Pediatric femur neck fractures: a retrospective analysis of 39 hips

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Abstract

Purpose The aim of this retrospective study was to analyze the radiological and clinical results of pediatric femur neck fractures.

Methods This study included 39 children (mean age 11.1, range 4 to 16 years) who had a femur neck fracture and had at least one year of complete follow-up. The most common etiological factor was traffic accident and the most common associated skeletal injury was pelvis fracture.

Results According to Delbet's classification system, there were no type I (transepiphyseal) fractures and 21 type II (transcervical), 14 type III (cervicotrochanteric), and four type IV (intertrochanteric) fractures. The mean follow-up was 3.4 (1–9.5) years. A satisfactory outcome according to Ratliff's radiological and clinical criteria was obtained in 28 (72%) hips. Avascular necrosis (AVN) of the femoral head was seen in 11 (28%) hips and the rate of satisfactory outcome was significantly higher in hips without AVN than in hips with AVN ($P < 0.001$). Transcervical fractures had the worst outcome ($P = 0.014$) and the highest rate of AVN ($P = 0.077$) when compared with cervicotrochanteric and intertrochanteric fractures. No significant correlation was found between both the outcome and development of AVN and age, gender, laterality, amount of

fracture displacement, treatment time, and the type of reduction (open/closed) ($P > 0.05$).

Conclusions It has been concluded that the development of AVN primarily influences the outcome in pediatric femur neck fractures and that fracture type is essentially correlated with the development of AVN and outcome.

Keywords Femur neck fracture · Children · Hip · Avascular necrosis of the femoral head

Introduction

Femur neck fractures constitutes less than 1% of the entire population of pediatric fractures. Although rarely seen, there is a considerable risk of complications such as avascular necrosis (AVN) of the femoral head and neck, coxa vara, non-union, delayed union, premature physeal arrest, and infection in pediatric femur neck fractures. The most common and serious complication of pediatric femur neck fractures is known to be AVN, which can lead to a further degenerative joint disease. It has been stated that several factors may contribute to the development complications and affect the outcome [1, 2].

We initially hypothesized that there should be some factors determining the clinical and radiographic outcomes in pediatric femur neck fractures. The aim of this retrospective study was to evaluate the clinical and radiological outcomes of the pediatric patients with femur neck fractures and to assess the effects of several preoperative, intraoperative, and postoperative factors, such as age, gender, laterality, fracture type, amount of fracture displacement, treatment time, open reduction allowing concurrent drainage of the intracapsular hematoma, and AVN on the clinical and radiological outcomes.

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Patients and methods

Forty-four hips of 44 consecutive patients (25 males and 19 females) whose ages ranged from 4 to 16 years were treated due to femur neck fracture at our department between January 1998 and September 2007. Among these, 39 patients had at least one year of complete clinical and radiological follow-up and were included the study. The mean age of the included patients was 11.1 ± 3.4 (4–16) years and 22 were male and 17 were female. Among the five excluded patients, two died at the early postoperative period due to multisystem injury and three were lost to follow-up within the first 3 months, postoperatively.

The most common etiological factor for the femur neck fracture was traffic accident (motor vehicle or pedestrian), followed by fall from height (Table 1). At least one associated skeletal injury was present in 15 patients (38%) and the most common was pelvis fracture, followed by distal radius fracture (Table 2). The affected side was the right side in 15 patients and the left side in 24 patients.

It was our crucial aim to make the definitive treatment of all children with femur neck fractures within the first 12 h following admission to our hospital, but a considerable number of patients was referred from other district hospitals. Therefore, the time from the initial trauma to definitive treatment could exceed 24 h in the patients with delayed referral from other hospitals. Obtaining an immediate radiographic anatomic reduction in two planes and secure maintenance of this reduction were the main points of our management protocol. Closed reduction under fluoroscopic control was initially attempted in all hips, under general anesthesia. Closed anatomic reduction failed in five hips and an open reduction which simultaneously obtained the drainage of the intracapsular hematoma was performed in these hips. Following the reduction procedure, the fracture was stabilized by internal fixation in 37 hips and by hip spica cast in two hips (both extra-articular intertrochanteric fractures) under fluoroscopic control. The configuration of the internal fixation was chosen by the attending surgeon and three 6.5-mm cancellous screws were used in 24 patients, two 6.5-mm cancellous screws in

