OPEN

Femoral fractures and abuse in children under 36 months old: a Swiss case series

Giacomo de Marco, Raimonda Valaikaite, Moez Chargui, Benoit Coulin, Oscar Vazquez, Anne Tabard-Fougère, Christina N. Steiger, Romain Dayer and Dimitri Ceroni

Abuse should be suspected in infant femoral fractures without significant trauma, especially if the child is non-ambulatory. Review the epidemiological and radiological characteristics of femoral fractures in children under 36 months old to identify those potentially related to child abuse. Cases involving 102 patients presenting with 103 femoral fractures between January 1990 and December 2020 were investigated, paying close attention to mechanisms of injury, fracture patterns, and their possible relations to child abuse. The annual incidence of femoral fractures in patients under 36 months old was estimated at 24.6 per 100 000; the incidence in infants under 13 months was significantly higher than among children between 13 and 36 months old. Most infants under 13 months suffered from transverse or oblique metaphyseal/diaphyseal fractures (93.2%), whereas 67.8% of older children presented with spiral shaft fractures. Data confirmed child abuse in 4.9% of all patients (one with bilateral fractures); femoral fractures were incompatible with their reported mechanisms of injury in 31 patients (30.4%), whereas 12 fractures (11.8%) occurred in unexplained circumstances. More than 50% of femoral fractures occurred with low-energy trauma. The difference in patterns according to patients' ages suggested different mechanisms of trauma in ambulatory and non-ambulatory infants. Confirmed abuses and unclear or inconsistent mechanisms of trauma, raised potential total child abuse cases to 47.1% of our cohort. Level of evidence: Level IV.

Journal of Pediatric Orthopaedics B 2024, **33**:452–461

Keywords: child abuse, femoral fracture, infants, pediatric, toddlers

Service of Pediatric Orthopedics, The Children's Hospital, Geneva University Hospitals, Switzerland

Correspondence to Giacomo de Marco, MD, Service of Pediatric Orthopedics, The Children's Hospital, Geneva University Hospitals, Rue Willy-Donzé 6, 1205, Geneva, Switzerland
Tel: +41 (0)795537992; e-mail: giacomo.demarco@hcuge.ch

Received 11 November 2022 **Accepted** 17 September 2023.

Introduction

Pediatric femoral fractures may lead to serious complications and disability and can have a significant impact on the child and their family [1]. In Western countries, these fractures are among the most common pediatric long-bone fractures, with a mean estimated incidence of 20 per 100 000 [2–5]. In some series, this rate reached 35 to 60 fractures per 100 000 [6,7]. Male teenagers are at the highest risk, in relation to their greater participation in sports and adolescent thrill-seeking [1,8]. Indeed, falls and motor vehicle collisions are responsible for two thirds of these fractures [2,9,10].

Abuse should be considered a potential cause of femoral fractures among infants who present with no significant trauma or an underlying bone pathology, especially when they are non-ambulatory. Highlighting the scale of this phenomenon, recent literature has suggested that abuse could be responsible for 60–93% of femoral fractures in non-ambulatory infants [11–13] and 30–46% in children under 4 years old [12,14]. However, it is extremely difficult to differentiate injuries due to abuse from accidental injuries in any age category [15]. According to existing literature, a fifth to one third of abused children consulted a physician at least once without any abuse being noted [16,17]. Children under 24 months who have suffered abuse present with patterns of non-accidental injuries consisting mainly of metaphyseal lesions, multiple fractures at different stages of consolidation, posterior rib fractures, and long-bone fractures [18,19]. Pediatric orthopedic surgeons must be aware that lesions such as humeral and femoral fractures in infants are most likely the result of child abuse [15].

Many studies have described femoral fractures in young children and have attempted to identify specific patterns that may indicate abuse [9,18,20–27]. A femoral fracture in a child under 24 months old is highly suggestive of non-accidental trauma (NAT) [9,21,26–30], especially if they are not yet walking. Some literature has focused on predictors of abuse, such as elements in the child's trauma history (inconsistent records, inappropriate delays, frequent consultations with physicians), physical

examination findings (inconsistent with history, concomitant head injury, fracture in non-ambulatory infants), and socio-economic background [31–33].

The present study focuses on femoral fractures in children under 36 months old in a single Swiss health district, with particular attention to epidemiology, circumstances of trauma and fracture patterns. The final aim was to review the epidemiological and radiological characteristics of these fractures to identify those related to child abuse. Our hypothesis is that femoral non-accidental fractures in children are more common than expected and that they can take several forms.

Methods

After the approval of the local Children's Hospital Review Board, we retrospectively reviewed the electronic medical records of all children under 36 months old admitted to our University Children's Hospital for femoral fractures between January 1990 and December 2020. The Children's Hospital is the only medical facility providing pediatric trauma, inpatient, and specialized medical care to the district's 460 000 inhabitants.

We were able to retrieve electronic data from our hospital inpatient database going back as far as 2000 and retrieved paper medical charts for older files.

Data on patient demographics (age and sex), month of admission, mechanism of injury, trauma circumstances and fracture pattern were collected. Fractures were then classified according to their location (epiphyseal, physeal, metaphyseal, or diaphyseal). We used the Salter–Harris classification for distal physeal fractures, and the Delbet classification for femoral head and neck fractures. For analytical purposes, mechanisms of injury were divided into specific groups: 1) accidents due to everyday activities (falls from standing, changing tables, or rolling off a parent's bed or sofa); 2) birth injuries at delivery; 3) outdoor accidents (scooters, swings, slides) and high-energy outdoor accidents (falls from a height > 1.5 m); 4) injuries from a heavy object/person falling on the patient's limb; 5) motor vehicle accidents; 6) unknown or inconsistent mechanisms of trauma; and 7) confirmed child abuse.

Pathological fractures caused by a disease or a specific medical condition were excluded from our series. In particular, 3 patients with osteogenesis imperfecta were excluded from the study.

Results were treated in three age groups: infants aged from 0 to 12 months, toddlers aged from 13 to 24 months, and children from 25 to 36 months old. This choice enabled straightforward comparisons with data in the existing literature and helped us to better understand the different mechanisms of injury related to children's physical activities.

