

Femoral Fractures in Children Under 2 years of Age in Western Australia: How Common is Inflicted Injury and What are the Risk Factors?

Thomas Volkman*

UCL (Great Ormond Street Hospital), UK

Submission: March 8, 2016; Published: April 04, 2016

*Corresponding author: Thomas Volkman, MBBS, UCL (Great Ormond Street Hospital), 4 Monet Court 2 Stubbs Drive Bermondsey SE163EG, UK, Tel: 07482080976; Email: tommy.volkman@gmail.com

Abstract

Background: Femoral fractures in infants under 2 years of age are a common presentation to Australian hospitals. Studies from North America and Europe have reported inflicted injury rates between 10-60% in these children 4,6,7, however there have been no similar studies in Australia. The aim of this study was to establish the prevalence of inflicted femoral fractures in the West Australian population and to determine the risk factors for inflicted injury.

Methods: A retrospective cohort study was performed on children under 2 years of age presenting to Princess Margaret Hospital in Western Australia with femoral fracture between 1998-2013. Cohorts of 228 patients with 235 femoral fractures were studied. The primary outcome variable was the percentage of cases determined to be inflicted injuries. Secondary outcomes were patient demographics, mechanism of injury and fracture type and location.

Results: The prevalence amongst the West Australian population is comparable to North America, with 10.9% of cases under 2 years of age and 16.4% in those under 1 year of age considered inflicted. This study found that age under 12 months ($p=0.009$), non-ambulatory status ($p\leq 0.01$), delayed presentation ($p\leq 0.01$), concurrent injuries ($p\leq 0.01$), bilateral fractures ($p\leq 0.001$) and unknown/inconsistent history of mechanism of injury ($p\leq 0.001$) are risk factors for inflicted femoral fracture in our population.

Conclusion: Children under 2 years of age presenting with femoral fracture have a significant risk of this injury being inflicted. Directed history taking and examination can be guided by established inflicted injury risk factors and careful assessment of the mechanism of injury.

Level of evidence: Retrospective cohort study, class IV

Keywords: Femur Fracture, Femoral Fracture, Child Abuse, NAI, Inflicted Injury, Australia

Background and Literature Review

Femoral fractures are a common orthopaedic cause for paediatric hospital admission in Australia [1]. Accidental causes of femoral fracture are common across the age spectrum but clinicians must be mindful of a possible abusive aetiology. The peak incidence of femoral fracture is reported to be in those aged 2-4 years [2], however many occur in those under 2 years old capable of limited ambulation. There is limited research on this topic originating from Australia. The reported incidence of inflicted femoral fracture in children < 2 years of age has been variable across many studies. Two large studies of children under 2 years of age revealed overall percentages of inflicted femoral fracture of 14% [3] and 15% [4] respectively. A recent review article ($n=24$ studies) of 10,717 children under 60 months of age showed abuse rates ranging from 16.7% to 35.2% in children under 12 months with femoral fracture [5]. None of the included

studies originated in Australia and only one was from the Asia-Pacific region, a small ($n=39$) study from Thailand [6]. There are two Australian studies of note in the literature [1,7] which examine non-accidental fractures in infants. One study examined the aetiology of long bone fractures and referral rates to child protective services. This study had three patients under the age of 3 years with femoral fractures [1]. The second study examined all fracture presentations in infants under 12 months but did not assess for inflicted injury, 19% of these fractures were femoral [7]. There has been limited research on femoral fracture type with regards to likelihood of abuse. Spiral fractures have been reported as the most common fracture type in many studies [8-11]. Historically, spiral fractures were considered commonly to be abusive [12,13] however other studies have reported fracture type not a statistically significant risk factor for inflicted injury [14]. Studies disagree, one recent study has shown transverse

fractures are associated with abuse [13]. Research with regards to risk factors for abusive femoral fracture has been more limited. In a recent study review article [5] (n= 24 studies) only 3 studies reported on historical characteristics, 4 on concurrent injuries, 3 on fracture pattern and 2 examined ambulatory status. Studies have demonstrated that risk factors for abuse include young age, concurrent injury, suspicious history, ambulatory status, unwitnessed fall and delayed presentation [9,15,16].

