Avascular Necrosis due to Delbet Type I Femoral Neck Fracture in an Adolescent: A Case Report and Literature Review

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Keywords
Femoral neck fracture · Pediatrics · Open reduction · Internal fracture fixation

Abstract
Among all pediatric fractures, femoral neck fracture is an infrequent injury that occurs due to high-energy trauma. The high risk of complications, such as avascular necrosis (AVN), which is the most common and serious complication, coxa vara, nonunion, premature physeal closure and infections, turns this fracture into an orthopedic emergency and increases the need for early treatment and intervention. Among the classifications of femoral neck fractures, which are known as the Delbet classification, type 1 is the least common but with the highest risk of AVN. Therapeutic action for these patients is close or open reduction with internal fixation under general anesthesia, which according to the evidences, open reduction is a more successful method. Due to the high probability of complications and the urgent need for treatment of femoral neck fracture, early intervention and timely treatment should be performed. Here, we report a 14-year-old boy who was brought to the emergency department with a Delbet type 1B fracture of the left femoral neck with detached epiphyseal portion of the femoral head due to a car accident. After one failed attempt to closed reduction, open reduction and internal fixation with a posterolateral (Kocher) approach was performed under general anesthesia. The reduction was maintained with guide pins and fixed with cannulated screws. After 8 months of follow-up, AVN was noticed.
Introduction

About 1% of all fractures in pediatrics are related to femoral neck fractures [1]. This injury is a rare condition that often occurs following high-energy traumas such as vehicles accident, fall from height, and severe injuries. Other causes of femoral neck fracture such as pathological fractures due to low-energy trauma and stress fractures following jumping or running are very rare [2, 3]. Unlike children, femoral neck fractures because of low-energy trauma are common in adults [4]. Femoral neck fractures in children are divided into four types according to Delbet classification. Type I is transepiphyseal that is divided into two types; A (undisplaced) and B (displaced). Type II is transcervical; type III is basicervical; and type IV is intertrochanteric. Type II, III, IV, and finally I are more common, respectively. Due to the importance of this classification on the prognosis of the lesion, it is important to pay attention to it [4]. Beside the main injury, what worries orthopedic specialists about femoral neck fractures are the complications of this lesion. Avascular necrosis (AVN), premature physeal closure, coxa vara, nonunion, and infection are some consequences that should be considered. Among all the complications, AVN is more common, which can be justified by the blood supply of the femoral head. AVN is more common in type I of Delbet classification and almost not seen in type IV [4].

Femoral neck fracture is an orthopedic emergency that can be treated with closed or open reduction and internal fixation (ORIF) surgery [5]. Here, we report a 14-year-old boy who brought to the emergency department after a car accident. With the help of clinical signs and imaging, Delbet type 1B fracture of the left femoral neck was diagnosed. ORIF were done by two cannulated screws after open reduction.

Case Presentation

A 14-year-old boy was brought to the emergency department by EMS after a car accident in a stable cardiorespiratory state. On presentation, he was oriented with a GCS of 15. On physical examination, external rotation deformity in the left lower limb with severe pain and loss of motion of the hip joint were noted. Neurovascular and other examinations were normal. Any specific past medical history was not mentioned.

Pelvic X-ray and CT scan presented Delbet type 1B fracture of the left femoral neck (shown in Fig. 1a, b). Further follow-up procedures including focused assessment with sonography in trauma and CT scan of the head, thorax, and abdomen were performed. The focused assessment with sonography in trauma scan did not show any free intraperitoneal fluid. Other imaging was normal too. After ensuring the absence of life-threatening symptoms in terms of brain and vital organ damage, the patient was transferred to the operating room approximately 5 h from injury.

Fig. 1. a Pelvic X-ray and pelvic CT scan (b) revealed Delbet type 1B fracture of the left femoral neck. c Fixation with two 6.5-mm cannulated screws.
After a failed closed reduction, the patient was placed in a lateral decubitus position for ORIF with a posterolateral approach. Gluteal muscle was dissected and sciatic nerve explored. For better exposure to the hip joint, short external rotators were incised. The epiphyseal portion of the femoral head was completely detached and was located in the soft tissue. It was first placed in the receiver with normal saline so that its viability would not be compromised. After irrigation and debridement of the hip joint, femoral epiphysis was placed in an anatomic position. Provisional fixation was checked by the C-arm, and definite fixation with two 6.5-mm cannulated screws was done (shown in Fig. 1c). Finally, the avulsed posterior part of the labrum and capsule was fixed with two suture anchors, muscles and fascia lata sutured, and suction drain inserted. After the surgery, intravenous cefazolin was prescribed for 2 days. Anticoagulants were not prescribed due to the absence of underlying disorders of hypercoagulability. About 48 h after the surgery, the suction drain was removed, and due to the stability of the fixation, gentle range of motion of the hip and touched down weight bearing for 6 weeks by two crutches were initiated. Full weight bearing was not allowed up to 3 months.

