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Management of pediatric femoral neck fractures: A prospective study

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Abstract
Introduction: Pediatric femoral neck fracture is an uncommon injury with a high complication rate, regardless of the appropriate diagnosis and management. The bony anatomy and blood supply of the proximal femur in a skeletally immature patient differs from those in adult patients. Pediatric femoral neck fractures are categorized using the Delbert classification system. This classification guides management and aids clinicians in determining the risk of avascular osteonecrosis.
Aim and Objective: Aim of this study was to develop a guideline for the management of femoral neck fracture in children rapidly and accurately with fewer complications based on the best available scientific evidence.
Materials and Methods: Thirteen children with fractures of femoral neck were included in this study. The enrolled patients presented in the emergency department of Bone and Joint Hospital, an associated hospital of Govt. Medical College Srinagar from June 2019- May 2020.
Results: Using the clinical and radiological assessment by the Ratliff system, 9 (69.23%) patients had a good clinical outcome and 4 (30.77%) had fair outcomes. We did not encounter any patients with a poor outcome in our series. Of the 4 patients with fair outcomes, 3 had AVN and coxa Vara and 1 had a deep-seated infection of the hip leading to arthritic changes of the hip.
Conclusion: In the management of pediatric femoral neck fractures, the early closed reduction and fixation may be effective to improve results and prevent long-term complications.

Keywords: Children, hip fractures, femoral neck fractures, management

Introduction

Pediatric femoral neck fractures constitute a rare entity accounting for less than 1% of the entire population of pediatric fractures [1-8]. Most of these fractures are a result of high-energy trauma [9], but pathologic hip fractures also occur, usually from low-energy trauma. Although rarely seen, there is a considerable risk of complications such as avascular necrosis (AVN) of the femoral head, non-union, delayed union, premature physical closure, and coxa Vara [10]. The most common and serious complication of these fractures is avascular necrosis (AVN) of the femoral head, 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 [11, 12].
As such, a thorough understanding of the fracture, including the anatomy is crucial for planning proper treatment. Classification is based on the location of the fracture line, being the most used for this type of fracture the Delbet system (1907), later popularized by Colonna (1929) [13], which divides fractures in types I, II, III and IV, which may assist in treatment decision-making, in addition to being a predictor of risk for complications.
The subject is important due to the fact that these are serious fractures, both in terms of trauma mechanism involved and frequent complications and disabling sequelae. Therefore, it is an orthopedic emergency that requires a fast and accurate strategy in order to reduce complications to a minimum, and thus the costs associated with treatment and rehabilitation of these patients.
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. The mode of treatment in all cases was internal fixation (either open or closed).

Materials and Methods

Thirteen children with femoral neck fractures who were presented in the emergency department of Bone and Joint Hospital, an associated hospital of Govt. Medical College Srinagar from June 2019- May 2020 were included in this study. The mean age of the included patients was 10.90 ± 3.4 (range 5–16) years and 8 were male and 5 were female. The most common etiological factor for the fracture was traffic accident (motor vehicle or pedestrian), followed by fall from height (Table 1). Initially femur neck fractures were classified according to the four-part classification system described by Delbet and popularized by Colonna [13] (Table 2). The fractures were also classified as un-displaced' and displaced (from minimum to complete). There were 10 (76.92%) displaced and 3 (23.08%) un-displaced fractures.

Table 1: Demography of patients (n=13)

Parameters		No. of patients	Percentage
Gender	Male	8	61.54
	Female	5	38.46
Age group	<10 Years	4	30.77
	>10Years	9	69.23
Mechanism of trauma	Road accidents	8	61.54
	Fall	5	38.46
Laterality	Right	6	46.15
	Left	7	53.85
	Bilateral	0	0
Type according to Delbert classification system	I	2	15.38
	II	5	38.46
	III	4	30.77
	IV	2	15.39

Table 2: Delbert four-part classification system

Fracture type	Parameters
I	An intra-articular trans epiphyseal fracture
II	An intra-articular trans cervical fracture
III	An intra-articular cervicotrochanteric fracture
IV	An extra-capsular intertrochanteric fracture.

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 were referred from other district hospitals. Therefore, the time from the initial trauma to definitive treatment could exceed 24 hours 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. All patients were operated on an urgent basis. The treatment modality used was open reduction/closed reduction and internal fixation depending upon the patient profile and fracture pattern. At the follow-up of 6 and 12 weeks post-operatively partial and full weight bearings were allowed respectively. The final clinical and radiologic assessment was made at the follow-up of one year using the Ratliff method [8] (Table 3). The radiographs were assessed for joint congruity, arthritic changes, neck-shaft angle, and AVN (AVN if present, was classified according to the Ratliff classification system for AVN (Table 4). A good outcome was rated as satisfactory, fair and poor outcomes.