Relevance of the Project Outline

As outlined above femoral fractures occur commonly in young infants, many of whom are not fully ambulant. Many of these children present to Emergency Departments and a preliminary determination of cause must be made and a decision whether to refer to a child protection authority. This can prove challenging and all too frequently historical information regarding the mechanism is lacking. The process of determination of an inflicted injury is often foreign to those working in a primary care environment and the statistical likelihood of the injury being inflicted is unknown. As outlined above the consequence of nonreferral can be serious. Our Child Protection Unit identified some such cases through a safety net meeting structure. A series of birth related injuries and low energy injuries in non-ambulant infants led our team to discuss what evidence existed and whether the risk factors outlined in our Emergency Department proforma were evidenced based in our context. This research project therefore will establish an Australian prevalence rate for inflicted femoral fracture which can then be compared against existing prevalence rates quoted in the literature review.

Aim and Hypothesis

The aim of this study was to establish the prevalence of inflicted femoral fractures in the West Australian population and to determine the risk factors for inflicted injury in a West Australian context. The hypothesis is that the prevalence of inflicted femoral fracture in Western Australia is comparable to that reported in large meta-analysis studies from Europe and North America. Secondly that established risk factors for inflicted injury (young age, concurrent injury, suspicious history, ambulatory status, unwitnessed fall and delayed presentation) are also statistically significant risk factors in the West Australian context.

Methods

A retrospective chart review was carried out for all children 2 years old or younger with a diagnosis of femoral fracture who presented to Princess Margaret Hospital (Perth, Western Australia) from 1998 to 2013. Princess Margaret Hospital is a 220 bed paediatric tertiary care centre with Level I trauma status with a large geographical referral area across the whole state of Western Australia. Our institution treats all paediatric femoral fractures in the State which includes patients from urban, rural and remote locations. This study made use of two

pre-existing databases for case selection. The trauma database uses diagnostic coding that is generated from patient notes after a patient's admission or discharge at Princess Margaret Hospital. Multiple injuries will generate multiple codes which are able to be searched individually in an electronic database. The radiology database operates in a similar manner with fracture diagnoses searchable in an electronic database. Additional search parameters, including age and other demographics can be used to limit the case list to a set of inclusion criteria. All patients under 2 years old at the time of presentation with femoral fracture treated at PMH across the 15 year period were identified from our hospital Trauma and Radiology databases and included in the study. This included patients where femoral fracture was an additional or incidental finding and differed from the initial presentation for primary care. Those patients older than two years were excluded from the study. Any patients where the written medical record was unavailable, illegible or inadequate were excluded from the study, this included 28 cases. Those without a written and signed radiological report or viewable digital radiological film were excluded from the study, this was a total of 19 patients. The two databases were cross referenced to search for duplicate cases or those where femoral fracture was not coded in the trauma database but the radiological diagnosis was. The written medical record was recalled for all patients on the study list and the study variable information was extracted by reviewing the discharge summaries and emergency/admission clerking of all patients. The written medical record included printed radiological reports for all included patients and those after 2003 also had their electronic plain x-rays available for viewing on PACS. Patient demographics were exported from the databases into an excel spreadsheet from which the manually recorded secondary variable data could be extracted. All children were treated with immobilization therapy either as an inpatient or outpatient by tertiary public paediatric tertiary orthopaedic surgical services. The primary outcome variable in this study was the percentage of children younger than 2 years presenting with femoral fractures considered to be inflicted. For the purposes of this study, the opinion of the hospital Child Protection Unit on the likely cause of the injury was used. The CPU is a multidisciplinary specialist unit based within Princess Margaret Hospital consisting of a group of child abuse physicians and child protection social workers. Cases of suspected abuse are referred to government agencies (Department for Child Protection and Family Support and the WA Police) for further investigation and action. Further determinations by these government agencies is not available in the medical record and occurs outside of the scope of this study.

