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Pattern of Fractures in Non-Accidental Injuries in the Pediatric Population in Singapore

Sumanth Kumar Gera, MBBS, Rakesh Raveendran, MBBS, Arjandas Mahadev, MBBS

Department of Orthopaedics Surgery, KK Women's and Children's Hospital, Singapore

Background: Fractures as a result of non-accidental injuries (NAI) are not uncommon among children. The purpose of our study was to describe the incidence, demographic characteristics, and associated risk factors in patients with NAI in a multiethnic Asian cohort.

Methods: A retrospective record review of patients admitted to our hospital between September 2007 and 2009 with the diagnosis of NAI was conducted.

Results: A total of 978 children were reported with suspicion of NAI. Among them, 570 patients (58.28%) were diagnosed with NAI. Fractures were observed in 35 children (6.14%). NAI fractures were highest among female infants (73.3%). The biological father was the most common known perpetrator of NAI (n = 155, 29.0%). The most common perpetrator sadly remained unknown (n = 14, 40%). All NAI fractures were closed (n = 35, 6.14%), and the most commonly affected bone was the humeral shaft (n = 10, 28.57%) with an oblique configuration. Age < 1 year and parental divorce were significant risk factors associated with these fractures.

Conclusions: The skeletal injury pattern and risk factors highlighted in our study will help treating physicians identify patients susceptible to NAI, as many of these patients are young and vulnerable. Protective measures can be initiated early by recognizing these injuries and preventing further physical and psychological harm to the child.

Keywords: *Child abuse, Bone fractures, Risk factors, Etiology*

Child abuse is a global problem with multiple causes[1] and is responsible for 11%–55% of children with physical trauma.[2] Non-accidental injuries (NAI) not only indicate serious assault but also signify child abuse in infants, toddlers, and non-communicative children. Recognizing fracture characteristics caused by NAI are important, as it helps clinicians initiate the timely process of child protection, which prevents further harm to the child.[3]

Racial differences exist in the evaluation and reporting of pediatric fractures in cases of child abuse.[4] Studies in Western populations report higher rates of NAI fractures among non-Caucasian children compared to those in Caucasian children.[5] It is difficult to compare prevalence across ethnicities due to different cultural practices, laws, and reporting mechanisms.[2] Additionally, international definitions and thresholds for NAI vary greatly among communities and may account for these ethnic differences.[4]

Existing data indicate that approximately one-third of children with NAI eventually consult an orthopedic surgeon for suspected fractures.[6] The incidence and characteristics of fractures among Asian children with NAI provide valuable information not only for orthopedic surgeons but also for pediatricians and other healthcare providers for holistic management.[7]

The purpose of this study was to describe the incidence, clinical features, risk factors, and fracture patterns in children with NAI among a large multiethnic Asian cohort.

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Correspondence to: Sumanth Kumar Gera, MBBS
Department of Orthopaedics Surgery, KK Women's and Children's Hospital, Level 4, Children's Tower, Singapore 229899
Tel: +65-63942171, Fax: +65-62919232
E-mail: Sumanth.Kumar@kkh.com.sg

METHODS

A retrospective study of patients diagnosed with NAI was conducted at KK Women's and Children's Hospital from January 2007 to October 2009. Risk factors were assessed with respect to type of abuse, likely perpetrators, and social status. Radiological data such as X-rays, skeletal surveys, and bone scans were reviewed to determine fracture characteristics. The children were stratified by age into four groups: infants (< 1 year), toddlers (1 to < 2 years), school children (2 to 13 years), and teenagers (13 to < 18 years) to allow for a comparative analysis among the groups. This study adhered to the Declaration of Helsinki, and ethics approval was obtained from the KK Women's and Children's Hospital Institutional Review Board.