All the patients with suspected child abuse were admitted as inpatients and had a complete checkup. This involved a skeletal survey including upper and lower extremity x-rays, skull, thorax and spine X-rays, a complete body check and an interview with patient's pediatrician and social services during the hospital stay. When a case of abuse was confirmed, the child was entrusted to a social service facility.

Data and statistical analysis

Statistical analyses were performed using R software (version 3.6.1) and the RStudio interface (RStudio, Inc., Boston, MA, USA). Chi-squared tests were performed and results were presented as n (%). For outcomes with significant effects ($P < 0.05$), *post-hoc* analyses were interpreted using a Bonferroni correction [$P < 0.017$ (0.05/3)].

Results

Patient characteristics

The medical charts of 105 infants under 36 months old were selected, and 3 cases of pathological fracture due to osteogenesis imperfecta were excluded. The study thus included 102 infants with 103 femoral fractures (one had bilateral fractures). The mean annual community population of 13 952 ± 706 infants under 36 months old from 1990 to 2020 had an average annual incidence of femur fractures of 24.6 new cases per 100 000. Male patients suffered 61 fractures (62.8%), implying a male-to-female ratio of 1.4:1. Right and left femurs were involved in 43 (41.8%) and 58 (56.3%) cases, respectively, with 1 case involving both femurs (1.9%). Figure 1 shows the distribution of patients according to their age (Fig. 1).

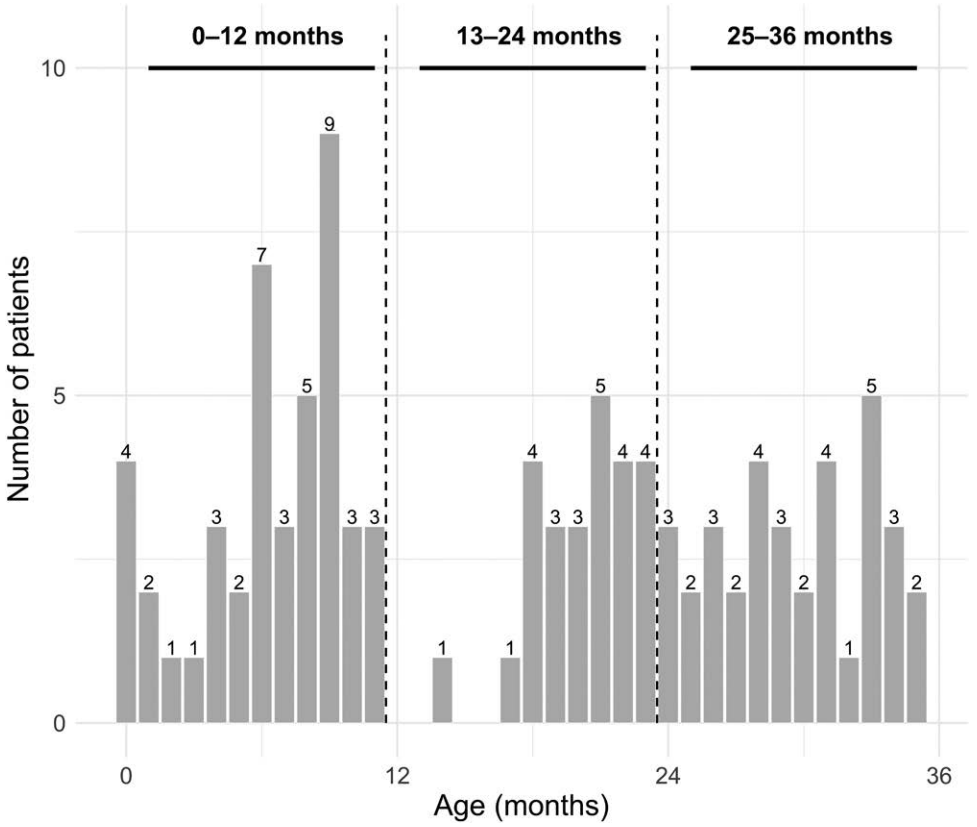
Mechanisms of fracture and patient age

Accidents occurring during everyday activities accounted for the largest overall percentage of fractures (53 cases, 51.9%), 5 fractures (4.9%) resulted from a fall >1.5 m, and 7 fractures (6.9%) were the consequence of an object/person falling on the child's limb. Femoral fractures occurred outdoors in 12 cases (11.8%) and in traffic accidents in 7 cases (6.9%). Child abuse was confirmed in 5 patients, with 1 of them having sustained bilateral fractures (4.9%). In 12 cases (11.8%), the mechanism of fracture remained unidentified, with no explanation furnished by the parents or caregivers, leading to a suspicion of child abuse. We encountered 1 case (0.9%) of iatrogenic fracture in a Cesarean delivery.

Mechanisms of fracture were subsequently analyzed according to patients' ages.

In infants between 0 and 12 months, 26 femoral fractures (60.5%) were related to everyday activity trauma, 7 (16.3%) had no clear reported cause, 4 patients (with 5 fractures one bilateral) (9.3%) sustained confirmed child abuse, 2 fractures (4.7%) resulted from a heavy object/person falling on the limb, 1 (2.3%) resulted from a fall

Fig. 1



Number of patients in each age group.

> 1.5 m, 1 (2.3%) from an outdoor accident (falling from the father's arms while skiing), 1 (2.3%) from a road accident, and 1 case (2.3%) resulted from iatrogenic fracture during a Cesarean delivery. Unclearly reported causes (7 cases, 16.3%) were considered very suggestive of child abuse, even if subsequent investigations by social workers could not prove this. These raised the percentage of confirmed and highly suspicious cases to 25.6% of traumas among infants between 0 and 12 months old with a femoral fracture.

In the 13-to-24-month-old toddlers' group, 12 fractures (48%) were related to everyday activity trauma, 3 (12%) resulted from a fall > 1.5 m, 3 (12%) occurred during an outdoor activity, 2 (8%) resulted from the limb being crushed by a heavy object/person, and 1 (4%) occurred in a road accident. Four (16%) had no clear reported cause, with parents giving confused versions of the accidents, and were thus considered highly suggestive of child abuse in this age group.

