination. The patient treated conservatively presented type I in classification with no additional injuries. The decision was made because of good alignment of bone fractures. As mentioned, there were 2 revisions. The first cause of ACL avulsion fracture revision was chronic instability. The patient had previously type IV according Meyers-McKeeever classification with both meniscal tear and osteochondral fracture of MTP. The patient had had arthroscopy with suturing of the ACL avulsion as well as of suturing the LM. At the time of revision 5 years after initial surgery, the patient presented MM tear and ACL tear. He had ACL reconstruction and MM suture, with good outcomes subsequently. The second cause was post-operative wound inflammation presented 2 weeks after the first surgery. During revision, debridement of the operated area with removal of threats were implemented. Initially the patient was also treated with arthroscopy with suturing of the ACL. Among 3 patients with proximal tibia fractures, 2 were right- and 1 left-sided. All cases were boys in the age bracket of 14–16, with median 16. One of them fell during school sports classes, 2 cases were not available in our data. According to Salter-Harris classification, there was only one patient who met the criteria. It was classified as SH I. The second case had closed growth plate, and the third had metaphyseal fracture not reaching the growth plate. No additional injuries were detected. There was 1/3 conservative and 2/3 surgical treatments. The conservative treatment in a cast was implemented in the patient with epiphyseal fracture with closed growth plate because of good alignment. The surgical treatment was closed reduction percutaneous pinning (CRPP) in SH I and metaphyseal fracture. No revisions were made. Among 2 mixed fractures including epiphyseal and tibial tubercle fractures, both were in boys aged 14 and 15 years. One was left- and one was right-sided. The fracture occurred during jumping – long jump and jump off. The cases were classified as Ogden IIIB and SH IV. No additional injuries were detected. The patients were treated surgically with CRIF.

The last case of tibial fracture was stress fracture in a left one-third upper tibia, in a boy aged 10. He mentioned aches after sports activity and in the morning after a long night sleep. The conservative treatment was implemented. Among 4 patients with distal femoral fractures, there were 3 girls and 1 boy. 3/4 were left-sided and

1/4 right-sided. The age bracket was 2–13, with median 13. All of cases suffered from a medical history taking. The fall was from a bike, bed, trampoline and as a result of being hit by a car. According to Salter-Harris classification, 3/4 were type II. 1/4 fracture was described as metaphyseal because it did not reach the growth plate. No additional injuries were detected. 2/4 cases with SH II were treated surgically with CRPP; other cases including SH II 1/4 and metaphyseal fracture were treated conservatively in a cast. The case with SH II treated in a cast was a 2-year old girl, who fell from the bed. There was 1 revision in a boy with SH II initially treated with CRPP. The cause of revision was the limitation of flexion in the knee joint, despite rehabilitation. Operatively there was made a realize of fibrous adhesions and removal of screws from femur.

DISCUSSION

These findings were then compared to other epidemiological research studies. General, a tendency to high-energy mechanisms is observed, which contributes to worse type fractures. Interesting findings are observed in ACL avulsion fractures. In early descriptions throughout the 1970–1990s, the most common risk factor was a fall from a bike (51%) with dominant fracture types 1 and 2 (79%) [11, 12]. In the current studies, sports are the most common (53% [13]; 57% [3]) and only 14% of patients are biking for recreation. The dominant types are 3 and 4 (67%). The tendency to higher frequency in young boys in comparison to girls is constant [3, 13]. In tibial tubercle fractures there are also some differences. In the 1990s two-thirds of fractures were classified as type I and II [14, 15], whereas currently mostly type II and III are presented, with type III in mainly [16, 17]. Constant are The strong domination of boys is constant. In proximal tibial physeal fractures, the risk factor and mechanisms strongly correspond with the age [10]. The importance of type III and IV is increasing while that of type II (51%) is still high but is decreasing [18]. Here the frequency of falls and sports' factors are similar and are the most common similar to boys' dominance. Our data are unfortunately too poor to comprise with it. Distal physeal femoral fractures tend to occur more in girls than in boys and the SH II are the most common, which is 64% according to the Swedish registry [8]. These are consistent with ours.

CONCLUSIONS

In summary, based on our analysis of intra- and peri-articular knee fractures in pediatric patients from 2018 to 2023, it was found that the most common injuries are proximal tibial fractures, particularly ACL avulsion fractures and tibial tubercle fractures. Distal femoral fractures were less frequent, occurring more often in girls than in boys. A clear trend of high-energy trauma was observed,

especially related to sports activities, leading to more complex fracture types. Comparison of the obtained results with the literature confirms global trends of increasing sports-related injuries in children and adolescents, as well as a rise in more severe fracture types (e.g., types III and IV according to Meyers-McKeeever classification and type III according to Ogden classification). This highlights the need for greater attention to sports injury prevention, early diagnosis, and appropriate therapeutic management.

DISCLOSURES

1. Institutional review board statement: This study was approved by the Ethics Committee of the Medical University of Lodz for conducting the study has been obtained (approval decision no. RNN/18/25/KE/KE, dated: 14.01.2025).
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4. Conflicts of interest: None.

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