Statistical Analysis

Descriptive statistics and univariate analyses were generated using chi-square tests to compare discrete outcomes, and *t*-tests were used to compare means across conditions, except when skewed distributions warranted use of the Kruskal-Wallis equality-of-populations rank test. Mean with standard deviation and median with 25th and 75th percentiles are displayed where appropriate. Collinearity ($r > 0.8$), the number of missing values, and missing data patterns were checked. Binary logistic regression modeling was applied in multivariate analyses. The covariables adjusted in the multivariate analysis were those found to be univariately associated with outcome (absence and presence of fractures) and included major confounding factors, such as age, inpatient stay, perpetrators, need for an investigation, and parental divorce. A $p < 0.05$ was considered significant. All analyses were performed using STATA/SE ver. 11.1 (Stata Corp., College Station, TX, USA).

RESULTS

Study Population

A total of 978 children were suspected to have NAI. Among them, 570 (58.28%) were diagnosed with NAI. Fractures were observed in 35 children (6.14%), and 304 children (53.3%) had soft tissue injuries. Table 1 shows the demographic data of the 570 children with NAI stratified by the presence or absence of fracture. Of the 535 patients (94.0%) with non-fracture related injuries, the majority were of Chinese ethnicity (n = 286, 53.5%). A total of 270 children from the NAI cohort (48.4%) required hospital admission. Those with fractures had a longer duration inpatient stay (6.6 days vs. 3.4 days, $p < 0.001$). All 35 children with NAI fractures needed investigating, such as a skeletal survey and bone scan ($p < 0.001$). Boys were affected more frequently than girls in both the fracture and non-fracture groups. Although NAI was most commonly noted among school children (n = 359, 67.1%), fractures were noted in infants (n = 19, 54.3%) and toddlers (n = 9, 25.7%) ($p < 0.05$). Biological fathers were the main perpetrators (n = 155, 29%) in the NAI without fractures cohort. The perpetrators remained unknown (n = 14, 40%) in the largest subset of NAI with fractures group. Approximately 94.0% (n = 536) of abuse was physical and was responsible for 97.1% (n = 34) of the fractures compared to psychological or sexual abuse. The presence of fracture tended to have a higher chance of the abuse being reported (94.3% vs. 86%), though this was not significant.

A significantly higher rate of parental divorce (n = 166, 29.2%) was noted among the study patients in the NAI cohort (n = 570) than those without fracture. Seventy-seven children (13.5%) reported repeated abuse. About 5.6% of children (n = 32) had a pre-existing illness, behavioral problems, or attention deficit hyperactivity disorder (each, n = 8, 25%). Autism (n = 5, 15.6%), nephrotic syndrome (n = 2, 6.25%), and developmental delay (n = 2, 6.25%) were the other diseases noted in the study children.

Fracture Characteristics

Table 2 shows the characteristics of the 35 of 570 children diagnosed with a fracture secondary to NAI stratified by sex. The largest number of fractures was noted among female infants (73.3%). All fractures in the study population (n = 35, 6.14%) were closed, and multiple fractures were documented in three cases (8.5%). A total of 40% of the children (n = 228) needed X-rays, of which 106 (46.5%) underwent a skeletal survey to establish a diagnosis. X-rays were most commonly performed on the skull (n = 42, 18.4%) followed by the humerus (n = 19, 8.3%), facial skeleton (n = 13, 5.7%), and spine (n = 11, 4.8%). The humerus was the most common site of fracture and was noted in 10 children (28.57%). Seven children (20%) each had femoral shaft and skull (parietal bone) fractures, whereas four (11.4%) had distal radius fractures as a result of NAI. The majority of the fractures were oblique (n = 13, 37.14%), followed by transverse fracture (n = 10, 28.57%). Details of the NAI fractures are depicted in Figs. 1 and 2.

Boys sustaining fractures underwent more physical abuse, and they had more pre-existing illness. Parental divorce and repeat abuse were noted equally in male and female children. However, none of these variables showed statistical significance.