In the 25-to-36-month-old group, 15 fractures (44.2%) resulted from everyday activity trauma, 8 (23.6%) occurred during outdoor activities, 5 (14.7%) occurred in road accidents, 3 (8.8%) resulted from the limb being crushed by a heavy object/person, 1 (2.9%) was related to a fall from > 1.5 m, 1 (2.9%) had no clear cause, and 1 (2.9%) was confirmed as the result of child abuse. A further 5.8% (1 abuse and 1 suspicion) of femoral fractures in this age group were highly suggestive of child abuse.

Type of fracture

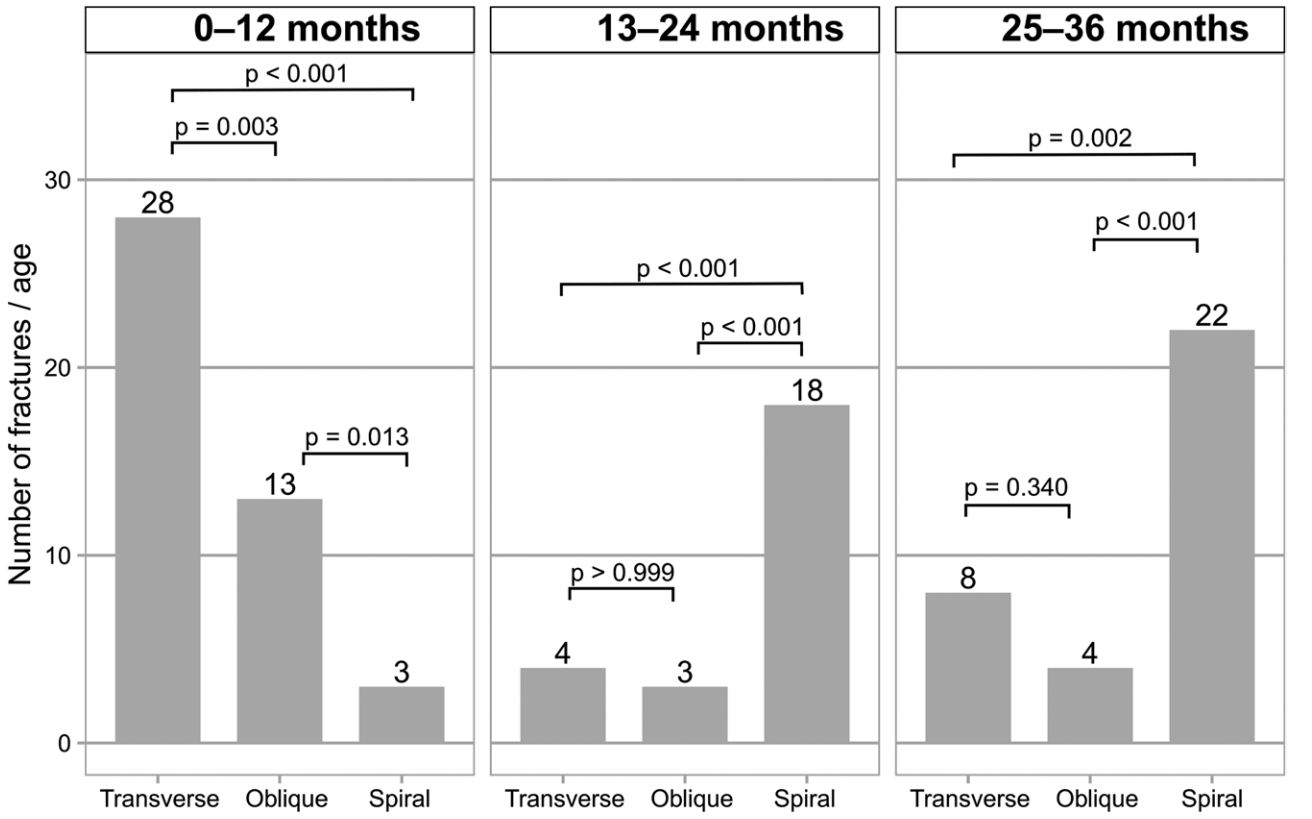
Sixty-eight fractures (66%) affected the femoral shaft, 21 (20.4%) the distal metaphysis, 8 (7.8%) the sub-trochanteric region, 4 (3.9%) the femoral neck, and 2 (1.9%) the distal physis (corner fractures). All the fractures were closed. When considering fracture shapes, 43 were spiral (41.8%), 40 were transverse (38.8%), and the remaining 20 (19.4%) were oblique.

Fracture patterns were then analyzed according to patient age. In the first group, we encountered 44 fractures (28 transverses, 13 oblique, 3 spiral), in the second group 25 fractures (4 transverses, 3 oblique, 18 spiral) and in the last group of age 34 fractures (8 transverse, 4 oblique, 22 spiral). Figure 2 represents the distribution of fracture patterns according to each group of age.

Treatment considerations

Of 102 patients, 81 (79.4%; mean age 19 months) were treated with a spica cast (pelvic long-leg brace), 10 (9.8%;

Fig. 2



Fracture type related to age groups. Chi-square statistical tests were used; results are reported as n. Significant post-hoc analyses can be interpreted with Bonferroni corrections [$P < 0.017$ (0.05/3)].

mean age 10 months) with distal metaphyseal transverse fractures were treated with a long-leg cast, 6 (5.9%; mean age 5 months) received a Pavlick harness, 3 (2.9%; mean age 29 months) underwent surgical treatment with flexible intramedullary nailing, and 2 (2%; mean age 10 months) were treated with rest only, because of their delayed diagnosis.