Each injury was classified according to the CPU opinion as inflicted injury (definite or suspicious), indeterminate (unable to determine whether inflicted or accidental) or accidental. Case determinations were made either from CPU records if referred or from the retrospective use of the study protocol. Those with

inadequate documentation of the study factors in the clinical record were determined to be of indeterminate (unknown) cause. The majority of indeterminate and abuse determinations were from a comprehensive CPU assessment contemporaneously following referral (77 referred cases). Secondary outcome variables included patient demographics (age, sex), injury characteristics (mechanism of injury, concurrent injuries, location, fracture type), features of history (presenting complaint, presentation delay, documented inconsistent history), individual patient factors (ambulatory status of child) and the results of investigative work up undertaken (radiography, skeletal survey, bone scan). Fracture location and type were defined as per radiology reports that were available for all reviewed patients. All imaging was reported in house by experienced tertiary paediatric radiologists. Fracture location was described using commonly used terms in radiology reporting to describe three distinct areas of the femur (and their subtypes). Ambulatory status was defined based on developmental history in the medical record and from the description of the child's activity during mechanism of injury. Children were described as ambulant when walking without support, Semi-ambulant when pulling to stand/cruising and non-ambulant not able to stand from sitting position. Across the study period changes in medical documentation occurred affecting the amount of written information available for study. The most important change was the introduction of an injury proforma in the PMH Emergency Department in 2005. This is a proforma used in all children presenting under the age of 2 with injury and is reviewed and countersigned by the most senior doctor in the department prior to the child's discharge. The proformas provide prompts to collect relevant information on demographics, injury characteristics and protective social factors and prompts to consider abuse with a list of concerning features.

Description of Statistical Analysis

We calculated a power analysis for multiple logistic regression as described by Hsieh et al 25. This power analysis assumes a background abuse rate of 20%. This calculation showed a required sample size of 211 patients, which correlates with true sample size. Data analysis was undertaken with the use of statistical computer software (SPSS™) by the primary author. Data in this study is presented as percentages, and comparison analysis was performed using Fisher exact test (P < 0.05) to identify significant risk factors for abuse.

Results

The study population of 256 children younger than 2 years who presented with femoral fractures and met the inclusion criteria were identified and categorized. Complete records were available for 228 of the cases and these cases were included for analysis, 77 were referred to CPU (Table 1).

Table 1: Demographics.

Demographics			
	Inflicted (Suspicious or Definite)	Indeterminate	Accidental
Overall (n=228)	25	34	169
Age <12 mo (n=122)	20 (80%)	15	87
Age >12 mo (n=106)	5 (20%)	17	82
Mean Age, days old	180	410	384
Sex			
Male	18 (15.7%)	26	96
Female	7 (9%)	10	71
Sex of the child was not a statistically significant predictor of injury. (p=0.195)			

Prevalence inflicted femoral fracture: The overall percentage of inflicted injury (possible or definite) in this study was 10.9% (25/228 cases). The percentage of inflicted injury in children younger than 6 months was 25.8% (15/58), under 1 year was 16.4% (20/122) and over 1 year was 4.7% (5/106) (p=0.009). The percentage of possible inflicted injury (defined as suspicious and indeterminate cases combined) was 25.8% (59/228 cases). The percentage of accidental cases was 74.2% (169/228 cases).

Referral rate: The referral rate to CPU amongst reviewed cases was 33.7% (77 cases). Of those referred 34 were ruled accidental, 25 inflicted and 18 indeterminate. There were 16 additional cases which were classified as potential missed referrals which were assessed and discharged from the emergency department or orthopedic services without CPU involvement. These cases were not reviewed contemporaneously by the CPU but in retrospective chart analysis has suspicious features on history or injury morphology.

Fracture type and location: Fracture type and location was described for all 235 fractures in the study. This included 6 recorded bilateral fractures and one suspicious case of two fractures in the same limb. Spiral fracture was the most common fracture type (40.9%), followed by transverse (34.9%), incomplete (15.7%) and oblique (8.5%). Incomplete fractures were almost always seen distally (94%) and were most commonly buckle fractures (45.9%), Salter Harris II (18.9%), greenstick (16.2%) and 7 cases (16.2%) of classic metaphyseal bucket handle fracture were seen. 85% of bilateral fractures were documented as inflicted (5 out of 6 cases) (Table 2). There was no statistical significance between spiral fractures in the inflicted and accidental groups (p=0.146). Transverse fractures were more common in the accidental group (p=0.041).

However incomplete fractures were associated with suspicious inflicted injuries ($p=0.045$) as were oblique fractures ($p=0.031$). Our study demonstrates that bucket handle fractures remain a concerning radiological finding for abuse ($p\leq 0.01$), 70% of cases of bucket handle fracture had additional fractures found on skeletal survey. There was no statistical significance between fracture location and inflicted injury ($p\geq 0.1$).