Multivariate logistic regression models were conducted for the risk factor assessment, as demonstrated in

Table 1. Characteristics of Children with Non-Accidental Injury Stratified by the Presence and Absence of Fractures

Characteristic	Without fracture (n = 535)	With fracture (n = 35)	*p*-value*
Age (yr)			< 0.001
Infants (< 1)	30 (5.6)	19 (54.3)	
Toddlers (1 to < 2)	60 (11.2)	9 (25.7)	
School children (2 to < 13)	359 (67.1)	7 (20.0)	
Teenagers (13 to < 18)	86 (16.1)	0	
Gender (male)	346 (64.7)	20 (57.1)	0.368
Race			0.11
Chinese	286 (53.5)	16 (45.7)	
Malay	137 (25.6)	15 (42.9)	
Indian	91 (17.0)	4 (11.4)	
Other	21 (3.9)	0	
No. of inpatient days	3.4 ± 4.7	6.6 ± 9.3	< 0.001
Perpetrator			< 0.001
Father	155 (29.0)	4 (11.4)	
Mother	98 (18.3)	3 (8.6)	
Other relatives/one parent and another non-parent	133 (24.9)	4 (11.4)	
Non-family members	96 (18.0)	10 (28.6)	
Unknown	53 (9.9)	14 (40.0)	
Type of abuse			0.72
Physical	502 (93.8)	34 (97.1)	
Physical + either psychological/neglect/sexual	32 (6.0)	1 (2.9)	
Sexual only	1 (0.2)	0	
Required investigation	180 (33.6)	35 (100)	< 0.001
Pre-existing illness			0.27
Unknown	358 (66.9)	19 (54.3)	
No	147 (27.5)	14 (40.0)	
Yes	30 (5.6)	2 (5.7)	
Parental divorce			0.007
Unknown	265 (49.5)	17 (48.6)	
No	108 (20.2)	14 (40.0)	
Yes	162 (30.2)	4 (11.4)	
Abuse reported	460 (86.0)	33 (94.3)	0.164
Medical social worker assessment			0.129
Unknown	171 (32.0)	17 (48.6)	
No	262 (49.0)	13 (37.1)	
Yes	102 (19.1)	5 (14.3)	
Resulted in death	3.0 (0.6)	0	

Values are presented as mean ± standard deviation or number (%).
*$p < 0.05$ for differences in characteristics by the presence and absence of fracture based on the chi-square or Student *t*-test.

Table 2. Characteristics of Patients with Non-Accidental Injuries and Fractures Stratified by Sex

Characteristic	Males (n = 20)	Females (n = 15)	*p*-value
Age (yr)			0.096
Infants (< 1)	8 (40.0)	11 (73.3)	
Toddlers (1 to < 2)	6 (30.0)	3 (20.0)	
School children (2 to < 13)	6 (30.0)	1 (6.7)	
Teenagers (13 to < 18)	0	0	
Race			0.048
Chinese	10 (50.0)	6 (40.0)	
Malay	10 (50.0)	5 (33.3)	
Indian	0	4 (26.7)	
Other	0	0	
No. of inpatient days	3 (0–4.5)	4 (0–12)	0.453
Perpetrators			0.156
Father	1 (5.0)	3 (20.0)	
Mother	2 (10.0)	1 (6.7)	
Other relatives/one parent and another non-parent	4 (20.0)	0	
Non-family members	7 (35.0)	3 (20.0)	
Unknown	6 (30.0)	8 (53.3)	
Type of abuse			0.241
Physical	20 (10.0)	14 (93.3)	
Physical + psychological	0	1 (6.7)	
Sexual only	0	0	
Multiple injuries	1 (5.0)	2 (13.3)	0.383
Soft tissue injury	19 (95.0)	15 (100)	0.380
Mechanism of injury			0.799
Not applicable	4 (20.0)	2 (13.3)	
Fall	14 (70.0)	12 (80.0)	
Direct impact	2 (10.0)	1 (6.7)	
Abuse reported	19 (95.0)	14 (93.3)	0.833
Pre-existing illness			0.227
Unknown	11 (55.0)	8 (53.3)	
No	9 (45.0)	5 (33.3)	
Yes	0	2 (13.3)	
Parental divorce	2 (10.0)	2 (13.3)	0.286
Medical social worker assessment			0.954
Unknown	10 (50.0)	7 (46.7)	
No	0	0	
Yes	3 (15.0)	2 (13.3)	
Feature			0.102
Buckle	0	1 (6.7)	
Comminuted	0	2 (13.3)	
Lateral condyle	1 (10.0)	0	
Oblique	8 (40.0)	5 (33.3)	
Transverse	7 (35.0)	3 (20.0)	
Site			0.264
Upper limb	11 (55.0)	7 (53.3)	
Lower limb	4 (30.0)	3 (20.0)	
Skull	2 (15.0)	4 (26.7)	

