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Diagnosis and treatment of fracture-related infection in children and adolescents: A retrospective study

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ABSTRACT

Introduction: A Fracture-related infection (FRI) is a rare but serious complication of surgical fracture treatment in children and adolescents. Exact data on the incidence of FRI in children and adolescents are not available in the literature. In adults, criteria for the diagnosis and treatment of FRI were published in 2018 by an expert group and divided into suggestive and confirmatory categories. However, there is no recommended approach for diagnosing and treating FRI in children or adolescents.

Purpose of the study: This study aimed to determine the incidence of FRI in children and adolescents who underwent operative fracture treatment at a Level I trauma center between 2019 and 2023, to evaluate age distribution, anatomical sites and bacterial spectrum of FRI in children and adolescents, to evaluate risk anatomical locations and initial fracture treatment methods in relation to the development of FRI and to assess the applicability of FRI diagnostic criteria in the pediatric patients.

Materials and methods: It is a retrospective monocentric study conducted by reviewing hospital database. The study included all patients under 18 years of age with present growth plates who underwent surgical fracture treatment between 2019 and 2023.

Results: The incidence of FRI in children was 0,95 % among 1156 osteosynthesis procedures performed between 2019 and 2023. The average age of pediatric patients with FRI was 11,18 years. The most common anatomical site of FRI in out cohort was the forearm (36,36 %). High-risk locations in terms of developing FRI relative to the number of osteosyntheses performed included the proximal femur (20 %) and the diaphysis of the humerus (7.69 %). The most common pathogen causing FRI in children was *S. aureus* (63,6 %). On average, 2.1 additional surgical procedures were required to eradicate the infection.

Conclusion: FRI in children is a rare but serious complication, which most commonly occurs in the upper extremity, specifically in the forearm area. However, some anatomical sites with a lower incidence of fractures demonstrate a significantly higher relative risk for the development of FRI. The recommended guidelines developed in 2018, including diagnostic criteria for FRI, can be successfully applied to the pediatric population.

Introduction

A fracture related infection (FRI) represents a rare but serious complication of surgical fracture treatment in children. Exact data on the incidence of FRI in children are not available in the literature. However, data on the incidence of osteomyelitis [1] and, in some cases, FRI and pin tract infections by anatomical site are available, although these mostly consist of case reports [2].

As in adults, criteria for the diagnosis and treatment of FRI in paediatric patients were unclear until 2018. In 2018, a group of experts published diagnostic criteria for FRI [3,4], though the study focused on the adult population. Metsemakers further classified diagnostic criteria for diagnosing FRI into suggestive and confirmatory categories [4]. The confirmatory criteria included clinical criteria (wound breakdown, presence of purulent secretion), microbiological criteria (detection of a pathogen in at least 2 tissue samples obtained intraoperatively) and histological criteria (presence of more than 5 neutrophils per field of view at 400x magnification or microscopic detection of bacteria in the histology slide preparation). Suggestive criteria included clinical criteria, encompassing local and systemic signs of inflammation (pain,

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redness, swelling, localized temperature increase, fever), newly developed joint effusion, and wound secretion (persistent, increasing, or newly developed), laboratory criteria (elevation of CRP, leukocytosis, increased sedimentation rate), radiological criteria (osteolysis, implant loosening, sequestration, delayed healing or non-union, and increased periosteal reaction) and last but not least, microbiological criteria, defined as the presence of a pathogen in 1 of 5 collected samples.

Fractures in childhood are common and typically occur as a result of everyday activities or sports [5]. The immature bone is more susceptible to injury but has excellent reparative mechanisms [6]. Unlike in adults, children's bones are more flexible and softer, which leads to unique types of fractures, such as bowing fractures, greenstick fractures, and torus (buckle) fractures [7,8]. Another major difference is the presence of growth plates (physes), which can be injured and, if treated improperly, may lead to growth disturbances – either growth arrest or overgrowth [9]. Physeal injuries are classified according to the Salter-Harris classification into types I through V, based on the fracture line's relation to the physis [10]. These injuries most commonly occur in the upper limb [10], especially at the distal radius [5].

Children's bones have a high remodeling potential, which results in a higher rate of conservative (non-surgical) treatment of fractures compared to adults [11]. The degree of remodeling depends on bone age, the specific remodeling potential of the affected bone, proximity to a joint, and the orientation of the fracture relative to the joint axis [6]. The main goal is to achieve an optimal outcome with minimal invasiveness [11].