Table 3: Clinical and radiologic assessment using the Ratliff system.

Parameters	Indications
Good	No or negligible pain, full or minimal restriction of hip movements, normal activity, or the avoidance of games. Normal or some deformity of the femoral neck in the radiograph
Fair	Occasional pain, less than 50% restriction of hip movement, normal activity, or avoidance of games. Severe deformity of the femoral neck, mild avascular necrosis in radiographs
Poor	Disabling pain, more than 50% restriction of hip movement, and restricted activity. Severe AVN, degenerative arthritis, arthrodesis in the radiograph

Table 4: Ratliff classification of avascular necrosis

Type	Parameters
Type 1	Diffused increased density of the proximal fragment, accompanied by the total collapse of the epiphysis
Type 2	Segmental involvement of the femoral head, minimal collapse of the epiphysis
Type 3	Metaphyseal AVN, changes confined to the femoral neck, excluding the epiphysis

Results

The mean age of the included patients was 10.90 ± 3.4 (range 5–16) years and 8 (61.54%) were males and 5 (38.46%) were females. The most common etiological factor for the fracture was traffic accident 8 (61.54), followed by fall 5 (38.46%). There were 10 (76.92%) displaced and 3 (23.08%) un-displaced fractures. According to Delbert classification system there were 2 (15.38%) of type I, 5 (38.46%) type II, 4 (30.77) type III and 2 (15.39%) type IV.

The mean time from initial trauma to definitive treatment was 18.60 (range 6-168) hours. The mean follow-up was 21.40 (range 12-47) months. Using the clinical and radiological assessment by the Ratliff system, 9 (69.23%) patients had a good clinical outcome and 4 (30.77%) had fair outcomes. We did not encounter any patients with a poor outcome in our series. Of the 4 patients with fair outcomes, 3 had AVN and coxa Vara and 1 had a deep-seated infection of the hip leading to arthritic changes of the hip.

A satisfactory outcome was observed in 12 (92.31%) patients. In the study, one patient with a displaced, type III fracture had AVN and coxa Vara. The patient had type III Ratliff AVN with

a neck-shaft angle of 120 degrees. We found no statistically significant association between the age of the patients, sex, fracture type and initial displacement, and outcomes in terms of the Ratliff system. However, we found a statistically significant association between the type of reduction and the outcome. Superficial wound infection was seen in one patient and completely resolved following parenteral antibiotic therapy.

Discussion

Pediatric femoral neck fractures (PFNFs) are extremely rare. The relatively dense and hard architecture of the proximal femur in children compared to adults is an important factor for this rarity [16]. Moreover, due to this structural difference, high-energy injury mechanisms such as traffic accidents and falls from height often play a role in etiology [15, 16]. In line with the literature, the fractures of most of our patients (66.7%) were caused by high-energy injury mechanisms, and all of these patients fell from a height.

PFNFs are classified by the Delbett system, an anatomical classification popularized by Colonna [17] in 1929. According to this classification, type II (intraarticular transcervical) fractures are the most common type followed by type III (cervicotrochanteric), IV (intertrochanteric), and I (trans epiphyseal) fractures. The results of our study are also consistent with this information. (type II: 50%, type III: 41.7%, and type IV: 8.3%). We did not encounter an extremely rare trans epiphyseal type I fracture during this period.

Surgical fixation is the main treatment approach recommended for pediatric femoral neck fractures due to the high risk of loss of reduction in patients treated conservatively. Surgical treatment is important for the maintenance of anatomical reduction [6]. The issue of performing anatomical reduction with open or closed techniques is debatable. In the literature, especially in studies suggesting an open reduction of displaced Delbert type II and III fractures, it is argued that capsular decompression can be performed, a safer anatomic reduction can be achieved, thus avascular necrosis can be prevented [6, 18, 19]. (However, these studies consist of a retrospective case series of small groups. In addition, the fact that all patients undergoing decompression in these studies consisted of patients who were already treated within 24 hours, may introduce bias. It appears that the preference of treatment for PFNFs other than type I trans epiphyseal fractures is often closed reduction (66% for type II, 54% for type III, and 72% for type IV PFNFs) [20]. Delayed surgery may increase the requirement for open reduction due to the fact that PFNFs can be a part of a polytrauma or due to late admissions of patients.

There is no evidence in the literature showing the effect of the diameter, and number of screws on postoperative complications. Age, gender, skeletal maturity, and type of fracture are factors to be considered when deciding on this matter. We believe that two or three cancellous screws of 4-6.5 mm to be placed in accordance with the principles of basic fracture fixation provide sufficient fixation. Also, the issue of diapophyseal screw placement is not clear. Patterson et al. recommended refraining from diapophyseal screw methods in patients aged less than 10 years [21]. However, stable fixation with trans-physical screws should not be compromised in unstable, small medial fragmented and vertical type fractures in older children.

