

No Negative Influence On Complications of femoral neck fracture Children Age Between 14 And 17 Years Treatment with Cannulated Screws Transphyseal fixation

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Research article

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Abstract

Background Hip fractures represent less than 1% of pediatric fractures. The physeal of femoral head closure at 14 to 17 years of age, and it provides capacity for spontaneous fracture remodeling. The primary purpose of the current retrospective study was to determine the influence of transphyseal fixation of cancellous screws on the outcomes in this age group.

Methods: From April 2007 to August 2016, all patients age between 14 to 17 years with Delbet type II and Type III hip fracture treatment with cancellous screws fixation were included. According to whether the cancellous screws thread across the proximal femur epiphysis, we divided the patients into the no cross epiphysis (NCE) group and cross epiphysis (CE) group. The outcome was analysis regarding osteonecrosis of femoral head, nonunion, delay union, premature physeal closure (PPC), coxa vara and overgrowth of femoral neck.

Results: Of the 28 patients were included in the study, most patients were male (92.9%).19 were classified as Delbet type II, 9 were type III. The CE and the NCE group both included 14 patients. The average follow-up time is 37.8 months (range 26-68 months). The rate of superficial infection, deep infection, AVN, non-union, delay union, coxa vara, PCE, overgrowth was not significantly different between the two groups.

Conclusion: This study demonstrated that the transphyseal fixation of cannulated screws has no negative influence on the outcomes, especially on femoral head osteonecrosis. Achievement of accurate reduction and rigid fixation for this unique injury is more important than preservation of the proximal femoral epiphysis.

Background

Hip fractures represent less than 1% of pediatric fractures[1-4]. It is usually the result of high-energy injury. Previous studies have reported a high risk of severe complications following a pediatric hip fracture[1-8]. As a result of anatomical differences, the complications observed in pediatric patients with hip fracture tend to different from those in adults, making this specific patient population and proper surgical management essential to characterize. Avascular necrosis (AVN) of the femoral head is the most devastating complication [4], with an incidence ranging from 20% to 29% [5-8]. The high rate of complications associated with hip fractures is directly related to its tenuous blood supply. The metaphyseal and epiphyseal blood supplies remain functionally separate until physeal closure at 14 to 17 years of age, and it provides little capacity for spontaneous fracture remodeling[1,9].

Pediatric hip fractures can be divided into four types as first described by Delbet [11], and popularized by Colonna[12,13]. Type I fractures are transphyseal, and types II, III, and IV are transcervical, cervicotrochanteric, and intertrochanteric fractures, respectively. Type II and III are the most common subgroups and often result in avascular necrosis, coxa vara, premature physeal closure, infection and nonunion[1-7]. Osteonecrosis was more likely to develop in older children because these patients cannot

revascularize the femoral head and because they sustain type II, and III fractures more often than do younger children[2].

Recently, some authors recommend use the 6.5- or 7.3-mm cannulated screws for fixation of Type I-III hip fractures more than ten years old[2,10]. However, most published series are reported from orthopedic societies or regional hospital systems or represent decades of a single institution's experience[10]. With only single-institution case series available in the literature, there is a lack of specific consensus for whether the implant should cross the proximal femoral epiphysis for Delbet type II and III fracture[1,2,10], especially for patients age between 14 to 17 years.

The primary purpose of the current retrospective study was to evaluate the clinical and radiographic outcome in Delbet Type II and III hip fractures and to determine the influence of transphyseal fixation of cancellous screws on the outcomes with children age between 14 and 17 years.

Methods

From April 2007 to August 2016, all chronological patients age between 14 to 17 years with Delbet type II and Type III proximal hip fracture treatment with cancellous screws internal fixation were included for evaluation. Children patients were excluded from this study if they had open fractures, metabolic bone disease, pathological fractures, slipped capital femoral epiphysis, intertrochanteric fractures, subtrochanteric fractures, or less than 1 year follow-up. The endpoint of follow-up was 30 August 2018. According to whether the cancellous screws thread across the proximal femur epiphysis, we divided the patients into the no cross epiphysis (NCE) group and cross epiphysis (CE) group.

Data collected included the following: age, gender, injury date, side, admission date, delay of admission time, type of reduction (open or closed), length of stay, BMI (body mass index), anesthesiology type (GA or LA), transfusion amount, ICU stay, and were obtained from the hospital's patient management system. Detailed definitions of admission laboratory parameters are available in the User Guide for the ACS NSQIP Participant Use File [14]. Radiographs and clinical notes were taken at the time of injury were analyzed to confirm the initial diagnoses of the fracture. Fractures were classified according to the system described by Delbet and adapted by Colonna: type 1 (transepiphyseal), type 2 (transcervical), type 3 (cervicotrochanteric), and type 4 (intertrochanteric).