Another important aspect is the vascular supply of children's bones. In childhood, bones are highly vascularized, and blood supply differs depending on the structure. This leads to faster healing and faster remodelation. While the epiphysis is supplied by epiphyseal vessels, no vessels pass through the physis itself. Instead, the physis receives blood from both epiphyseal and metaphyseal vessels. The metaphysis is fenestrated, allowing entry of metaphyseal vessels and is further supplied by periosteal and intramedullary vessels [12]. This vascularization also plays a significant role in bone healing.

The aim of this study is to assess the overall incidence of FRI in children at a level I trauma centre over a five-year period. Other objectives include evaluating risk anatomical locations, patient age and initial fracture treatment methods in relation to the development of FRI. Additionally, the study seeks to assess the applicability of FRI diagnostic criteria in the pediatric patients.

Materials and methods

It is a monocentric retrospective study, utilizing data from the hospital system FONS NIS Akord. This database includes records of all outpatient examinations and follow-ups, all textual documentation recorded during hospitalization, as well as imaging documentation, including stored clinical photographs. The study was conducted at a level I trauma centre, a facility providing comprehensive care for paediatric trauma. The study adhered to all ethical standards in accordance with the Helsinki Declaration (1975) ethical principles and was approved by the hospital's ethics committee – reference number 113/2023.

Patients, fracture surgery and antibiotic prophylaxis

Patient data were collected from the FONS NIS Akord system. All patients under 18 years of age with growth plates present who underwent operative fracture treatment between 2019 and 2023 were included in the study. Criteria excluding inclusion in the study were (1) patients who underwent surgery at the trauma centre but were subsequently followed up in their place of residence (2) patients who were 18 years of age or older at the time of FRI diagnosis and (3) patients under 18 years of age with closed growth plates on X-ray images.

The study included all patients under 18 years of age with growth plate present who underwent operative treatment with osteosynthesis for fracture treatment under general anaesthesia. The surgical procedures included both open and closed reductions followed by osteosynthesis using Kirschner wires, screws, intramedullary implants (TEN), plates, and intramedullary nails (LFN, ALFN), in some cases as a combination of methods.

For paediatric osteosynthesis procedures, antibiotics were administered only in cases of open surgery (ORIF), where first-generation cephalosporins (Cefazolin, dosed according to the child's body weight) were given as part of premedication. In the case of closed reduction followed by internal fixation (CRIF), antibiotics were not administered.

Clinical and radiological follow-up

In all paediatric patients with fracture treated with osteosynthesis, the following were monitored in a specialized outpatient clinic at regular intervals according to the given site until fracture healing and full weight-bearing: age at the time of injury, fracture site, method of primary treatment, possible presence of suggestive and confirmatory FRI criteria, and the necessity and, if applicable, the number of performed revision procedures. Suggestive and confirmatory criteria were assessed according to the work of Metsemakers, specifically investigating possible wound dehiscence, the presence of purulent secretion, local or systemic signs of inflammation (pain, redness, swelling, localized temperature increase, fever), and newly developed joint effusion or wound secretion.

During the follow-up of all paediatric patients after osteosynthesis, control X-rays were taken in two views. These were actively examined for the presence of suggestive radiological criteria of FRI, including osteolysis, implant loosening, sequestration, delayed healing or non-union, and increased periosteal reaction.

Diagnosis of FRI

The diagnosis of FRI was established according to the confirmatory criteria defined by Metsemakers [4]. The diagnostic criteria included 1) wound dehiscence and presence of purulent secretion 2) presence of a pathogen in at least 2 intraoperatively collected sample 3) presence of more than 5 neutrophils in 5 microscopic fields of vision at 400x magnification.

The diagnosis of FRI was determined by the surgeon based on available microbiological culture results and clinical findings. For the diagnosis of FRI, at least 5 tissue samples were always collected for culture, and in individual cases, a sample was also taken for histological examination. The samples were then cultured on blood agar in a thermostat-controlled box at a temperature of 37 °C; for aerobic cultures, incubation was performed under two different conditions – atmospheric air and an atmosphere with increased CO_2 content. For anaerobic cultures, samples were incubated on special Schedler media labelled "W" in an anaerobic box, and for targeted anaerobic G- bacterial cultures, selective Schedler media labelled "WS" were used. Standard culture examinations were assessed after 2 days, while extended cultures were conducted for 2 weeks, with readings taken at 7 and 14 days before culture termination.