Table 2 List of the associated skeletal injuries seen in 15 patients

Pelvis fracture	7
Distal radius fracture	4
Acetabulum fracture	2
Clavícula fracture	2
Zygomatic fracture	1
Multiple rib fractures	1
Vertebra fracture	1
Scapula fracture	1
Proximal humerus fracture	1
Humerus shaft fracture	1
Scaphoid fracture	1
Femur distal fracture	1
Calcaneus fracture	1

three patients, three or four Kirschner wires in five patients, a combination of one 6.5-mm cancellous screw and two Kirschner wires in four patients, and a dynamic hip screw (DHS) plate in one patient. Needle aspiration of the intracapsular fracture hematoma was not performed in none of the intracapsular fractures in which a successful closed reduction could be obtained. A postoperative hip spica was not applied in all but three surgically treated patients who were between 4 and 6 years of age. Partial and full weight bearings were allowed at postoperative 6 and 12 weeks, respectively.

Femur neck fractures were initially classified according to the four-part classification system described by Delbet and popularized by Colonna [3]. ‘Type I’ was an intra-articular transepiphyseal fracture, ‘type II’ an intra-articular transcervical fracture, ‘type III’ an intra-articular cervicotrochanteric fracture, and ‘type IV’ an extracapsular intertrochanteric fracture. The fractures were also classified as ‘non-displaced’ and ‘displaced’ (from minimum to complete). The time period from initial trauma to final treatment was divided into two groups, ‘ ≤ 24 h’ and ‘ >24 h.’

The clinical and radiological outcomes of the hips at the latest follow-up were assessed using Ratliff’s classification [4] (Table 3). Good outcome was rated as a ‘satisfactory outcome’ and fair and poor outcomes were rated as an ‘unsatisfactory outcome.’ AVN of the proximal fragment was classified according to the Ratliff’s classification system [4], as this system has become the gold standard in pediatric femur neck fractures for many years and also seems to not accurately coincide with the classification systems used in developmental hip dysplasia. Type I has a diffuse increased density of the proximal fragment and is accompanied by a total collapse of the epiphysis. Type II has less significant and local changes and is accompanied by minimal collapse of the epiphysis. Type III has changes which are confined to the femoral neck, excluding the epiphysis.

Table 1 The etiological factors for femoral neck fractures in the present series

Etiology	Number of patients	%
Traffic accident	17	43
Fall from height	13	33
Simple fall	5	13
Fall from bicycle	3	8
Fracture during physiotherapy	1	3
Total	39	100

Table 3 The clinical and radiographic assessment system [4]

Good: clinically, no or negligible pain, full or minimal restrictive hip movement, and normal activity or the avoidance of games. Normal or some deformity of the femoral neck in the radiograph

Fair: clinically, occasional pain, hip movement restriction less than 50%, and normal activity or the avoidance of games. Severe deformity of the femoral neck, mild avascular necrosis in the radiograph

Poor: clinically, disabling pain, hip movement restriction more than 50%, and restricted activity. Severe AVN, degenerative arthritis, arthrodesis in the radiograph

The Chi-square and Fisher's exact tests were used for the comparison of the ratios in different groups and a *P*-value of less than 0.05 was considered to be significant.

Results

There were no type I fractures and 21 type II (54%), 14 type III (26%), and four type IV (10%) fractures. There were 31 displaced (80%) and eight non-displaced (20%) fractures. The mean time from initial trauma to definitive treatment was 36.7 ± 56.6 (4–240) h.

The mean follow-up was 3.4 ± 2.5 (1–9.5) years. The clinical and radiographic outcomes at the latest follow-up was considered to be good in 28 (72%), fair in four (10%), and poor in seven (18%) hips. AVN was seen in 11 (28%) hips and eight were type I, one was type II, and two were type III. A satisfactory outcome was observed in 27 of 28 patients (96%) without AVN and one of 11 patients (9%) with AVN during the follow-up period ($P < 0.001$). The only satisfactory outcome following AVN due to femur neck fracture was observed in an 8-year-old girl having a type III AVN (Fig. 1). The only unsatisfactory outcome without AVN was seen in a 14-year-old girl who had a deep wound infection, which would lead to a further hip arthrodesis.

There was a significant correlation between the type of fracture and the outcome; type II fracture had the worst

outcome ($P = 0.014$) (Table 4). Also, type II fracture had the highest occurrence rate of AVN ($P = 0.077$) (Table 5). There was no statistically significant correlation between the outcome and occurrence of further AVN with age, gender, laterality, amount of displacement, treatment time, or type of reduction ($P > 0.05$) (Tables 4 and 5).

