Efficacy and complications after delayed fixation of femoral neck fractures in children

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Abstract

Objective: This study evaluated the efficacy of surgery for femoral neck fractures in children after a 24-h delay and the factors affecting the risk of complications. Methods: The study included 16 children who underwent surgery after the first 24 h for femoral neck fractures. According to Delbet's classification, there were 2 type I, 11 type II, and 3 (four hips) type III cases. The mean time from injury to surgery was 85 h (range 27–240 h). According to Garden's classification, there were 1 type II, 14 type III, and 1 type IV (two hips) cases. Initial surgery consisted of closed reduction and hematocele drainage with a 20-mL needle tube. If the procedure failed, open reduction was performed. Internal fixation (K-wire pinning, screw) was performed after closed (n = 9) or open (n = 8) reduction. The results were assessed using the Ratliff criteria after a mean follow-up of 23.2 months. Patient age, type of fracture, complications, treatment, and avascular necrosis (AVN) were evaluated. Results: The results were good in 15 hips (88.2%) and fair in 2 hips (11.8%, one type II case with closed reduction and one type I case with open reduction). The most frequent complication was AVN (4 of 17; 23.5%; three Ratliff good and one fair), which was significantly related to poor outcomes. AVN occurred in one hip in the closed reduction group (Delbet's type II, 12.5%) and in three in the open reduction group (one Delbet's type I, 50%; two Delbet's type II, 66.7%). There were no significant differences in the time from injury to operation (27, 54, 64, and 116 h) and AVN incidence or Ratliff criteria. Conclusions: The efficacy of delayed reduction fixation of the femoral neck was better in the closed reduction group than in the open reduction group. Fracture location closer to the femoral head and older age affected the incidence of AVN.

Keywords:
vascular necrosis, delayed reduction fixation, pediatric femoral neck fractures

Introduction

Pediatric femoral neck fractures are exceedingly rare and account for less than 1% of pediatric fractures and adult femoral neck fractures; most of these fractures are caused by high-energy trauma, such as traffic accidents or a high fall.1,2 These fractures are associated with high rates of premature physeal closure, delayed union, coxa vara, lower limb length discrepancy, and avascular necrosis (AVN) without internal fixation.3 There are no effective treatments for AVN, and proper primary treatment of this hazardous fracture is the key to a successful outcome. Surgery is recommended within 24 h after injury (even in 12 h) to avoid AVN.4 However, in China, many parents and some doctors do not pay enough attention to pediatric femoral neck fractures, and patients often present at the hospital more than 24 h after the injury. We share our experience...
and understanding of this fracture by retrospectively reviewing 16 patients who underwent surgery for femoral neck fractures in our institution after the first 24 h and analyze the effects of age, fracture type, delayed hours, and surgery type. The patients were treated with closed or open reduction and internal fixation and underwent conservative management in spica.

Patients and methods

Patients

We retrospectively reviewed all children with femoral neck fractures treated in our department between September 2010 and December 2015. Sixteen children (17 hips, 10 boys and 6 girls, 1–14 years, mean 10.4 years) who completed a mean follow-up of 23.2 months (range 10–58 months) were included in the study (Table 1). Patients underwent surgery at 27–240 h (mean 85 h) after the injury. Written consent for participation in this retrospective study was obtained from the parents we were able to contact at the time of drafting the study.

Treatments

The fractures were classified according to Delbet’s system, as described by Colonna.5 The treatment modalities used were conservative management, open reduction and internal fixation (ORIF), or closed reduction and internal fixation (CRIF), depending upon the patient profile and fracture pattern.

Assessment

The final outcome was assessed at the last follow-up visit using Ratliff’s method. A good outcome was rated as a