Table 2: Fracture type and location (n=235).

Fracture Type and Location (n=235)				
Fracture Location	Inflicted (n=31) ₁	Indeterminate (n=35) ₂	Accidental (n=169)	Significant Dif. ₃
Proximal	6 (19.3%)	4 (11.1%)	26 (15.5%)	$p\geq 0.1$
Midshaft	15 (48.3%)	22 (61.1%)	97 (57.1%)	$p\geq 0.1$
Distal	10 (32.2%)	9 (25%)	46 (27.3%)	$p\geq 0.1$
Fracture Type				
Spiral	11 (35.5%)	17 (47.2%)	68 (40.5%)	$p=0.146$
Oblique	6 (19.3%)	3 (8.4%)	11 (6.5%)	$p=0.031$
Transverse	6 (19.3%)	9 (25%)	67 (39.9%)	$p=0.041$
Incomplete	8 (25.9%)	7 (19.4%)	22 (13.1%)	$p=0.045$

₁ Inclusive of one limb with multiple fractures and 5 bilateral fractures

₂ Inclusive of one bilateral fracture

₃ Comparison between inflicted and accidental groups

Mechanism of injury (MOI): The documented MOI are described in Table 3 below for the 187 of 228 cases where it was documented.

Table 3: MOI Documentation.

	Inflicted (n=25)	Indeterminate (n=34)	Accidental (n=169)
No Explanation	13 (52%)	23 (67.6%)	5 (2.9%)
Low Energy Mechanism (171/228) 93%			
Falls	9 (36%)	8 (23.5%)	117 (69.1%)
- Care giver fell carrying child	3 (12%)	3 (8.8%)	23 (13.6%)
- Mechanical fall from standing	-	2 (5.9%)	18 (10.6%)
- Fall from height <1m	6 (24%)	2 (5.9%)	32 (18.9%)
- Fall from height >1m	-	-	44 (26%)
Direct trauma to leg (e.g. sibling fell on leg, object fell on leg)	-	1 (2.9%)	28 (16.5%)
High Energy Mechanism (16/228) 7%			
Unrestrained occupant in car	-	-	5 (2.9%)
Restrained occupant in car	-	-	2 (1.2%)
Pedestrian vs. car	-	-	3 (1.8%)
Birth related injury	-	2 (5.9%)	4 (2.3%)
Involved in DV	1 (4%)	-	-
Thrown and caught	1 (4%)	-	4 (2.3%)
Manipulated limb during benign activity	1 (4%)	1 (2.9%)	4 (2.3%)
Iatrogenic orthopedic	-	-	1 (0.6%)

Ambulatory status: 43% of the cohort was ambulatory, 34% were non ambulatory, 22% were semi ambulatory, with a significant amount of non-ambulatory children sustaining fractures. Amongst inflicted injury group 64% (16) were non ambulant compared to 28.4% (48) in the accidental group ($p\leq 0.001$). Comparing children semi ambulant in the inflicted injury group 16% (4) and accident group 27% (47) there was no statistically significant difference ($p= 0.733$).

Presenting complaint and external signs of injury: Presenting complaints were recorded on presentation to the primary physician. Interestingly obvious external signs of injury were recorded in 92 (40.3%) of the presentations at triage (eg. significant bruising, deformed or swollen). A significant proportion presented with a functional change (28.5%), such as limited weight bearing. Most importantly 19.7% of cases presented with a “non specific” symptomatic presentation, and required clinical suspicion of a bony injury. Many of these cases of crying or unsettled children had represented to health care facilities on multiple occasions. There was no statistical difference between those with or without multiple presentations and the accidental and inflicted groups.

External Concurrent injury: External evidence of concurrent injuries were found in 14.9% (34 cases) at the time of emergency presentation and were more common in those with inflicted injuries 40% (10 cases) compared to 12.4% (21 cases)

in the accidental group ($p \leq 0.001$). Those involved in MVA's had a high rate of sustaining external concurrent injuries 80% (8/10 cases).