Regardless of the type of reduction and fixation, it is obvious that the most important controllable factor in the development of avascular necrosis is time to surgery [22-25]. Patients receiving delayed treatment (> 24 hours) have been found to develop avascular necrosis 4.2 times more frequently than patients treated definitively in the first 24 hours [20]. Also timing of surgery may affect time to union. Delayed union can be expected in patients operated more than 24 hours after admission [26]. We think that providing definitive fixation in the first 6 hours in all of our patients-except for two children with polytrauma- was the key point to prevent avascular necrosis.

Serious complications may develop after PFNF, with rates varying between 20% and 60% in different series [10, 27]. Avascular necrosis is the most common complication among these, and its incidence has been reported in the literature in a wide range from 0% to 92% [28]. Age, time to surgery, initial displacement, and fracture type are factors that can affect the development of avascular necrosis [10, 16, 25, 29], The incidence of avascular necrosis increases with age which is thought to be associated with the lower femoral head revascularization capacity in older children. Due to similar reasons, an increased incidence of avascular necrosis has been observed in intracapsular and more proximal fractures. Compared with type IV fractures, avascular necrosis has been reported to develop 15, 6, and 4 times more frequently in type I, type II, and type III fractures, respectively [28, 30]. Fracture displacement is thought to be a critical predisposing factor for the development of avascular necrosis through damage on vessels supplying the femoral head. Also, high intracapsular pressure in nondisplaced fractures may even be effective in avascular necrosis by indirectly impairing the blood supply to the femoral head. Therefore, a few studies have supported routine drainage of intracapsular hematoma by needle aspiration or open capsulotomy technique for intracapsular fractures [18, 19, 23]. In contrast, Inan et al. reported in their series of 39 cases that routine open reduction and hematoma drainage had no significant effect on preventing postoperative complications [3]. Open capsulotomy may be a radical intervention to reduce intracapsular pressure only, as long as closed reduction can be achieved in PFNFs. Furthermore, we doubt the persistence of low intracapsular pressure to be achieved by needle aspiration without capsulotomy. Certainly, surgeons must avoid attempting forceful and repeated closed reduction maneuvers and they should be able to decide timing for open reduction.

There is very limited data in the literature regarding the time interval between injury and avascular necrosis. Although it has been mentioned that radiological findings can usually be observed within the first year after trauma [8], Pavone et al. reported patients with avascular necrosis developed at 14 and 16 months postoperatively [30]. From this point of view, the minimum follow-up period of 12 months in our series can be considered as a limitation of the study. Long-term follow-up of children is important in terms of potential late complications.

Other serious complications include nonunion, premature closure of the physical plate, and coxa Vara. Fracture fixation techniques with low maintainability such as immobilization with a plaster cast, Kirschner wires or fixation with threaded pins are considered to be important risk factors for nonunion [31, 32].

In different studies, the incidence of coxa Vara after PFNFs has been reported in the range of 7-32% [33]. The incidence of coxa Vara in our cases (16.7%) is consistent with the literature. It has been stated that there are factors such as nonoperative treatment, insufficient fixation, and early closure of the physical plate in the etiology of coxa Vara. Internal fixation with screws has been recommended to avoid this complication. It is also important to avoid early weight-bearing protocols, especially in adolescents with vertically extending fractures [34]. Fixation by screws exceeding the growth plate can prevent the development of coxa Vara in vertical Delbert type II PFNFs with small medial

fragments [35]. In our patients, we avoided early weight-bearing protocols to prevent loss of reduction. It was a notable finding that both of our patients who developed coxa Vara were older than other patients, had Delbert type II fractures with vertical extension and early closure of the physical plate in their follow-ups. However, we don't have enough statistical data to clearly state which of these factors played the key role in coxa Vara etiology. Coxa Vara is a significant complication in terms of unsatisfactory results. 1 patient with coxa Vara had already low Ratliff scores. Our study has several limitations. Small sample size and lack of control group limited definitive statistical measurements. Other limitations of the study are mainly related to be retrospective and to the relatively shorter minimum follow-up period.

Multicenter prospective studies with a large number of patients are needed to determine the optimal surgical technique that will affect long-term results.

Conclusion

Pediatric femoral neck fractures are extremely rare injuries that can lead to serious complications. When we evaluate our experience with the current literature, we are of the opinion that the early closed reduction and fixation of these fractures may be effective to improve results and prevent long-term complications.

Conflict of Interest

Not available

Financial Support

Not available

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