Superficial wound infection was seen in one patient and completely resolved following parenteral antibiotic therapy. A persistent deep wound infection was seen in one 14-year-old patient who had L1 compression, non-displaced pelvis, displaced acetabulum anterior wall, and transcervical femur neck fractures. Open reduction and plate fixation of the acetabulum fracture and closed reduction and screw fixation of the femur neck fracture were performed during the same session. However, an early *Staphylococcus aureus* infection occurred in the acetabulum fracture wound, and this infection further involved the hip joint. A hip arthrodesis was performed due to joint destruction, movement restriction, and pain one year postoperatively. Early hip arthrodesis one year postoperatively was performed in a patient who had a displaced transcervical fracture at 16 years of age and had early type I AVN, leading severe pain and movement restriction. Cementless total hip arthroplasty nine years postoperatively was performed in one patient who had a displaced transcervical fracture at 13 years of age and who had type I AVN, leading to severe hip pain during the follow-up period (Fig. 2).

Fig. 1 Anteroposterior hip radiographs of an 8-year-old girl who had a left non-displaced cervicotrochanteric femur neck fracture due to a traffic accident. **a** Preoperative. **b** Postoperative. **c** At 6 years postoperatively. Although she had a type III AVN, the outcome was considered as 'good'

Table 4 Correlation between several factors and clinical and radiographic outcomes

	Satisfactory outcome	Unsatisfactory outcome	<i>P</i> -value
Age			
≤10 years	14	3	0.288
>10 years	14	8	
Gender			
Male	18	4	0.158
Female	10	7	
Laterality			
Right	12	3	0.477
Left	16	8	
Fracture type			
Transcervical (II)	11	10	0.014
Cervicotrochanteric (III)	13	1	
Intertrochanteric (IV)	4	0	
Fracture displacement			
Non-displaced	8	0	0.078
Displaced	20	11	
Treatment time			
≤24 h	19	7	1.0
>24 h	9	4	
Type of reduction			
Open	3	2	0.609
Closed	25	9	
Total	28	11	

Discussion

Femur neck fracture is a rare injury in children. The child/adult ratio in femur neck fractures has been reported to be 1/130 [4]. There are several factors differentiating the pediatric femur neck fractures from the adult fractures, and the two most important ones should be mentioned. First, the main etiologic factor is the high-energy trauma, as proximal femoral bone excluding physis is very strong in children and requires a significant force to break it, whereas minor trauma is the main etiological factor in adults [2]. This is the main reason why pediatric femur neck fractures are rare injuries. The findings of the present study supported this knowledge, as nearly 85% of the fractures were due to a major trauma. Secondly, the blood supply of the femoral head is different. The adult hip has intraosseous blood vessels that supply the femoral head. However, the blood vessels cannot cross the open physis and, therefore, the blood supply to the femoral head is critical and can be easily disrupted by a hip fracture in children [2]. So, AVN is the most common and damaging complication in pediatric femur neck fractures. The most extensive microscopic necrotic changes are visible within

Table 5 Correlation between several factors and the development of AVN

	AVN+	AVN–	<i>P</i> -value
Age			
≤10 years	4	13	0.725
>10 years	7	15	
Gender			
Male	4	18	0.158
Female	7	10	
Laterality			
Right	3	12	0.477
Left	8	16	
Fracture type			
Transcervical (II)	9	12	0.077
Cervicotrochanteric (III)	2	12	
Intertrochanteric (IV)	0	4	
Fracture displacement			
Non-displaced	1	7	0.400
Displaced	10	21	
Treatment time			
≤24 h	7	19	1.0
>24 h	4	9	
Type of reduction			
Open	2	3	0.609
Closed	9	25	
Total	11	28	

the first year after injury and, therefore, the risk of femoral head collapse increases in this period [5]. It is classical knowledge that the treatment of AVN is unsuccessful and does not alter the natural history in pediatric femur neck fractures [1]. However, it was recently suggested that intertrochanteric osteotomy might have a biological role in helping restore viability to a non-collapsed femoral head with AVN seen after femur neck fractures [6]. Ratliff [4] mentioned that the presence of AVN usually affected the prognosis adversely. The results of the present study have revealed that the development of AVN significantly influences the clinical and radiological outcomes, as 91% of the patients with an unsatisfactory outcome have AVN, whereas 96% of the patients with a satisfactory outcome do not have any type of AVN. However, Leung and Lam [7] noted that the clinical and radiological outcomes of the same hips could change significantly within a few years in pediatric femur neck fractures.