Surgery for FRI

In cases where FRI was suspected, most often due to the presence of one of the suggestive criteria, revision surgery with sample collection with debridement of soft tissues and irrigation (with or without removal of osteosynthetic material) was indicated. In this case, the procedure followed the same protocol as in adult patients – during the revision surgery, 5 tissue samples were taken from the fracture site, each using a separate set of sterile instruments. These samples were then sent for microbiological culture, including extended incubation lasting 14 days. In case the revision procedure included removal of osteosynthetic

material, it was sent for sonication of the material with subsequent culture of the sonicate, lasting identically 14 days.

Antibiotic treatment for FRI

If the samples tested positive, patients received targeted treatment immediately after the culture results were available; initially, intravenous antibiotics were administered, and after 7–14 days, if the clinical findings were favourable, treatment was switched to oral antibiotics. The total duration of antibiotic therapy was typically 6 weeks.

Statistical analysis

Data were processed using MS Excel, and standard descriptive statistical methods were used for patient data analysis. The average (standard deviation) and median were used for data evaluation.

Results

Incidence of FRI in childhood

Between 2019 and 2023, the incidence of FRI in children and adolescents under 18 years of age with present growth plates was 0.95 % of all performed osteosyntheses. A total of 11 cases of FRI in children were recorded out of 1156 osteosyntheses performed (Table 1).

Age, fracture site, and primary treatment method

The average age of paediatric patients with FRI was 11.18 years (±4.49 years). The youngest patient was 4 years old, while the oldest was 17 years old. The median age was 12 years.

Of the 11 children with FRI, 5 were initially treated with open reduction and internal fixation. Another 5 patients were treated with closed reduction and internal fixation. 1 patient underwent a combination of methods, utilizing an external fixator along with closed reduction and internal fixation (Table 2).

Anatomical sites of FRI

The most common site of FRI in our cohort was the forearm, accounting for 36.36 % (n = 4) of cases. In other affected sites, FRI occurred only in isolated cases in the clavicle, humeral diaphysis, wrist, proximal femur, femoral diaphysis, distal tibia and fibula and metatarsals. 63.6 % of the diagnosed FRI cases in our case series occurred in the upper limb, while 36.4 % occurred in the lower limb. The incidence of FRI related to specific sites and the number of osteosyntheses performed is shown in detail in Table 3.

The high incidence of FRI in the forearm region is primarily attributed to the large number of osteosynthesis procedures performed in this area. In the case of closed reduction and intramedullary osteosynthesis, the incidence of FRI for this method was 3.8 %, with an average patient age of 8 years (range 7–10). In contrast, with open reduction followed by intramedullary osteosynthesis, the incidence of FRI was only 0.88 %, with this condition occurring in just one patient aged 4 years. Comparatively, the incidence of FRI in the upper limb was relatively higher in the humeral diaphysis, where 7.69 % of osteosyntheses were complicated by the development of FRI. This patient was the only one in our cohort treated with closed reduction and intramedullary fixation using K-wires. In contrast, the incidence in the clavicle region was lower, with only one patient treated using open reduction and intramedullary rod fixation, resulting in an FRI incidence of 3.57 %. The final case of FRI in the upper limb was observed in the distal forearm, but the risk of FRI here was very low in relation to the overall number of operations in this area, with an incidence of 0.54 %. The only patient with FRI in this region was treated with open reduction and plate fixation, resulting in a 9.09 % incidence for this method. More detailed data, including patient ages, are presented in Table 4.

The incidence of FRI in the lower limb was overall lower, but due to the lower number of surgeries in these locations, some procedures were more prone to FRI. The highest risk was associated with a combined procedure in the ankle area, using closed reduction combined with the application of an external fixator and the insertion of K-wires and screws. This case was the only procedure of its kind. Relative to the total number of osteosyntheses in the ankle region, the risk was 0.97 %. High risk was also observed with osteosynthesis in the proximal femur, where, of the two patients treated with closed reduction and intramedullary elastic rod osteosynthesis, one developed FRI, resulting in a 50 % risk for this specific method and a 20 % risk for this location, with the patient being 6 years old. A relatively high risk of FRI was also observed with closed nailing of the femoral diaphysis using the LFN Synthes nail (8.33 % for this method, 2.5 % for this location) and with open reduction and plate fixation in the foot region (25 % for this method, 4 % for this location). These patients were adolescent, however with growth plates

Table 1
Number of osteosyntheses performed and incidence of FRI.