Considerations about child abuse or suspected child abuse

As mentioned above, we suspected child abuse in 47.1% (48 of 102 patients) of the cases overall in our series. Among them, five (4.9%, one with bilateral fractures) suffered confirmed child abuse, and a further 12 (11.8%) were reported to have unexplained fractures. Additionally, 31 patients (30.4%) reported a very low-energy trauma with a mechanism of trauma inconsistent with the fracture thus making a total of 47.1% among confirmed and suspected abuse. In 1 case among these 48, we found a sequela of an ancient femoral fracture which suggested NAT. There was no sex predominance since these fractures occurred in 25 males and 23 females. The locations of the fractures in this group were 24 mid-diaphysis fractures (49%), 12 distal metaphyseal fractures (24.5%), 4 proximal diaphyseal fractures (8.1%), 3 sub-trochanteric fractures (6.1%), 2 'corner' fractures (4.1%), 2 distal diaphyseal fractures (4.1%), and 2 per-trochanteric fractures (4.1%). As to fracture patterns, 19 were transverse (38.8%), 19 were spiral (38.8%), and 11 were oblique (22.4%) (Fig. 3).

Among patients with suspected child abuse, most of those who fall from height had spiroid fractures (11/14, 79%); whereas patients with confirmed child abuse had only transverse (3/5, 60%) and oblique (2/5, 40%) fractures (Fig. 4).

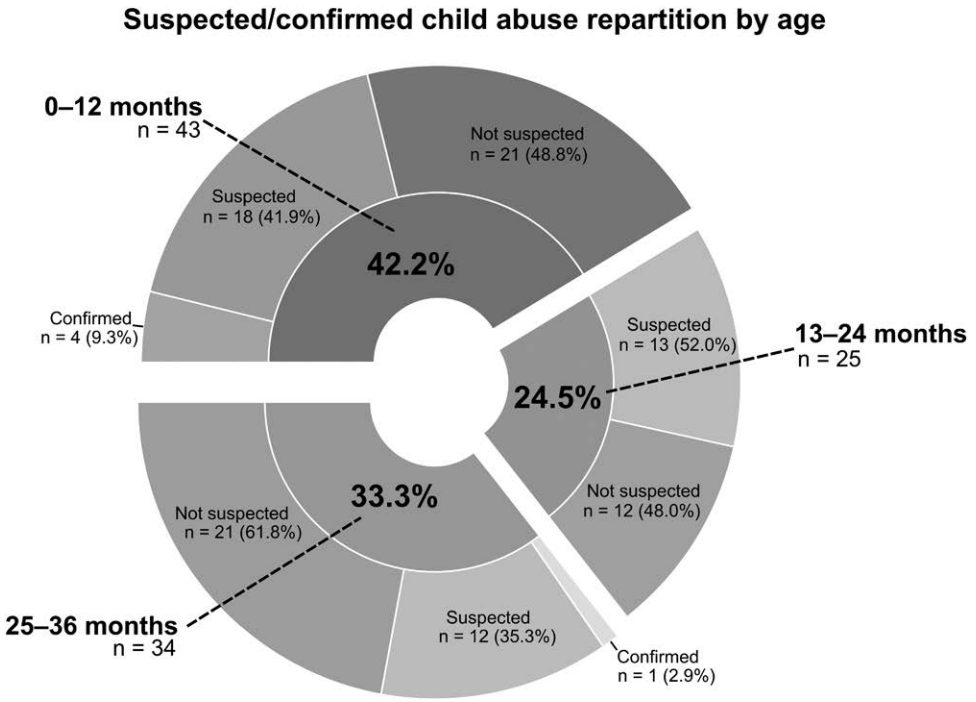
Considerations about Swiss Law

Swiss legal provisions in the event of confirmed or suspected situations of child abuse

In Switzerland child protection services (AEPA: 'Autorité de protection de l'enfant et de l'adulte') are under the jurisdiction of each region.

Professionals in medicine, psychology, social service, educators, teachers, and those involved in the field of religion and sport, are required to notify the child protection authority when a concrete treat to the physical, psychological, or sexual integrity of the child is present or suspected.

Fig. 3



Confirmed and suspected child abuse cases by age group.

When a report reaches the authorities through the hospital social services, a procedure is initiated to protect the child. During this procedure, the situation of the child is assessed to rule out if there is a danger to the good of the child. After this first step, a decision is taken and, if necessary, measures are ordered to protect the child and or to support the family. Most of the time, the competent authority tries to find a solution with the agreement of the family. If possible, this option is more durable than if a measure must be ordered under pressure. Only in exceptional cases, the legal authority may limit the child's access to his own family or even decide to remove him from the family unit. Monitoring of the child's well-being is then initiated and carried out by the social services with home visits by specialized nurses or school nurses.

In the context of emergencies, the pediatric orthopedist is expected to play an important role. In fact, his traumatology knowledge is a major asset to detect fractures that appear suspect according to the energy required, their type, and the circumstances reported by parents. A multidisciplinary team, the CAN Team (Child Abuse and Neglect Team), is then mandated to assess the situation, make inquiries, with the child's pediatrician and the school nurse, to take the appropriate steps at the level authorities, and to guide health professionals. In the event of a report, it is the CAN team that must communicate to the family about the gravity of the situation and its legal consequences.