It was previously stated that a better outcome in pediatric femur neck fractures was correlated with the absence of AVN during follow-up, patient's age (<8 years), type of fracture (cervicotrochanteric, intertrochanteric fractures, and fractures without any displacement), a proper initial

Fig. 2 Anteroposterior hip radiographs of a 13-year-old girl who had a right displaced transcervical femur neck fracture due to a traffic accident. **a** Preoperative. **b** Postoperative. **c** At nine years postoperatively. She had a type I AVN and the outcome was considered as ‘poor’

management procedure (early, anatomical, stable internal fixation), decompression of the intra-articular fracture hematoma, and application of postoperative immobilization [1, 4, 7–19]. The present study has a satisfactory outcome rate of 72%. Transcervical fractures have a lower rate of satisfactory outcome (52%) when compared with cervicotrochanteric (91%) and intertrochanteric (100%) fractures. Besides, the non-displaced fracture group has a somewhat better outcome rate.

The reported incidence of AVN due to femur neck fractures in children varies from 0 to 92% [20]. Several factors may correlate with the development of AVN; however, in a recent meta-analysis, it was reported that fracture type and the patient's age were the two most significant variables. The risk of AVN was found to be 15, six, and four times higher in transepiphyseal, transcervical, and cervicotrochanteric fractures, respectively, than in intertrochanteric fractures. Besides, older children were considered as having a higher risk of the development of AVN and this risk was found to increase 1.14 times for each year of increasing age [20]. The present study has an AVN rate of 28%. The rate of AVN is higher in transcervical fractures (43%) than in cervicotrochanteric (14%) and intertrochanteric (0%) fractures. Besides, the non-displaced fracture group has only one AVN that has resolved without any sequel. Ratliff [4] formerly stated that severe AVN (type I) always had fair or poor outcome, while type II and III might AVN have good outcomes. The results of the present study seem to support this observation, as most of the AVNs were type I and all had unsatisfactory outcomes. Among three type II and type III AVNs, only one had a satisfactory outcome.

The reported rate of iatrogenic infection is 1% in pediatric femur neck fractures [1]. When compared with the classical knowledge, the rate of infection seems to be higher in the present series (5%). One case had a superficial wound infection which could be resolved by antibiotic therapy, and one had an infectious hip arthritis which

originated from a neighborhood wound infection and developed further significant joint damage.

The present series includes 39 cases with a minimum follow-up period of one year. Femur neck fractures are rare injuries and, when compared with the previous published case series in the literature, the number of cases in the present study is considerably high, but the mean follow-up is not so long, and this may be considered as a shortcoming of the study. However, it was previously stated that radiographic diagnosis of AVN could be made within one year after injury [4]. So, the minimum follow-up of the cases of the present study seems to be enough for making comments on AVN. The present study includes no trans-epiphyseal fractures and only four intertrochanteric fractures, and this may be considered as another shortcoming of the study, as drawing stronger conclusions about these two types of fractures is not possible. However, both types are not as frequent as transcervical and cervicotrochanteric fractures, which constitute nearly 65–85% of the entire population of pediatric femur neck fractures [1]. Besides, the number of cases in the ‘undisplaced fracture’ and ‘open reduction’ groups can be considered as small in order to draw stronger conclusions about these variables.

We believe that obtaining a radiographically proven intraoperative anatomic reduction by closed or open methods and maintaining this reduction by internal fixation or by hip spica cast are the two important key points in the successful management of pediatric femur neck fractures. In our opinion, internal fixation with three 6.5-mm cancellous screws seems to be the most convenient method in children, but this configuration needs be modified in younger children by using two screws or a combination of screws and Kirschner wires or multiple Kirschner wires alone in order to avoid a full filling of the diameter of the femoral neck, which may disrupt the femoral head vascular supply. Besides, it may be better to apply a postoperative hip spica cast in children younger than 7 years of age. Based on our results, we can suggest that the existence or absence of

AVN is the main determinant of the clinical and radiographic outcomes in pediatric femur neck fractures and the development of this complication should not be underestimated. AVN cannot be completely prevented or effectively treated, but its rate of occurrence may be decreased by performing an appropriate management, as stated above. This series has not included transepiphyseal fractures; however, with the numbers available in the present study, AVN is commonly seen in transcervical femur neck fractures and this leads a higher rate of unsatisfactory outcome in such fractures. Although not statistically proven, displacement of the fracture may also have some adverse effects on the outcome. So, in the future, the parents' of children with such kind of femur neck fractures should initially be warned about the possible development of significant complications and an unsatisfactory outcome. Patient's age and gender, laterality, the time from the initial trauma to the definitive treatment, and performing a closed reduction without draining the intracapsular hematoma or an open reduction leading to the drainage of the intracapsular hematoma seems to have no significant effects on the development of AVN and the outcome.

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Conflict of interest statement None.

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