Mean with standard deviation, median with 25th and 75th percentiles, and numbers with percentages are presented where appropriate based on the chi-square/Student *t*-test/Kruskal-Wallis equality-of-populations rank test.

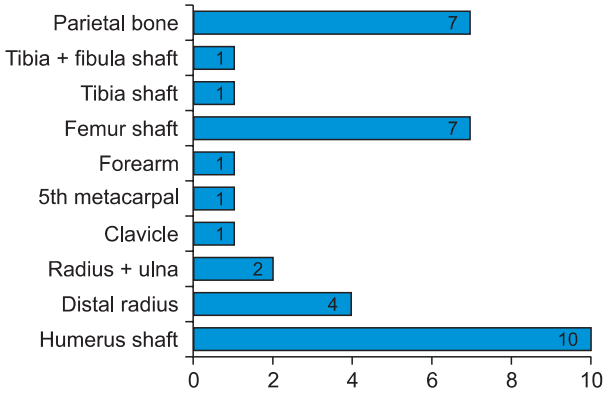

Fig. 1. Fracture sites secondary to non-accidental injuries noted among 35 children.

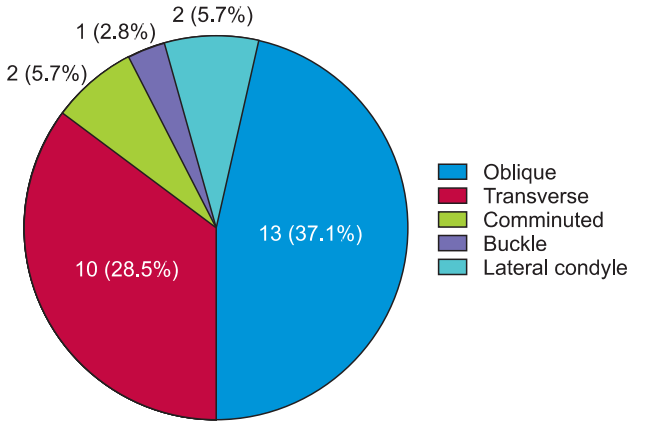

Fig. 2. Types of fractures secondary to non-accidental injuries noted among 35 children.