Discussion

Considerations about non-accidental trauma and pathological fractures

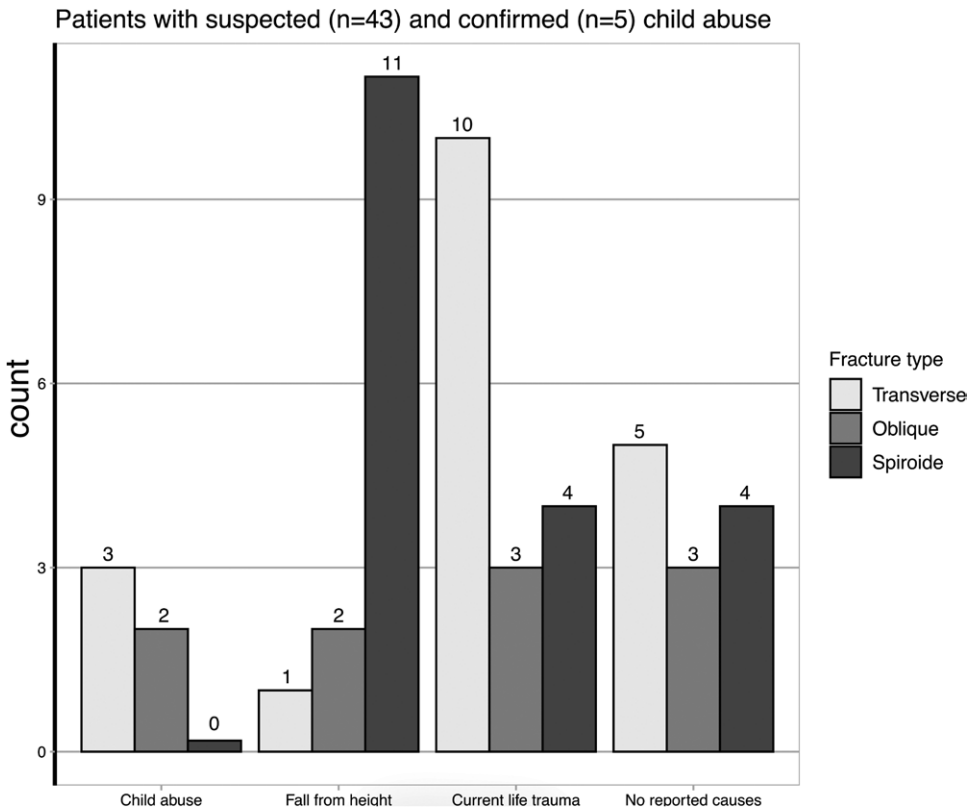
Even for the craftiest and experimented clinicians assessing child abuse is often complex. In addition, several rare bone diseases may explain suspicious fracture when the traumatic mechanism is inconsistent with an usual femoral fracture [34].

It is recognized that child abuse is much more common than bone disorders to explain femoral fractures, especially in children under 3 years old. On this point, Leventhal *et al.* [35] showed that underlying metabolic or bone disorders were found in less than 1% of children hospitalized for fractures in the USA.

In case of doubt, biochemical studies on collagen may be required in patients with a suspected fracture [36].

Consequences of misdiagnosis of osteogenesis imperfecta or pathologic fractures as child abuse could be potentially devastating for families [37], and clinicians should be aware of the importance to not rely only on radiological information to discriminate between pathologic and NAT [38]. Thus, biochemical studies should be conducted in presence of every child sustaining multiple fractures suggestive of abuse without any other abuse signs such as bruises or head injuries [39]. Prior to report any abuse, the evidence should include not only positive signs of child abuse, but also a demonstration

Fig. 4



Suspected child abuse cases based on fractures type and mechanisms of injury.

that diseases that can mimic NATs have been ruled out [40].

Overall considerations

The literature about femoral fractures among children from 0 to 36 months old is principal based on administrative databases, and few series have focused on radiological data [7,9,11–13,16,19,21,35,41,42].

Our results revealed that the annual Incidence of infant femoral fractures in the Geneva district (24.6 per 100 000 population from 0 to 36 months old) was relatively similar to the rate of 25.5 per 100 000 reported by Hinton *et al.* [5], but noticeably lower than the 38 per 100 000 rate reported by Brown *et al.* for this age range [7]. Our study's fracture rate was significantly higher among infants between 0 and 12 months old than among those between 13 and 24 months or 25 and 36 months old. Indeed, the 0 to 12 months group had 72% and 26.5% more fractures than the 13 to 24 months and 25 to 36 months groups, respectively.

Previous studies expressed different opinions about femur fracture rates in infant populations. Some considered femoral fractures in patients between 0 and 12 months old to be less common than in children walking [29,43]. By contrast, a study by Brown *et al.* [7] found the highest femur fracture rates among children between 0 and 12 months and 13 and 24 months, which confirmed our study's results. Focusing on femoral fracture rates and the mechanisms of trauma in children from 0 to 12 months old is essential since there are few plausible explanations for a femur fracture in non-ambulatory infants other than intentional injury.

In the present cohort, femur fractures were mostly located on the femoral shaft (66%), far more than on the distal metaphysis (20.4%). This finding corroborates the idea that the most common location for femoral fractures in both abused and non-abused children is the midshaft of this bone [44,45]. We nevertheless noted that fracture shapes were very different depending on the patient's age. Infants between 0 and 12 months old mostly suffered from transverse or oblique fractures (93.2%), whereas 67.8% of infants over 12 months old presented with spiral fractures. Indeed, the group of infants less than 12 months old demonstrated a low rate of diaphyseal spiral fractures (6.8%) but a high rate of transverse (essentially metaphyseal; 63.6%) and oblique (essentially diaphyseal; 29.6%) fractures. Previous studies also reported greater proportions of metaphyseal/diaphyseal fractures among abused infants, suggesting that the pattern of our results was more likely to have been the result of abuse [41,44].

Our findings, showed no substantial differences in the distribution of transverse, spiral, and oblique fractures between the group of abused/suspected-abused infants and the group of non-abused patients [46]. These results suggested the absence of any 'common' femoral fracture pattern that could be clearly identified as abuse related [29]. In addition, we did not find spiral fractures to be the most common femoral fracture among abused children under 15 months old, as suggested by other series [15]. Finally, the metaphyseal corner fracture, which is seen as highly specific to child abuse in current medical literature, was only encountered once in our cohort, highlighting the theory propounded by Baldwin *et al.* that any femoral fracture could be associated with abuse and should alert professional caregivers [42]. Indeed, our series contained 12 cases of femoral fracture for which no family members could explain the mechanism of injury and a further 31 cases (30.4%) with reported circumstances inconsistent with the trauma. Abuse should thus be suspected, or at least included among the potential causes of injury, if family caregivers provide inconsistent or implausible accounts of the mechanism of fracture.

An algorithm is here suggested according to clinical evidence and family history of the patient to rule out suspected child abuse (Fig. 5). The associated table 1 described what the pediatric orthopedist should know about child abuse and what he should be worried about.

Fig. 5

Algorithm according to clinical evidence and family history of the patient to rule out suspected child abuse.