| Case | Gender | Age (years) | Time of delay (h) | Injury mechanism | Associated injury | Delbet type | Open or closed reduction | Garden’s classification | Length of follow-up (months) | Short femoral neck | Ratliff score |
|------|--------|-------------|------------------|-----------------|------------------|-------------|-------------------------|-------------------------|-------------------------|-------------------|---------------|
| 1    | Female | 13          | 27               | Slip            | No               | I           | Open                    | II                      | 50                      | AVN               | Good          |
| 2    | Female | 8           | 31               | Traffic accident| No               | III         | Closed                  | III                     | 58                      |                   | Good          |
| 3    | Female | 13          | 43               | Slip            | No               | II          | Closed                  | III                     | 10                      | —                 | Good          |
| 4    | Male   | 12          | 54               | Fall            | Pubic fracture   | II          | Open                    | III                     | 14                      | AVN               | Good          |
| 5    | Male   | 12          | 61               | Slip            | No               | II          | Closed                  | III                     | 23                      | —                 | Good          |
| 6    | Female | 11          | 64               | Slip            | No               | II          | Closed                  | III                     | 10                      | AVN               | Good          |
| 7    | Male   | 14          | 78               | Slip            | No               | II          | Closed                  | III                     | 12                      | —                 | Good          |
| 8    | Male   | 13          | 89               | Fall            | Fractures of olecranon, humerus, and pubic | II          | Closed                  | III                     | 39                      | —                 | Good          |
| 9    | Male   | 13          | 90               | Traffic accident| Fractures of skull and pelvic | II          | Closed                  | III                     | 25                      | —                 | Good          |
| 10   | Male   | 5           | 116              | Fall            | No               | II          | Open                    | III                     | 34                      | AVN               | Good          |
| 11   | Male   | 4           | 96               | Slip            | No               | II          | Closed                  | III                     | 18                      | —                 | Good          |
| 12   | Male   | 1           | 240              | Unknown         | No               | I           | Open                    | III                     | 21                      | Short femoral neck | Fair          |
| 13   | Male   | 8           | 118              | Fall            | Fractures of iliac and T5 transverse process, pneumothorax, pulmonary contusion | III         | Open                    | IV                      | 13                      | —                 | Good          |
| 14   | Female | 13          | 52               | Slip            | No               | II          | Open                    | III                     | 15                      | —                 | Good          |
| 15   | Male   | 13          | 78               | Slip            | No               | III         | Closed                  | III                     | 14                      | —                 | Good          |
| 16   | Female | 13          | 27               | Traffic accident| No               | II          | Closed                  | III                     | 15                      | —                 | Good          |

AVN: avascular necrosis.
“satisfactory outcome,” and “fair” and “poor” outcomes or the presence of complications were rated as an “unsatisfactory outcome.” Radiographs were also evaluated for joint congruency, arthritic changes, neck-shaft angle, and AVN, which was further classified according to Garden’s classification (Table 2)⁶ and Ratliff’s classification (Table 3).⁷

**Statistical analysis**

Data were analyzed using the Student’s t-test with SPSS 19.0. Differences with p value <0.05 were considered statistically significant.

**Results**

**General clinical data**

As presented in Table 1, of the 16 cases (17 hips), 2 were type I (transepiphyseal separation; two ORIF), 11 were type II (transcervical; three ORIF and eight CRIF), and 3 were type III (cervicotrochanteric; four hips, two ORIF, and two CRIF). There were no cases of Delbet’s type IV (intertrochanteric). According to Garden’s classification of femoral neck fractures, 1 was type II (without displacement), 14 were type III (partial displacement), and 1 was type IV (two hips, total displacement). The mechanisms of injury included traffic accidents in three cases, falls (falls from height) in four, slips (slip or fall) in eight, and reason unknown in one case. All the 16 fractures underwent surgery ≥24 h after injury because of delayed arrival at the hospital and extensive associated injuries.

Of the 16 fractures, the associated injuries included pubic fracture in one; olecranon, supracondylar humeral, and pubic fractures in one; skull and pubic fractures in one; and ilium, thoracic vertebral fractures, pneumothorax, and pulmonary contusion in one.

**Outcomes of the two treatments**

Displaced fractures were treated by CRIF under fluoroscopy or by open reduction if closed anatomical reduction failed after three attempts. The Watson-Jones approach or Smith-Petersen approach was used, and patients underwent internal fixation after reduction. The patients began to move in bed and walked at 2 months after lying in the bed in a hip cast.

According to the Ratliff classification, 15 hips had satisfactory outcomes and two hips had fair outcomes (one case of CRIF, Delbet’s type II; one case of ORIF, Delbet’s type I); there were no poor outcomes.

**AVN incidence in the patients undergoing CRIF or ORIF**

As presented in Table 4, four hips (23.5%) developed AVN. Of the four AVN cases, three hips had Ratliff good outcomes and one case had a Ratliff fair outcome. In the CRIF group, one hip developed AVN (Delbet’s type II, Garden’s type III, 1/9 hips, 11.11%). In the ORIF group, three hips developed AVN (3 of 8 hips, 37.50%), of which one was Delbet’s type I or Garden’s type II (1 of 2 hips, 50%) and two were Delbet’s type II or Garden’s type III (2 of 3 hips, 66.7%).