Birth related injury: There were six cases of birth related injury which resulted in femur fracture. Two of these cases were delayed diagnoses on day 5 and 6 of life respectively after the patient returned home. These were referred for assessment by visiting midwife staff. Both of these cases presented due to concerns regarding the movement of the baby's legs but with no obvious swelling or deformity. Both of these cases were found to have distal incomplete buckle fractures. Both of these cases were ruled to be of indeterminate cause due to the difficulty of establishing a timeline for injury due to their discharge home. One case was a term caesarian section in extended breach position with moderate difficulty disengaging the legs at caesarian, with the legs requiring flexion at the popliteal fossa. Interestingly this movement was photographed by the father at the birth. The other case was a term spontaneous vaginal delivery with no complications noted. Four of the other cases of birth related femur fracture were discovered on 1-3 whilst inpatient under maternity care. All of these had obviously swollen limbs and mechanisms of birth suggestive of the potential for trauma. Three had spiral mid shaft femur fractures and one a transverse femur fracture. One of these cases had additional unexpected fractures and later tested positive for Osteogenesis Imperfecta type I.

Inconsistent history and delay in presentation: Inconsistent histories were documented in 14 patients. These comprised of 2 inconsistent time lines, 3 differing accounts from separately interviewed parents and 2 inconsistent accounts of whether incident witnessed. Of those 14 inconsistent histories, 8 were found to be likely inflicted and 4 were found to be possibly inflicted. The reported mechanisms of injury were unknown, unwitnessed or historically inconsistent in 72% (18 cases) suspicious for abuse, this compared to 7.1% (12 cases) in the accidental group ($p \leq 0.01$). There was a delay in presentation documented in 60% (15 cases) in the inflicted group and 11% (19 cases) in the accidental group ($p \leq 0.01$).

Utility of investigations: Skeletal surveys were used frequently (92%) in those with inflicted injuries, with 56% showing radiographic signs of additional bony injury. There were 10 bone scans undertaken amongst the inflicted group, 6 of these bone scans showed additional injuries not reported on the skeletal survey (1 skull fracture, 3 additional sets of rib fractures, 1 growth plate injury and 1 vertebral fracture). This is interesting as bone scans are not traditionally predictive for skull fractures. Importantly 2 bone scans did not show injuries seen on the skeletal surveys, although these injuries were older injuries with advanced stages of healing.

Discussion

The aim of this study was to establish a prevalence rate of inflicted injuries in femoral fractures amongst a pediatric

population under 2 years of age in West Australia. The tertiary referral nature of Princess Margaret Hospital and its wide catchment area makes this population reflective of a varied Australian Population. The rate of inflicted injury was 10.9% which is comparable to a Canadian study by Hui et al. [9], however substantially lower than other reported studies [4,6,12,16-18]. This may be reflective of the different referral systems, thresholds for referral and diagnosis and also classification of cases. Our study shows that the defining inflicted injury purely on the basis of referral to Child protective services by the primary physician or specialist child protection physicians may inflate the reported incidence. Inflicted injury is more prevalent in under 1 year olds (16.4%) and non ambulant children. This prevalence rate is similar to those seen in large database studies in the USA or Canada [3,4] however there is variability in practice within different health systems in the West Australian public health system. Previous studies have established a variety of risk factors [8,12,16,18,19]. This study confirmed that age younger than 12 months ($p=0.009$), non-ambulatory status ($p \leq 0.01$), delayed presentation ($p \leq 0.01$), concurrent injuries ($p \leq 0.01$), bilateral fractures ($p \leq 0.001$) and unknown/inconsistent history of mechanism of injury ($p \leq 0.001$) are risk factors for inflicted femoral fracture in our population. These factors should be the focus of training of primary care physicians. This may avoid the discharge of cases that should have been referred and investigated (7% or 16 cases in our study which were on retrospect considered suspicious). The implementation of an injury proforma in the Emergency Department of our institution showed an increased rate of referral (29% pre introduction and 35% post) as well as decrease in the proportion of referred cases found to be accidental (45% to 29%).

There has been a long standing notion that midshaft spiral fractures were characteristic of a violent twisting force and often represented inflicted injury [13,20]. Our study showed that spiral midshaft fracture was the most common presenting fracture in both the accidental and inflicted group, comparable to other studies [8,9,21]. The location of fracture did not have a statistical relation to inflicted injury. The classic radiographic findings in inflicted injury are metaphyseal lesions which is caused by a to-and-fro shaking mechanism [1,8,21-23]. In conflict to another study [9] we confirmed that the classic metaphyseal corner or bucket-handle fractures are the single most diagnostic fracture type for inflicted Injury. Unwitnessed or unexplained mechanisms of injury were common in the inflicted group reflecting the inability or unwillingness to provide history in such cases. High energy injuries (including birth injuries and MVA) were uncommon and all were classed in the accidental group. Injuries involving motor vehicles frequently had concurrent injury findings (80%) and fractures described as displaced (80%). Our patterns of mechanisms of injury were comparable to a previous study of this age group [24].