The rate of suspected and confirmed child abuse in the present series was 47.1%. This rate is higher than in previous review articles examining femoral fractures in young children and child abuse. In one systematic review of published articles on femur fracture etiology in children less than 5 years old, abuse rates among children between 0 and 12 months ranged from 16.7 to 35.2%, whereas they only reached 1.5 to 6.0% in children older than 12 months [19]. Yet a study on long-bone fractures conducted by Thomas *et al.* [11] demonstrated that at least 36%, but probably up to 44%, of femoral fractures were related to child abuse. Even more alarmingly, a retrospective case series study by Anderson *et al.* [49] showed that 19 of 24 children under 24 months old had sustained their femoral injury through abuse, whereas another report mentioned that almost half of femoral fractures were the result of abuse in this age group [21]. Thus, our 47.1% rate of fractures due to suspected or confirmed child abuse does not appear disproportionate to the data from these three studies. The suspected and confirmed child abuse rates described in previous studies are reported Table 2.

The main limitation of the present study is the ambiguity of the assessment of child abuse. Assessing suspected victims of child maltreatment is very challenging, especially when children less than 3 years are involved. In addition, there's no single clinical test to 'prove' or 'disprove' child abuse.

The second limitation is the exclusion of pathologic fractures. We decided to exclude pathologic fractures since the presence of bone abnormalities constitute a factor which may explain the femoral fractures. A

Table 1 **What the pediatric orthopedist should know about child abuse and what should he be worried about.**

1.	Time elapsed between trauma and consultation	Most consultations for non-accidental fractures occur late and may be motivated even by other reasons.
2.	Child's age	Young age is a highly discriminating factor in a non-accidental fracture. Eighty percent of all non-accidental fractures occur in children under 18 months. Even worse, it is estimated that child abuse is the main etiology in nearly 70% of children under 18 months who consult with a fracture [47].
3.	Lack of correlation between the described mechanism and the child's psychomotor stage of development.	Accidental fractures are generally correlated with the child's age and his psychomotor development. Indeed, any fracture occurring in an infant who hasn't yet achieved his walking milestones remains highly suspicious of abuse.
4.	Anatomical localization of fractures.	Ribs fractures are exceptional in infants and young children, especially when they occur without high-energy mechanisms such as MVA. Other locations such as the sternum, scapulae and vertebral spinous processes should be also considered highly suspicious.
5.	Presence of multiple fractures.	The occurrence of multiple without high-energy trauma, should raise suspicions about the non-accidental nature of the lesions. It is recognized that nearly 85% of hospitalized children with a diagnosis of maltreatment have 3 or more fractures [48].
6.	Fractures/lesions of different ages	Suspicion of child abuse increases when fractures of different ages are observed during the radiological assessment. Caregivers and pediatric orthopedist may even encounter old fractures without medical records in the patient's file.
7.	Delay between fracture occurrence and seek for medical care	In some cases, seek for medical attention is delayed and some fractures already show consolidation signs. This often raises doubts about a given history of acute trauma.
8.	Concomitant lesions	Presence of other lesions such as bruises on the child's mouth, neck, ears, and trunk are strongly suggestive of abuse. Multiple bruises localizations on the child's body make the situation even more suspicious. It is therefore essential to undress and examine the child completely when a suspicion of abuse exists.
9.	Intracranial or abdominal injuries	These injuries are not compatible with minor accidental trauma, as they usually result from serious and documented traumas such as MVA or falls from great heights.

Table 2 **Suspected and confirmed child abuse rates in previous studies**

Study	Number of patients	Age	Suspected abuse	Confirmed abuse
Anderson *et al* [49].	24	0–2 YO	-	79.1%
Susan A. Thomas *et al* [11].	25	0–3 YO	44%	36%
Yongjot J. *et al* [50].	39	0–5 YO	23%	2.5%
R. H. Gross *et al* [21].	74	0–5 YO	-	45.9%
		0–1 YO		69.2%
R. K. Beals and E. Tufts[51]	79	0–4 YO	40%	30%
C. Hui *et al* [12].	127	0–3 YO	19%	11%
		0–1 YO		17%
Yaniv Y. *et al* [52].	131	0–5 YO	58.8%	16,8%
H. J. Dalton *et al* [53].	138	0–3 YO	70%	31%
Jochen P. Son-Hing [54]	138	0–4 YO	-	21.7%
R. M. Schwend *et al* [55].	139	0–4 YO	9%	-
Louise Capra *et al* [56].	203	1–5 YO	10.3%	1.5%
Scherl *et al* [27].	207	0–6 YO	36.7%	6.2%
Leventhal *et al* [13].	215	0–3 YO	32.6%	24.2%
C. Coffey *et al.* [57] (Tibia and Femur)	555	0–18 MO	-	32%
Loder, Randall T. *et al* [9].	1076	0–2 YO	-	15%
J. N. Wood *et al* [19].	10 717	0–1 YO	-	16.7–30.5%
		1–5 YO		1.5–6.0%
This study	102	0–3 YO	47.1%	4.9%

known medical condition that predisposes to bone fragility generally explains the fracture even if the trauma is not important or inconsistent. However, we could not exclude absolutely a NAT in a child with bone fragility [40]. The decision to exclude these patients was taken to avoid confusion between diagnostics.

Conclusion

The present study revealed that 5 patients' femoral fractures (4.9%) were due to confirmed child abuse, and the reported circumstances of a further 12 patients' fractures (11.8%) were very suspicious. Indeed, with 31 patients' mechanisms of injury (30.4%) being inconsistent with a femoral fracture, especially in non-ambulatory infants, this implied that over 45% of these children were suspected or confirmed subjects of child abuse. We, therefore, believe that abuse should be suspected, or at least included as a possible cause, when caregivers' accounts of how an infant's femoral fracture occurred are inconsistent or incoherent.

We thus recommend that every femoral fracture in a non-ambulatory infant should be considered a potential child abuse fracture until proven otherwise. Infants should be admitted as inpatients until detailed social investigations of previous suspicious events or reports from child protection institutions have been examined and have ruled out abuse. The patient's pediatrician should be questioned about the patient's familial history and previous issues that raised suspicions of child abuse; also social workers need to be involved as soon as possible. A skeletal radiological survey, including a low-dose radiation protocol for the limbs and chest, should be made to search for other potential fractures and/or periosteal reactions. With ambulatory children, a complete radiological survey should be done in cases where the mechanism of injury is unknown, inconsistent with accidental trauma, or there is a suspicion of child abuse.