Complications were categorized as superficial and deep infection. The outcome was analysis regarding osteonecrosis of femoral head, nonunion, delay union, premature epiphyseal closure (PPC), coxa vara and overgrowth of the femoral neck. Nonunion was defined as implant breakage, loss of reduction, or persistence of a visible fracture line at a minimum of 6 months after the index procedure. Premature epiphyseal closure was defined as 50 % or more linear closure of the physis. Coxa vara was defined as neck-shaft angles of less than 120°. The minimum follow-up time for inclusion of cases without evidence of ON was two years.

Statistical analysis

Data were analyzed with the 22.0 IBM-SPSS statistical package (SPSS Inc., USA) for Windows. Results are expressed as the mean \pm SD, median [25–75 interquartile] for non-normal distribution quantitative data or number (percentages). The standard distribution variables were assessed using an independent t-test and a Chi-square test. When comparing two independent samples without normal distribution, the Wilcoxon rank-sum test was used. A two-sided significance test was performed for all tests, where a p-value <0.05 was considered statistically significant.

Ethics, funding, and potential conflicts of interest

This study was performed following approval from the institutional ethical review board (2017-48). Informed consent was obtained from the parents of all children included in this study. All authors declare that they have no conflicts of interest

Results

Over the 10-year study period, 33 Delbet type II and III hip fracture patients whose age between 14 to 17 years were admitted into our hospital. Among them, two patients were excluded for pathological fractures. Also, outcomes data of 3 patients were not retrievable, and therefore they were excluded from the final statistic analysis.

Finally, 28 patients were included in the study. Most patients were male ($n=26$, 92.9%), and the CE and the NCE group both included 14 patients. The mean age (shown as Mean \pm SD) of the NCE group and CE group was 15.14 ± 0.95 years (14-17 years) and 15.14 ± 0.86 years (14-17 years), respectively. The average follow-up time is 37.8 months (range 26 to 68 months). The Baseline of patients characteristics of the two groups is shown in Table 1 to Table 3.

According to the Delbet system, 19 were classified as Delbet type II, 9 were type III. As presented as Table 1, regarding the baseline characteristics of two groups, the difference is not statistically significant.

As Table 2 and Table 3 shown, in term of baseline variables, including the revision surgery and length of stay, the difference between the NCE group and CE group is not significantly.

In the term of complications, including superficial infection, deep infection, AVN, non-union, delay union, coxa vara, PCE, overgrowth was not significantly related to whether the cancellous screws cross the proximal femur epiphysis (Table 4).

The details of three unique cases are also presented as follows (**Figure 1-3**).

Discussion

In this retrospective study, we retrospectively analyzed 28 pediatric patients at 14 to 17 years of age with Delbet type II to III femoral neck fractures performed internal fixation with cannulated screws. Our results

demonstrated that the thread of cannulated screws cross the epiphysis has no adverse influence on the complications and outcomes, especially on femoral head osteonecrosis.

Delbet Type II and type III fractures are the most common types in pediatric patients with hip fractures. Due to the high failure rate of lost reduction of conservative treatment, operative treatment with internal fixation is preferred [4]. Recently, some authors recommendation use cannulated screws for fixation of Type I-III fractures more than ten years old[4,2,10]. However, the treatment of femoral neck fractures in children age between 14 and 17 years with an open physis can be challenging.

Due to lack of biomechanics data to guide the fixation method and specific algorithms or guideline for hardware selection, the means of fixation are primarily dependent on the surgeon's preferences [10,4]. There is an increasing body of evidence that suggests that stable fixation should be given priority over preservation of the physis [2,10,15,16,1]. On the other hand, the smaller diameter of the pediatric femoral neck carried the risk of injury to the superior and inferior retinacular arteries with additional hardware[4]. Some authors propose that the cannulated screws can achieve firm and compressive fixation of the fragments. The threads can cross the physis from the age above 15 years without the risk of significant limb length discrepancy from premature growth arrest[17]. The use of small diameter smooth pins, in such situations, can lead to inadequate fixation and distraction of fragments[17,15]. However, it is unclear of whether the transphyseal fixation of cancellous screws in femoral neck fractures patients age 14 to 17 years have negative affect on the complications, especially on the incidence of AVN of the femoral head.