Clinicians must have a good understanding of child development, forces involved in common mechanisms of injury

and patterns of parental presentation to carry out an accurate evaluation, take an accurate history and refer appropriately. Many children presented with non-specific presentations and re-presented to multiple health care professionals. Re-examination and listening to parental concern is vital. 30% to 50% of children returning to an abusive may be re-injured and 5% to 10% will die [18]. Studies in the field of Child Protection are met with significant limitations. For this reason it is important to make comment of the diagnostic difficulty when studying inflicted injury. There is no tool or diagnostic code for identifying victims of abuse with universal reliability. Demographic and social factors can influence the determination of abuse, and can therefore create the inherent issue of circuitous logic with diagnosis. In Princess Margaret Hospital a multidisciplinary team of child abuse physicians and child welfare workers make the determination of suspicion of child abuse which is then corroborated with the evidence gained by police. This is a determination of probability of abuse and not a diagnosis of it. There are inherent limitations associated with the retrospective nature of this study, in particular a lack of a control group. Case identification can also be challenging. The availability and accuracy of documentation in the medical record can have effect case identification. . In total 28 records were not available for inclusion in this study and poor documentation could affect the interpretation of risk factors due to positive reporting bias. Case selection with the use of cross-referenced trauma and radiological databases relies on accurate coding of injuries. The presence of only 7 Classic femoral metaphyseal lesions across the study period was a smaller number than expected and there is a potential for poorly coded injuries in multi-trauma to not have been identified by our database. The electronic database system is a relatively recent addition to our hospital and this limited case numbers and while this studies sample size was sufficient to produce some statistically significant results, a larger study would have more statistical power with regards to small incidence sub analysis.

The strength of this study is that it provides a large cohort population of children under 2 years old with femoral fracture for analysis to provide an accurate Australian prevalence rate. Princess Margaret Hospital is the trauma referral centre for the entire state of Western Australia reflecting a variable population. Our institution has a robust trauma and radiological database which has been operating across the entirety of the study period. These databases were cross referenced to produce the study list, minimising the risk of duplicate or missed cases. Limiting the population to children under 2 has allowed sub-analysis of younger age groups with good sample size and minimizing the amount of high energy trauma seen in older children that is included in other study samples. The stability of medical staffing and diagnostic process in the Child Protection Unit across the time period of the study aids standardization of diagnosis and therefore results.

Conclusion

Children under 2 years presenting with femoral fracture have a significant risk of this injury being inflicted, although this may be less than previously reported. A West Australian prevalence rate of suspected inflicted injury is 10.9% of femur fractures under 2 and 16.4% of femur fractures under 1. A high but targeted index of suspicion should exist in children of this age group presenting with femoral fracture. A significant amount of indeterminate cases and the amount of those incorrectly determined accidental can be minimized with careful history taking and medical documentation and utilization of a multidisciplinary expert Child Protection unit. Careful history taking and examination can be guided by established risk factors for inflicted injury and meticulous recreation of the mechanism of injury and comparing this to the sustained bony injury. Introduction of a prescribed proforma can standardise this process and may increase quantity and quality of referrals to child protective agencies. Such a proforma should record information on evidence based risk factors. This study suggests that age under 12 months, non-ambulatory status, delayed presentation, concurrent injuries and unknown/inconsistent history of mechanism of injury should be the basis for such a proforma. Interestingly these features are all included in the existing emergency department proforma used at Princess Margaret Hospital. Unlike previously reported in some studies, fracture location and type seems to play a minimal role other than classic metaphyseal bucket handle fractures which have a strong association. Young infants commonly present with low energy mechanisms of injury. Birth fractures are a particularly difficult group to assess the mechanism of injury. Diligence in recreating the mechanism of injury and postulating sustained forces must be compared with the fracture pattern seen in all cases.

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