Acknowledgements

Prof. Ceroni and Dr. De Marco designed the study and wrote and revised the initial manuscript until a final version was achieved. Dr. Valaikaite, Dr. Coulin, Dr VAzquez and Dr. Chargui analyzed and developed the data after extracting them from the relevant population in the 1990 to 2020 database. Dr Tabard-Fougère did the statistical analysis and created the graphics for the study, also contributing to the article's submitted version. Dr. Steiger and Dr. Dayer critically reviewed the manuscript and made important contributions to the final version. All the authors approved the final manuscript as submitted and agree to be held accountable for all aspects of the work.

Research involving human participants and/or animals: This research was carried out in compliance with the Declaration of Helsinki.

Institutional Review Board/Ethics Committee approval: The Children's Hospital Review Board approved the retrospective review of the electronic medical records of all children under 36 months old admitted to the Children's Hospital for femoral fractures between January 1990 and December 2020.

Conflicts of interest

There are no conflicts of interest.

References

1 Naranje SM, Erali RA, Warner WC, Sawyer JR, Kelly DM. Epidemiology of pediatric fractures presenting to Emergency Departments in the United States. *J Pediatr Orthop* 2016; **36**:e45–e48.
2 Valaikaite R, Tabard-Fougère A, Steiger C, Samara E, Dayer R, Ceroni D. A retrospective epidemiological study of paediatric femoral fractures. *Swiss Med Wkly* 2020; **150**:w20360.
3 Poolman RW, Kocher MS, Bhandari M. Pediatric femoral fractures: a systematic review of 2422 cases. *J Orthop Trauma* 2006; **20**:648–654.
4 Rewers A, Hedegaard H, Lezotte D, Meng K, Battan FK, Emery K, *et al*. Childhood femur fractures, associated injuries, and sociodemographic risk factors: a population-based study. *Pediatrics* 2005; **115**:e543–e552.
5 Hinton RY, Lincoln A, Crockett MM, Sponseller P, Smith G. Fractures of the femoral shaft in children Incidence, mechanisms, and sociodemographic risk factors. *J Bone Joint Surg Am* 1999; **81**:500–509.
6 Vetti N, Lindtjorn B, Engesaeter LB. [406 femoral fractures in children]. *Tidsskr Nor Laegeforen* 1998; **118**:3415–3418.
7 Brown D, Fisher E. Femur fractures in infants and young children. *Am J Public Health* 2004; **94**:558–560.
8 Patel DR, Luckstead EF. Sport participation, risk taking, and health risk behaviors. *Adolesc Med* 2000; **11**:141–155.
9 Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and mechanisms of femur fractures in children. *J Pediatr Orthop* 2006; **26**:561–566.
10 Petkovic L, Djan I, Gajdobranski D, Marić D, Petković M. [Pediatric femur fractures, epidemiology and treatment]. *Vojnosanit Pregl* 2011; **68**:9–14.
11 Thomas SA, Rosenfield NS, Leventhal JM, Markowitz RI. Long-bone fractures in young children: distinguishing accidental injuries from child abuse. *Pediatrics* 1991; **88**:471–476.
12 Hui C, Joughin E, Goldstein S, Cooper N, Harder J, Kiefer G, *et al*. Femoral fractures in children younger than three years: the role of nonaccidental injury. *J Pediatr Orthop* 2008; **28**:297–302.
13 Leventhal JM, Thomas SA, Rosenfield NS, Markowitz RI. Fractures in young children distinguishing child abuse from unintentional injuries. *Am J Dis Child* 1993; **147**:87–92.
14 Kempe CH, Silverman FN, Steele BF, Droegemueller W, Silver HK. The battered-child syndrome. *JAMA* 1962; **181**:17–24.
15 Kemp AM, Dunstan F, Harrison S, Morris S, Mann M, Rolfe K, *et al*. Patterns of skeletal fractures in child abuse: systematic review. *BMJ* 2008; **337**:a1518.
16 Ravichandiran N, Schuh S, Bejuk M, Al-Harthy N, Shouldice M, Au H, *et al*. Delayed identification of pediatric abuse-related fractures. *Pediatrics* 2010; **125**:60–66.
17 Thorpe EL, Zuckerbraun NS, Wolford JE, Berger RP. Missed opportunities to diagnose child physical abuse. *Pediatr Emerg Care* 2014; **30**:771–776.
18 Jones MA, Stratton G, Reilly T, Unnithan VB. A school-based survey of recurrent non-specific low-back pain prevalence and consequences in children. *Health Educ Res* 2004; **19**:284–289.
19 Wood JN, Fakeye O, Mondestin V, Rubin DM, Localio R, Feudtner C. Prevalence of abuse among young children with femur fractures: a systematic review. *BMC Pediatr* 2014; **14**:169.
20 Arkader A, Friedman JE, Warner WC, Wells L. Complete distal femoral metaphyseal fractures: a harbinger of child abuse before walking age. *J Pediatr Orthop* 2007; **27**:751–753.
21 Gross RH, Stranger M. Causative factors responsible for femoral fractures in infants and young children. *J Pediatr Orthop* 1983; **3**:341–343.
22 Greene WB. Displaced fractures of the femoral shaft in children Unique features and therapeutic options. *Clin Orthop Relat Res* 1998; **353**:86–96.
23 Lynch JM, Gardner MJ, Gains B. Hemodynamic significance of pediatric femur fractures. *J Pediatr Surg* 1996; **31**:1358–1361.
24 Nafei A, Teichert G, Mikkelsen SS, Hvid I. Femoral shaft fractures in children: an epidemiological study in a Danish urban population, 1977-86. *J Pediatr Orthop* 1992; **12**:499–502.