**Correlation between time from injury to operation and AVN incidence**

In patients who developed AVN, the interval times from injury to operation were 27, 54, 64, and 116 h (Table 5). There was no statistically significant correlation between the outcome and the occurrence of further AVN, or low Ratliff score and interval time.

| Table 2. Garden’s classification for clinical and radiographic assessment. |
|-----------------------------------------------|
| Type | Nondisplaced or displaced | Radiograph |
| I Nondisplaced | Incomplete femoral neck fracture, with valgus impaction |
| II Nondisplaced | Complete but nondisplaced fracture |
| III Displaced | Complete and partially displaced fracture with alignment of the femoral neck relative to the neck in varus deformity |
| IV Displaced | Complete fracture with complete displacement |

AVN: avascular necrosis.

| Table 3. Ratliff system of clinical and radiographic assessment. |
|-----------------------------------------------|
| System | Pain | Hip movement restriction | Activity | Radiograph |
| Good | No or negligible pain | Full or minimal restrictive hip movement | Normal activity or the avoidance of games | Normal or some deformity of the femoral neck in the radiograph |
| Fair | Occasional pain | Hip movement restriction less than 50% | Normal activity or the avoidance of games | Severe deformity of the femoral neck and mild AVN in the radiograph |
| Poor | Disabling pain | Hip movement restriction more than 50% | Restricted activity | Severe AVN, degenerative arthritis, and arthrodesis in the radiograph |

AVN: avascular necrosis.
AVN: avascular necrosis; CRIF: closed reduction and internal fixation; ORIF: open reduction and internal fixation.

*p Value <0.05 compared with Delbet’s type I group or Garden’s type II group.

**p Value <0.05 compared with CRIF group.

| Delbet’s type | Garden’s type | AVN | Coxa vara | Lower limb length discrepancy | Premature physeal closure | Short femoral neck |
|---------------|---------------|-----|-----------|-------------------------------|---------------------------|-------------------|
| I (n = 2)     | II (n = 1)    | 1 (50%) | 0 | 0 | 0 | 1 (50%) |
| II (n = 12)   | III (n = 14)  | 3 (25%) | 0 | 1 (8.33%) | 0 | 2 (16.66%) |
| III (n = 3)   | IV (n = 2)    | 0 | 0 | 0 | 0 | 0 |
| Total (n = 17)| Total (n = 17)| 4 (23.6%) | 0 | 1 (5.89%) | 0 | 3 (17.65%) |

AVN: avascular necrosis.

*p Value <0.05 compared with Delbet’s type I group or Garden’s type II group.
AVN: avascular necrosis.

epiphyseal artery and supply blood to the femoral head surface, not to the femoral head. Therefore, even in minimally displaced fractures, the arteries around the femoral head are exposed to increased intracapsular pressure, which may compromise blood flow to the femoral head through a tamponade effect. To determine whether the displacement degree of femoral neck fracture is related to AVN, we used Garden’s classification and found that although the femoral neck displacement was the most serious in one patient (two hips) with Garden type IV, AVN did not occur because Delbet III was located at the base of the femoral neck and had no effect on the femoral neck blood supply ring. The displacement of children with Garden II and III was not as severe; however, the corresponding Delbet classification was types I and II, and the blood supply ring of the femoral neck was destroyed. These cases developed AVN, which also indicates that AVN is mainly caused by the vulnerability of the blood supply to the femoral head and neck.

In delayed surgery for femoral neck fractures, it is difficult to determine whether to perform CRIF or ORIF. Researchers differ regarding the optimum type of operation. The incidence of AVN is lower and efficacy is better in ORIF because ORIF reduces the pressure in the hip capsule and promotes recovery of blood circulation. However, there are few cases of surgery performed 24 h after injury. Other scholars report that CRIF is better than ORIF because open reduction can destroy the blood supply to the femoral head.

Many scholars support that femoral neck fractures should be treated within 24 h. The risk of AVN increases with increased time after injury. However, whether the increased incidence of AVN is proportional to delayed fracture reduction time remains unclear. In the present study, the incidence of AVN was not proportional to delayed time in operations performed at 24 h after injury. We speculate that because the femoral neck blood supply is destroyed after 24 h, the risk of AVN does not differ in surgeries performed after 24 h, although this needs to be verified in future studies.

Previous studies showed that age is a statistically significant predictor of outcome, and older children have a 1.14-fold higher likelihood of developing AVN for every year of increasing age. Therefore, the incidence of AVN should be 2.82-fold higher (47%) in patients aged 12.67 years than in those aged 5.67 years. In the present study, the incidence was 1.5-fold higher, suggesting that older children were more likely to develop AVN, but the incidence was not as high as that reported previously.

The results of our statistical analysis validate previous observations that specific risk factors can predict the occurrence of AVN. Fracture type, displacement, age, and treatment may all contribute to the development of AVN. Older children with type I and II fractures are at the highest risk for developing AVN. This was a retrospective study, and the treatment option for closed reduction depended on the fracture characteristic, and the treatment was not randomized. The efficacy of delayed reduction and fixation of the femoral neck was better in the closed reduction group than in the open reduction group. This may be related to the fact that the closed reduction group was preselected by the fracture characteristics as a group with a better outcome. The probability of a fracture location closer to the femur head, a higher incidence of AVN, and a poor prognosis increased with age. There were no correlations between delayed reduction fixation and high AVN incidence or other severe complications.