Radiographic union of the femoral neck and epiphysis was presented after 3 months, and he just had complaint of slight limping. Due to the possibility of AVN occurrence, the patient was being observed. Five months later, the patient has complained of pain and limited of movements in his injured limb. The radiograph revealed AVN (shown in Fig. 2). Due to the young age of the patient and not closing the growth plates, surgery was not recommended, so conservative treatment was initiated. The patient is currently being observed.

Discussion

Femoral neck fractures in children are among the rare injuries that mostly occur due to high-energy traumas. According to Delbet classification, there are 4 types of this femoral neck fractures [4], where among them, type I is the rarest with the highest risk of AVN. Type I occurs when the epiphysis separates from the metaphysis, and it is divided into type 1A, in which the femoral head is not dislocated, and type 1B, in which the femoral head is dislocated. In comparisons between these two types, the risk of AVN is higher in type 1B. Type II which...
is a transcervical form has the highest prevalence in children [6]. In the presented case, we encountered a case of type 1B femoral neck fracture and its management.

Management of femoral neck fractures in children is an orthopedic emergency, and treatment should be done as soon as possible to avoid the risk of complications. The most commonly used method in the treatment of femoral head fractures in children is closed or open reduction with internal fixation. Although initial procedure in the treatment of femoral neck fractures is closed reduction, it has been suggested that it is better to use open reduction in type 1B of femoral neck fractures [6, 7]. In this case, we used both techniques, but closed reduction was not successful.

Fixation in children over 4 years is done with smooth pins, cannulated screws, or the combination of the screw and pin [6]. We used two cannulated screws.

The most important complication with the highest prevalence in femoral neck fractures in children is AVN. Factors influencing the incidence of AVN include fracture type, quality, timing of surgery, and age (4). Based on Moon ES and Mehlman CT [8], the AVN rate is 38% in Delbet type I, 28% in Delbet type II, 18% in Delbet type III, and 5% in Delbet type IV.

Another common complication is coxa vara that occurs due to reduced neck-shaft angle. Coxa vara occurs when the neck-shaft angle is less than 120°. It can reduce the strength of the hip abductor and shorten the extremities [6].

Nonunion is one of the complications associated with the type of treatment. Failure to fixation or reduction properly can cause nonunion complication. Nonunion with casting is more common [6].

Premature physeal closure can be the consequence of internal fixation devices. Because of the impact of capital femoral physis on growth of lower extremities, it is important to pay attention to it [6]. Infections after surgery are least common among complications [4].

Ratliff et al. [9], described different patterns of AVN after femoral neck fracture in pediatrics for the first time in 1962. Based on his review on 29 cases, the highest incidence was of AVN involving the total head (type I, 15 cases), partial necrosis of the epiphysis (type II, 7 cases), and necrosis between the epiphyseal plate and the fracture line (type III, 7 cases). According to this classification, our case classified as Type I and also based on the Ratliff system of clinical and radiographic assessment, is in good stage.

In the literature, we found some articles which reported the same situation, and all of them reported AVN as the result of these types of fractures. We have briefly described them in Table 1.

After Ratliff, in 1969, Stougård [10] reported post-traumatic AVN of the femoral head in two children. Both of them showed evidence of AVN, 5 months and 6 weeks after the accident.

In 2002, Mohammad et al. [11] reported transepiphyseal fracture of the femoral neck with dislocation of the femoral head and fracture of the posterior column of the acetabulum in an adolescent, in which after 24 months follow-up, evidence of mild AVN was noted. In 2006, Akahane et al. [7] reported a Delbet type I fracture of proximal femur combined with a fracture of the mid-shaft of ipsilateral femur in a child. AVN of capital femoral epiphysis was seen by a bone scan 6 months after surgery.

Abbas et al. [12] reported post-traumatic AVN of the femoral head in three teenagers, in 2008. The evidence of AVN was noted 10, 5, and 6 months postoperatively. All cases were treated by a modified transtrochanteric rotational osteotomy.

Venkatadass et al. [13] reported bilateral femoral neck fractures which classified as Delbet type II following seizure in an adolescent. In the first episode of seizure, he experienced left femoral neck fracture which had developed segmental AVN with collapse of the head after 6 months. In the second episode of seizure, right femoral neck fracture occurred which showed evidence of AVN 6 months later.