25 O'Connor-Read L, Teh J, Willett K. Radiographic evidence to help predict the mechanism of injury of pediatric spiral fractures in nonaccidental injury. *J Pediatr Orthop* 2007; **27**:754–757.
26 Rex C, Kay PR. Features of femoral fractures in nonaccidental injury. *J Pediatr Orthop* 2000; **20**:411–413.
27 Scherl SA, Miller L, Lively N, Russinoff S, Sullivan CM, Tornetta P. Accidental and nonaccidental femur fractures in children. *Clin Orthop Relat Res* 2000; **376**:96–105.
28 Flynn JM, Schwend RM. Management of pediatric femoral shaft fractures. *J Am Acad Orthop Surg* 2004; **12**:347–359.
29 Kocher MS, Kasser JR. Orthopaedic aspects of child abuse. *J Am Acad Orthop Surg* 2000; **8**:10–20.
30 McMahon P, Grossman W, Gaffney M, Stanitski C. Soft-tissue injury as an indication of child abuse. *J Bone Joint Surg Am* 1995; **77**:1179–1183.
31 Lane WG, Rubin DM, Monteith R, Christian CW. Racial differences in the evaluation of pediatric fractures for physical abuse. *JAMA* 2002; **288**:1603–1609.
32 McKinney A, Lane G, Hickey F. Detection of non-accidental injuries presenting at emergency departments. *Emerg Med J* 2004; **21**:562–564.
33 Sidebotham PD, Pearce AV. Audit of child protection procedures in accident and emergency department to identify children at risk of abuse. *BMJ* 1997; **315**:855–856.
34 Paul AR, Adamo MA. Non-accidental trauma in pediatric patients: a review of epidemiology, pathophysiology, diagnosis and treatment. *Transl Pediatr* 2014; **3**:195–207.
35 Leventhal JM, Martin KD, Asnes AG. Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database. *Pediatrics* 2008; **122**:599–604.
36 Steiner RD, Pepin M, Byers PH. Studies of collagen synthesis and structure in the differentiation of child abuse from osteogenesis imperfecta. *J Pediatr* 1996; **128**:542–547.
37 Singh Kocher M, Dichtel L. Osteogenesis imperfecta misdiagnosed as child abuse. *J Pediatri Orthop B* 2011; **20**:440–443.
38 Dent JA, Paterson CR. Fractures in early childhood: osteogenesis imperfecta or child abuse? *J Pediatr Orthop* 1991; **11**:184–186.
39 Gahagan S, Rimsza ME. Child abuse or osteogenesis imperfecta: how can we tell? *Pediatrics* 1991; **88**:987–992.
40 Wardinsky TD, Vizcarrondo FE, Cruz BK. The mistaken diagnosis of child abuse: a three-year USAF Medical Center analysis and literature review. *Mil Med* 1995; **160**:15–20.
41 Taitz J, Moran K, O'Meara M. Long bone fractures in children under 3 years of age: is abuse being missed in Emergency Department presentations? *J Paediatr Child Health* 2004; **40**:170–174.
42 Baldwin K, Pandya NK, Wolfgruber H, Drummond DS, Hosalkar HS. Femur fractures in the pediatric population: abuse or accidental trauma? *Clin Orthop Relat Res* 2011; **469**:798–804.
43 Nimkin K, Kleinman PK. Imaging of child abuse. *Radiol Clin North Am* 2001; **39**:843–864.
44 Carty H, Pierce A. Non-accidental injury: a retrospective analysis of a large cohort. *Eur Radiol* 2002; **12**:2919–2925.
45 Hoytema van Konijnenburg EM, Vrolijk-Bosschaart TF, Bakx R, Van Rijn RR. Paediatric femur fractures at the emergency department: accidental or not? *Br J Radiol* 2016; **89**:20150822.
46 Bishop N, Sprigg A, Dalton A. Unexplained fractures in infancy: looking for fragile bones. *Arch Dis Child* 2007; **92**:251–256.
47 Flaherty EG, Perez-Rossello JM, Levine MA, Hennrikus WL; American Academy of Pediatrics Committee on Child Abuse and Neglect. Evaluating children with fractures for child physical abuse. *Pediatrics* 2014; **133**:e477–e489.
48 Chauvin-Kimoff L, Allard-Dansereau C, Colbourne M. The medical assessment of fractures in suspected child maltreatment: infants and young children with skeletal injury. *Paediatr Child Health* 2018; **23**:156–160.
49 Anderson WA. The significance of femoral fractures in children. *Ann Emerg Med* 1982; **11**:174–177.
50 Jeerathanyasakun Y, Hiranyavanitch P, Bhummichitra D, Sukswai P, Kovitvanitcha D, Thumkunanon V. Causes of femoral shaft fracture in children under five years of age. *J Med Assoc Thai* 2003; **86**(Suppl 3):S661–S666.
51 Beals RK, Tufts E. Fractured femur in infancy: the role of child abuse. *J Pediatr Orthop* 1983; **3**:583–586.
52 Yonai Y, Ben Natan M, Finkel B, Klein A, Berkovich Y. Factors associated with referral of children with a femur fracture to a social worker by an orthopedist for suspected child abuse. *Pediatr Emerg Care* 2022; **38**:613–616.
53 Dalton HJ, Slovis T, Helfer RE, Comstock J, Scheurer S, Riolo S. Undiagnosed abuse in children younger than 3 years with femoral fracture. *Am J Dis Child* 1990; **144**:875–878.
54 Son-Hing JP, Deniz Olgun Z. The frequency of nonaccidental trauma in children under the age of 3 years with femur fractures: is there a better cutoff point for universal workups? *J Pediatr Orthop B* 2018; **27**:366–368.
55 Schwend RM, Werth C, Johnston A. Femur shaft fractures in toddlers and young children: rarely from child abuse. *J Pediatr Orthop* 2000; **20**:475–481.
56 Capra L, Levin AV, Howard A, Shouldice M. Characteristics of femur fractures in ambulatory young children. *Emerg Med J* 2013; **30**:749–753.
57 Coffey C, Haley K, Hayes J, Groner JI. The risk of child abuse in infants and toddlers with lower extremity injuries. *J Pediatr Surg* 2005; **40**:120–123.