Year	Number of osteosyntheses	Number of FRI Cases	FRI Incidence
2019	224	1	0.45 %
2020	242	3	1.24 %
2021	255	2	0.78 %
2022	208	3	1.44 %
2023	227	2	0,88 %
Total	**1156**	**11**	**0.95 %**

Table 2
Age distribution, fracture site, and primary treatment method.

Patient Number	Age	Fracture Site	Treatment Method
1	16	Diaphysis of the humerus	CRIF, K-wires
2	7	Diaphysis of the forearm	CRIF, TEN - ESIN
3	12	Ankle – bimalleolar	CREF/CRIF, ZF + *K*-wires + screw
4	17	Diaphysis of the clavicle	ORIF, TEN
5	6	Proximal femur	CRIF, TEN
6	17	Diaphysis of the femur	ORIF, LFN
7	10	Diaphysis of the forearm	CRIF, TEN - ESIN
8	4	Diaphysis of the forearm	ORIF, TEN
9	15	Diaphysis of the 5th metatarsal	ORIF, plate
10	7	Diaphysis of the forearm	CRIF, TEN - ESIN
11	12	Distal metaphysis of the radius	ORIF, plate
Average Age	**11.18**		
Median	**12**		

Table 3
FRI sites.

Anatomical site	Number of osteosynthesis at anatomical site	Number of FRI at anatomical site	Percentage of FRI at anatomical site	Percentage of FRI at anatomical site of all FRI
Collarbone	60	1	1,66 %	9,09 %
Diaphysis of the humerus	13	1	7,69 %	9,09 %
Forearm	113	4	3,54 %	36,36 %
Wrist	185	1	0.54 %	9,09 %
Proximal femur	5	1	20 %	9,09 %
Diaphysis of the femur	40	1	2.5 %	9,09 %
Distal tibia/fibula	103	1	0,97 %	9,09 %
Foot	26	1	3,84 %	9,09 %

Table 4
Incidence, anatomical sites and age of patients witch FRI – upper extremity.

Locality	Osteosynthesis performed	Number of patients	Patients with FRI	% of fractures in this area	% for this type of surgery	Age average, range
Clavicle	CRIF TEN	10				
	ORIF TEN	28	1	1,60 %	3,57 %	17
	ORIF K-wire	8				
	ORIF, plate	14				
Proximal humerus	CRIF, K-wire	2				
	CRIF, TEN	13				
	ORIF K-wire	3				
	ORIF, TEN	5				
Diaphyseal humerus	CRIF, K-wire	1	1	7,69 %	100 %	16
	CRIF, TEN	7				
	ORIF, plate	5				
Distal humerus	CRIF, K-wire	221				
	ORIF, K-wire	56				
	ORIF, screw	38				
Proximal forearm	CRIF, K-wire	21				
	CRIF, TEN	21				
	ORIF, K-wire	12				
	ORIF, plate	3				
Diaphyseal forearm	CRIF, K-wire	2				
	CRIF, TEN	79	3	2,65 %	3,80 %	8 (7 - 10)
	ORIF, TEN	25	1	0,88 %	4,00 %	4
	ORIF, plate	7				
Distal forearm	CRIF, K-wire	168				
	CRIF, TEN	5				
	ORIF, K-wire	1				
	ORIF, plate	11	1	0,54 %	9,09 %	12
Hand	CRIF, K-wire	122				
	ORIF K-wire	9				
	ORIF, plate	7				
	ORIF, screw	7				

still present. More detailed data is shown in Table 5.

Pathogens causing FRI and administered antibiotics

The most common causative agent of FRI in the observed patient group was *S. aureus* (63.6 %, $n = 7$), followed by *S. epidermidis* (18.2 %, $n = 2$). Additionally, fungi organisms, *E. cloacae*, were captured in the cultures. In one case, no pathogen was cultured; however, since the confirmation criterion of a fistula with purulent secretion was met, this patient was also treated as a confirmed case of FRI (Table 6).

Antibiotic treatment for FRI was administered according to the pathogen's sensitivity – most commonly Oxacillin and Clindamycin, see Table 6 for a more detailed overview. In cases where osteosynthetic material was present and Gram-positive cocci were cultured, Rifampicin was sometimes added as an anti-biofilm antibiotic.