Kim et al. [14] reported a Delbet type II femoral neck fracture in a child, in 2018. Around 8 months after surgery, AVN of the femoral head was noted. They used femoral head wedge resection for treatment the AVN.
| Author            | Age/sex | Type of fracture                                                                 | Management                                                                 | The time of AVN evidence | Treatment of the AVN                                      |
|------------------|---------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------|----------------------------------------------------------|
| Stougård [10]    | 13/M    | Avulsion of the greater trochanter without fracture or dislocation of the head or neck | Bed rest and active exercises for 6 weeks                                | 5 months after the accident | Rest in bed with balanced traction on the leg for 6 weeks |
|                  | 11/M    | Just slight increase of the joint space                                           | Rest in bed                                                               | 6 weeks after the accident | Bed rest and traction                                    |
| Mohammad et al. [11] | 15/M   | Transepiphyseal fracture of the femoral neck + posterior dislocation of the femoral head + fracture of the posterior column of the acetabulum | Two AO cannulated screws to fix formal neck + pelvic reconstruction plate and screws for stabilizing the acetabulum | 24 months after the surgery | Not mentioned                                            |
| Akahane et al. [7] | 2/F     | Transverse fracture of the mid-shaft of the femur + transepiphyseal fracture of the proximal femur | Two smooth Kirschner wires to fix femoral shaft + two smooth Kirschner wires to fix proximal femur | 2 months after the accident | Abduction orthosis to prevent incongruity or deformity of the femoral head |
| Abbas et al. [12] | 14/M    | Transcervical fracture of the femoral neck                                         | Managed nonoperatively due to the nondisplacement fracture                | 10 months after the surgery | Modified transtrochanter rotational osteotomy + autogenous bone grafting |
|                  | 15/M    |                                                                                   |                                                                          | 5 months after the surgery, his pain initiated, but he referred to the clinic 11 months after the surgery |                                                          |
| Venkatadass et al. [13] | 16/M   | Bilateral Delbet type II femoral neck fracture                                    | Three 6.5-mm cancellous screws for left femur + two 6.5-cancellous screws for right femur | In both sides, 6 months after the surgery | Not mentioned                                            |
| Kim et al. [14]  | 9/F     | Delbet type II fracture of the femoral neck                                       | Two cannulated screws                                                    | 8 months after the surgery | Femoral head wedge resection                             |
| Naik et al. [15] | 3/F     | Bilateral Delbet type II fracture of the femoral neck                              | Single 4-mm cannulated cancellous screw on both sides                     | 3 months after the surgery | Double hip spica for 3 months                            |
| Rinat et al. [16] | 10/F    | Delbet type II fracture of the femoral neck                                       | NAA LCP Pediatric hip Plate 5.0                                           | After a year from the surgery | Conservative treatment                                   |
|                  | 12/F    | Delbet type III fracture of the femoral neck                                      | Compression hip screw augmented with a 7.5-mm cannulated screw            | No sign of AVN till the last follow-up in 2 years | No need                                                  |
In 2021, Naik et al. [15] reported bilateral Delbet type II fracture neck of femur in a child. Three months after surgery, bilateral Ratliff type three AVN and bilateral delayed union were seen.

Rinat et al. [16] reported two cases who suffered from femoral neck fracture which classified as Delbet type II and III, in 2021. The younger one showed signs of AVN in 1 year of follow-up while the other one had a good outcome without any sign of AVN after 2 years of follow-up.

In conclusion, since the femoral neck fracture in children is one of the rare conditions and the risk of hazardous and serious complications are high, so management and proper treatment should be considered. Relatively long time to transfer to the emergency room and preparation of the operating room (about 5 h), the impossibility of using titanium screws due to economic conditions and sanctions, inability to use a spica cast due to the patient's obesity, and needing to pass the device (screws) through the physis to achieve proper fixation have been limitations of our approach to manage this lesion. As we mentioned before, type I of the femoral neck fracture has the lowest prevalence and the highest risk of AVN, and the risk is even higher in type 1B; therefore, it is necessary to conduct more comprehensive research on the risk of complications as well as treatment methods.

We believe that orthopedic surgeons should be aware about the prevalence of the risk of AVN in femoral neck fractures, especially in pediatrics. Because most of the time, surgery intervention is not possible due to their age and their growth plate. Shortening the time of injury to intervention, perfect reduction, and appropriate restriction of weight bearing can decrease the progression of AVN and even can delay the onset of AVN evidence.

Statement of Ethics

Ethical approval was not required for this study in accordance with local/national guidelines, but written informed consent for publication of this case report and any accompanying images was obtained from the patient’s parents because he was under legal age. All steps were described to the patient's parents and assured that all personal information would be kept confidential.

Conflict of Interest Statement

The authors declare no potential conflict of interest, with respect to the research, authorship, and/or publication of this article.

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Authors Contributions

Shahin Talebi was the chief investigator; Shirin Sheibani and Pedram Hassani were responsible for the analysis and searched about the case; and Abolfazl Ghadiri was the corresponding author and responsible for the organization and coordination. All the authors contributed to the writing of the final manuscript.
Data Availability Statement

The authors confirm that the data supporting the results and findings of this study are available within the article.

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