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### References

1. Palocaren T. Femoral neck fractures in children: a review. Indian J Orthop 2018; 52(5): 501–506.
2. Yeranosian M, Horneff JG, Baldwin K, et al. Factors affecting the outcome of fractures of the femoral neck in children and adolescents: a systematic review. Bone Joint J 2013; 95-B(1): 135–142.
3. Ebner R, Singer G, Ferlic P, et al. Post-traumatic coxa vara in children following screw fixation of the femoral neck. Acta Orthop 2010; 81(4): 442–445.
4. Spence D, DiMauro JP, Miller PE, et al. Osteonecrosis after femoral neck fractures in children and adolescents: analysis of risk factors. J Pediatr Orthop 2016; 36(2): 111–116.
5. Colonna PC. Fracture of the neck of the femur in childhood: a report of six cases. Ann Surg 1928; 88(5): 902–907.
6. Frandsen PA, Andersen E, Madsen F, et al. Garden’s classification of femoral neck fractures. An assessment of inter-observer variation. J Bone Joint Surg Br 1988; 70(4): 588–590.
7. Ratliff AH. Fractures of the neck of the femur in children. J Bone Joint Surg Br 1962; 44-B: 528–542.
8. Papakostidis C, Panagiotopoulos A, Piccioli A, et al. Timing of internal fixation of femoral neck fractures. A systematic review and meta-analysis of the final outcome. Injury 2015; 46(3): 459–466.
9. Han YH, Jeong HJ, Sohn MH, et al. Incidence and severity of femoral head avascularity after femoral neck or intertrochanteric fractures on preoperative bone single photon emission computed tomography/computed tomography: preliminary study. *Nucl Med Commun* 2019; 40(3): 199–205.

10. Venkatadass K, Avinash M, and Rajasekaran S. Bilateral avascular necrosis of the femoral head following asynchronous postictal femoral neck fractures: a case report and review of the literature. *J Pediatr Orthop B* 2018; 27(3): 274–278.

11. Moon ES and Mehlman CT. Risk factors for avascular necrosis after femoral neck fractures in children: 25 Cincinnati cases and meta-analysis of 360 cases. *J Orthop Trauma* 2006; 20(5): 323–329.

12. Stockton DJ, O’Hara LM, O’Hara NN, et al. High rate of reoperation and conversion to total hip arthroplasty after internal fixation of young femoral neck fractures: a population-based study of 796 patients. *Acta Orthop* 2019; 90(1): 21–25.

13. Moon NH, Shin WC, Kim JS, et al. Cementless total hip arthroplasty following failed internal fixation for femoral neck and intertrochanteric fractures: a comparative study with 3-13 years’ follow-up of 96 consecutive patients. *Injury* 2019; 50(3): 713–719.

14. Crock HV. Anatomy of the medial femoral circumflex artery and its surgical implications. *J Bone Joint Surg Br* 2001; 83(1): 149–150.

15. Upasani VV, Badrinath R, Farnsworth CL, et al. Increased hip intracapsular pressure decreases perfusion of the capital femoral epiphysis in a skeletally immature porcine model. *J Pediatr Orthop.* Epub ahead of print 29 October 2018. DOI: 10.1097000000000001284.

16. Dendane MA, Amrani A, El Alami ZF, et al. Displaced femoral neck fractures in children: are complications predictable. *Orthop Traumatol Surg Res* 2010; 96(2): 161–165.

17. Qi B, Yu A, Zhang G, et al. The treatment of displaced femoral neck fractures with vascularized great trochanter periosteal flap transposition in children. *Microsurgery* 2008; 28(1): 21–24.

18. Pavone V, Testa G, Riccioli M, et al. Surgical treatment with cannulated screws for pediatric femoral neck fractures: a case series. *Injury* 2019; 50(suppl 2): s40–s44.

19. Scott B, Taylor B, Shung JR, et al. Bilateral femoral neck fractures associated with complex pelvic ring injuries in a pediatric patient: a case report. *J Pediatr Orthop B* 2017; 26(4): 350–357.

20. Nayeemuddin M, Higgins GA, Bache E, et al. Complication rate after operative treatment of paediatric femoral neck fractures. *J Pediatr Orthop B* 2009; 18(6): 314–319.

21. Ju L, Jiang B, Lou Y, et al. Delayed treatment of femoral neck fractures in 58 children: open reduction internal fixation versus closed reduction internal fixation. *J Pediatr Orthop B* 2016; 25(5): 459–465.