Need for revision procedures

In cases of clinical or laboratory signs of FRI, additional surgical procedures were indicated. The average number of procedures per patient was 2.1 (1–4). The most frequently indicated procedure was sample collection (with debridement and irrigation, performed 5x), sometimes followed by the removal of osteosynthetic material (3x). Complete removal (including debridement and irrigation as well) with sample collection was performed 5x. Other procedures in these patients included re-debridement, revision under general anaesthesia, or spongioplasty, usually accompanied by additional sample collection. All patients were subsequently monitored, and no recurrence of symptoms was recorded. In two cases, the implant was left in situ without subsequent removal – this involved a femoral nail and a distal radius plate (Table 7).

Discussion

FRI in children and adolescents is a rare complication of surgical fracture treatment. In our cohort, the incidence of FRI in children and adolescents from 2018 to 2023 was 0.95 %. There are no known literature data on the incidence of FRI in children or adolescent, but studies on paediatric osteomyelitis are available, Walter reports an incidence of osteomyelitis in children of 9.2 per 100,000 [1]. However, these figures cannot be directly compared, as they mainly concern hematogenous osteomyelitis without prior trauma. When comparing the observed data from the paediatric population with the adult population, the incidence of FRI in children and adolescents is lower. The reported incidence of infectious fracture complications in adults is 1–2 %, according to Fang [13] and Depypere [14]. Similarly, Walter reports an incidence of FRI in Germany in 2018 of 1.23 % [15]. A study conducted in the Czech Republic on the adult population found an incidence of FRI of 2.33 % [16].

The average age of patients with FRI in our cohort is 11.18 years. No direct comparison for the paediatric population is available in the literature. Thus, FRI occurs even in younger children. For comparison, Walter [1] reports the highest incidence of osteomyelitis in children aged 10–15 years. However, the observed standard deviation of 4.49 years and the minimum age of 4 years confirm that FRI also occurs in younger children.

In children, FRI most commonly occurred in the forearm, which corresponds to the incidence of these fractures and their usual treatment; in his epidemiological study, Cintean reports forearm fractures as the most frequently operated fractures in children [17]. In adults, the incidence of FRI in this site is significantly lower [18–20]. Other sites appeared only in isolated cases in our study. A higher percentage of FRI was observed in the upper limb (63,6 %), whereas in adults, a higher incidence is reported in the lower limb [13].

Osteosyntheses performed in certain locations showed a higher risk of FRI, particularly in relation to the number of surgeries performed and the chosen surgical techniques. Specifically, this concerned the diaphyseal fracture of the humerus, where the incidence of FRI was 7.69 % of cases. However, in this case the 16-years-old patient was treated by closed reduction and K-wire fixation, which could have led to lack of stability and create conditions for FRI development. In this type of fracture, an alternative osteosynthesis method, such as ORIF with plate fixation or closed humeral nailing, should have been chosen. While data

Table 5
Incidence, anatomical sites and age of patients witch FRI – lower extremity.

Locality	Osteosynthesis performed	Number of patients	Patients with FRI	% of fractures in this area	% for this type of surgery	Age average, range
Pelvis	ORIF, screw	4				
	ORIF, plate	1				
	CREF, exfix	1				
Proximal femur	CRIF, screw	1				
	CRIF, TEN	2	1	20 %	50 %	6
	ORIF, screw	1				
	CREF, exfix	1				
Diaphyseal femur	CRIF, TEN	19				
	CRIF, nail	12	1	2,50 %	8,33 %	17
	ORIF, TEN	3				
	ORIF, plate	3				
	CREF, exfix	3				
Distal femur	CRIF, Kw	4				
	ORIF, Kw	1				
	ORIF, screw	2				
	ORIF, plate	1				
Proximal tibia	CRIF, Kw	6				
	ORIF, Kw	12				
	ORIF, screw	10				
	ORIF, plate	3				
Diaphyseal tibia/ fibula	CRIF, TEN	13				
	ORIF, TEN	2				
	ORIF, plate	3				
	ORIF, screw	2				
	CREF, exfix	6				
Distal tibia/fibula	CRIF, Kw	12				
	CRIF, screw	43				
	ORIF, Kw	2				
	ORIF, screw	24				
	ORIF, plate	19				
	CREF, exfix	3				
	CREF/CRIF ZF, K-wire, screw	1	1	0,97 %	100 %	12
Foot	CRIF, K-wire	11				
	CRIF, screw	2				
	ORIF, screw	7				
	ORIF, plate	4	1	4,00 %	25 %	15
	CREF, exfix	1				

Table 6
Pathogens and their sensitivity.