Table 3. Risk Factors for Fractures in Children with Non-Accidental Injuries

Variable	Model 1		Model 2	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age (yr)				
School children (2–13)	1		1	
Toddlers (1 to < 2)	0.237 (0.096–0.586)	0.002	0.073 (0.012–0.464)	0.005
Infants (< 1)	0.031 (0.012–0.079)	< 0.001	0.018 (0.003–0.106)	< 0.001
Sex				
Male	1		1	
Female	1.373 (0.687–2.744)	0.370	1.122 (0.292–4.316)	0.867
Abuse				
Physical	1		1	
Non-physical	2.235 (0.297–16.841)	0.435	3.320 (0.391–28.210)	0.272
Pre-existing illness				
No	1		1	
Yes	1.429 (0.308–6.616)	0.648	1.468 (0.070–30.595)	0.886
Parental divorce				
No	1		1	
Yes	0.190 (0.061–0.594)	0.004	0.194 (0.040–0.946)	0.042
Inpatient days	1.133 (1.055–1.216)	0.001	1.192 (1.071–1.326)	0.001
Perpetrator				
Father	0.92 (0.169–5.382)	0.931	0.90 (0.142–5.221)	0.933
Mother	0.74 (0.147–3.675)	0.709	0.71 (0.145–5.511)	0.699
Non-family members	1.77 (0.427–7.384)	0.430	1.67 (0.422–6.534)	0.398
Unknown	5.11 (1.206–21.604)	0.027	4.89 (1.212–19.854)	0.026
Hospital admission				
No	1		1	
Yes	1.453 (0.728–2.899)	0.289	1.124 (0.513–2.462)	0.771

Model 1: adjusted for age and sex, Model 2: adjusted for age, sex, inpatient stay duration, perpetrator, and parental divorce. OR: odds ratio, CI: confidence interval.

Table 3. After adjusting for variables that were univariately significant such as age, sex, inpatient stay duration, perpetrator, and parental divorce, infants (odds ratio [OR], 0.10; 95% confidence interval [CI], 0.03 to 0.11; $p < 0.001$) and higher rate of parental divorce (OR, 1.19; 95% CI, 0.04 to 0.94) were associated with an increased risk of sustaining a fracture. Additionally, fractures were associated with longer duration of hospitalization (OR, 1.19; 95% CI, 1.07 to 1.33). Moreover, there was a five-fold increase in the incidence of fracture when the perpetrator remained unknown (OR, 4.89; 95% CI, 1.21 to 19.8; $p = 0.026$).

DISCUSSION

The results show that NAI was common among male school children in our multiethnic Asian cohort. However, NAI fractures were more common in female infants (31.4%), which required them to be hospitalized for a longer duration for further investigation. Humerus fractures with an oblique configuration were the most common in this group. Age < 1 year, unknown perpetrator, and parental divorce were significantly associated with NAI fractures.

Our results further support existing data that fractures resulting from NAI are most commonly seen in infants and toddlers.[8-13] However, the presence of multiple fractures consistent with NAI, as observed in other studies, was not detected in our study.[10,11,14,15] Additionally, our results show that the humerus was the most common fracture site as opposed to other studies reporting classic metaphyseal lesions, rib,[3,15] and skull fractures[9,10] to have the highest risk of NAI. The parietal bone was the most commonly involved skull fracture in patients suffering NAI, which was found in other studies.[3,10,14] Among the humerus fractures associated with NAI, the oblique fracture configuration is the most common,[14-16] and was confirmed in our study. These data emphasize that NAI should to be excluded in infants and toddlers with a humerus fracture. Parental divorce and unknown perpetrators as factors associated with NAI fractures is new information.

The difference in results noted in our multiethnic Asian cohort pediatric population with those in Caucasian populations could be attributed to lifestyle variations. Definitions of NAI vary between Asian and Western communities and this could account for the findings in our study.[2] The fracture trend noted among the Asian cohort, which was quite different from that in Caucasians, can be used to predict the NAI pattern in our community.

Although our sample size was large, the prevalence of fractures was rather low compared to that in other studies.[2,3] This could either be due to underreporting or improved lifestyle and better childcare in this part of Asia. Our data provide new and interesting findings among our multiethnic cohort of Chinese, Indian, and Malay children, which will certainly help with the diagnosis and management of NAI. As our study was retrospective, a prospective study in an Asian pediatric population with NAI is needed. Our study was also limited by the lack of a control group with fractures due to causes other than NAI.

The results of our large retrospective study involving multiethnic Asian children with NAI show that age < 1 year and parental divorce were risk factors associated with fractures, whereas an unknown perpetrator was a related factor. These findings are not only helpful to identify doubtful cases of NAI fracture in our community but also will help with timely and multidisciplinary management of these children.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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