Patient Number	Pathogen	Antibiotic Therapy
1	S. aureus	Clindamycin, Rifampicin
2	E. cloacae	Cefotaxim
3	No pathogen, fistula	without antibiotics
4	S. epidermidis, P. acnes	Clindamycin
5	S. aureus + fungi	Cefadroxil
6	S. epidermidis	Oxacillin, Rifampicin
7	S. aureus	Oxacillin
8	S. aureus	Oxacillin
9	S. aureus	Oxacillin
10	S. aureus	Clindamycin
11	S. aureus	Oxacillin

Table 7
Number of required revision procedures.

Patient Number	Sample Collection Only	Removal + Sample Collection	Removal Alone	Other Procedures (Count)	Total Procedures Under GA
1			X	X (1)	2
2	X		X		2
3		X		X (3)	4
4		X		X (1)	2
5	X		X	X (1)	3
6	X			X (3)	4
7	X		X		2
8		X			1
9		X			1
10		X			1
11	X				1
Average					**2,1**

on the incidence of FRI in the humeral diaphysis is not precisely established, a relatively frequent occurrence of FRI in the proximal humerus in adult patients is described [21]. In the lower extremity, the ankle region was identified as an area of concern, with the incidence of FRI in our cohort being notably higher with one specific surgical technique (a combination of closed reduction, external fixation, and percutaneously inserted Kirschner wires and screws), though the overall incidence in this location was only 0.97 %. The incidence of FRI in the ankle is significantly higher in adults [16]. Another area of increased risk for FRI development in our cohort was the proximal femur, with an FRI incidence of 20 %. In the adult population, the incidence of FRI in the proximal femur is reported to be 2.1 % [22]. Additionally, femoral diaphysis osteosynthesis appeared to be a risk factor in our group, with an FRI incidence of 2.5 % and 8.33 % for the closed reduction and intramedullary nailing technique, respectively, which is consistent with reported data on FRI incidence in the adult population [23].

The most common pathogens causing FRI in children are, as in adults [13,24], Gram-positive cocci, which accounted for 81,8 % of the pathogens identified in our study. This is consistent with the microbial origin of osteomyelitis in children [1,25]. Enterococci and fungal organisms were also present in the samples. Polymicrobial FRI occurred in 18, 2 % of cases, which is lower than in adults, where polymicrobial FRI is reported in 20–30 % of cases [14]. A case of culture-negative FRI was also recorded, where the presence of a fistula with purulent secretion served as the confirmation criterion for infection. Gitajn reports up to a 9 %

incidence of culture-negative infections following osteosynthesis [26]. Given the spectrum of pathogens, the most commonly administered antibiotics were higher-class penicillins, represented by oxacillin, and cephalosporins.

The occurrence of FRI significantly increases the need for surgical interventions under general anaesthesia. The average number of revision procedures required to treat FRI was 2,1. For the most complicated patients, up to 4 revision procedures were necessary, yet with good outcomes. No patient experienced a recurrence.

This study has several limitations. The first is the small sample size of only 11 patients, which is influenced by the low incidence of this diagnosis. Another limitation is the absence of a control group. Additionally, functional outcomes of the patients are not included in this study. Further prospective analysis is needed.

Conclusion

FRI in childhood is a relatively rare but serious complication of surgical fracture treatment in children. In our cohort, the incidence of FRI in children was 0.95 %. FRI in children in our study occurred more frequently in the upper limb, most commonly in the forearm. However, the relative rate was significantly higher in humeral diaphysis, proximal and diaphyseal femur, and foot. The average age of patients with FRI was 11.18 years. The most common pathogen causing FRI was *S. aureus*. An average of 2,1 revision procedures was required for FRI eradication. None of the patients in our cohort experienced a recurrence of FRI, which contributes to the view, that the recommended guidelines developed in 2018 by a group of experts, including diagnostic criteria for FRI, can also be successfully applied to the pediatric population.

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Ethics in publishing statement

I testify on behalf of all co-authors that our article submitted followed ethical principles in publishing.

All authors agree that:

This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work.

This manuscript represents entirely original works and or if work and/or words of others have been used, that this has been appropriately cited or quoted and permission has been obtained where necessary.

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All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

CRediT authorship contribution statement

Michaela Doležalová Hrubá: Writing – original draft. **Tomáš Zídek:** Writing – review & editing. **Martin Kloub:** Writing – review & editing, Supervision. **Jiří Urban:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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