The reported incidence of avascular necrosis after femoral neck fractures varies considerably, range from 0 % to 92% in literatures [18,15,5,6,7,8]. The overall rate of osteonecrosis in our study is 10.7%, with type II of 10.5% (2/19) and type III 11.1% (1/9), respectively. The rate of AVN was not significantly related to whether the cancellous screws cross the proximal femur epiphysis. We experienced avascular necrosis only in three cases, and our findings are consistent with more earlier literature[18-20]. Flynn et al. reported only a low rate of 6% of AVN in 18 patients[19]. Swiontkowski and Winquist reported an incidence of 10% in children with displaced fractures of the hip, treated by urgent open reduction, internal fixation[21]. Only a prospective multicenter therapeutic study in India reported a low incidence of 14.2% (4/28)[22]. However, these studies failed to evaluate the influence of transphyseal fixation of the cancellous screw on the complications of Delbet type II to III femoral neck fractures patients age from 14 to 17 years.

One possible reason for the low incidence of AVN might be the stable fixation can facilitate earlier rehabilitation after surgery and sequent reduce the occurrence of AVN. Despite the incidence of avascular necrosis in this study was significantly lower than that reported in the most recent series. While we cannot conclude that the transphyseal fixation of screws accounted for the low incidence, rigid internal fixation may have restored the blood supply to the femoral head. The ability to detect a difference was further confounded by the relatively small sample size and retrospective study nature. Further prospective multicenter study deserves to determine whether the screws should be performed transphyseal fixation in this specific age group patients.

Time to diagnosis of osteonecrosis in our study was highly variable. Hence we reported a median time to diagnosis of osteonecrosis of 7.8 months. Many previous reports have suggested that avascular necrosis of the hip after an injury in children usually presents within one year, our minimum follow-up of 22 months should have detected all potential cases. However, more recent studies have suggested that avascular necrosis becomes evident within 12 to 24 months of injury and therefore, patients should be screened up to 2 or 3 years after injury to identify late development of osteonecrosis with repeat clinical examination and MRI as indicated [23,24,2,19,5]. Next, we should extend the follow-up time to determine the mid-term and long-term outcomes of these patients.

Our study encounters a case of late-onset septic arthritis, secondary idiopathic hip subluxation (**Figure 2 A-L**). This is the first report of an infrequent complication of a pediatric femoral neck fracture. Fortunately, the functional loss of the affected hip in this boy is limited. The incidence of postoperative infection is relatively rare after hip fractures in children and adolescents, generally reported to occur in 1% to 10% of patients and most often after open reductions as well as after closed reduction with percutaneous fixation[2,16,25,26]. Taylor and McHale [27] reported a deep infection after percutaneous pin fixation of a femoral neck fracture in the 12-year patient.

This study has some limitations. First, this retrospective review with small sample size making it difficult to generate guidelines for treating this rare injury. Second, future longitudinal and multi-center studies should deserve to determine whether the screws should be performed transphyseal fixation in this specific age group patients.

Conclusion

In this retrospective study, we retrospectively analyzed 28 pediatric patients at 14 to 17 years of age with Delbet type II to III femoral neck fractures performed internal fixation with cannulated screws. This is the first study to demonstrate that the thread of cannulated screws cross the epiphysis has no negative influence on the complications and outcomes, especially on femoral head osteonecrosis. Achievement of accurate reduction and rigid fixation for this unique injury is more important than the preservation of the proximal femoral epiphysis. The cannulated screws cross the epiphysis has no negative influence on the complications and epiphysis. These findings could profitably the future researches to generate guidelines for treating this rare injury in children.

Declarations

-Ethics approval and consent to participate

The study was approved by Biomedical Ethics Sub-Committee of West China Hospital of Sichuan University (ref. 2018/33). Upon registration in West China Hospital of Sichuan University, the patients accept that their data maybe used in research. No further approval from the patients has therefore been sought for this study. **Informed consent:** No consent was required. Only general non-identifiable data on a

series of patients is included. All data are presented on an aggregated level and the individual patient cannot be identified.

-Consent for publication

Not applicable.

-Availability of data and material

The data that support the findings of this study are available from the corresponding author but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of corresponding author.

-Competing interests

The authors declare that they have no competing interests.

-Funding

Not applicable.

-Authors' contributions

All authors participated in the design of the study. YL and ZXD collected the data. ZXD set up the dataset and performed the analysis. YL was a major contributor in writing the manuscript. All authors participated in revising the manuscript. All authors read and approved the final manuscript.

-Acknowledgements

Not applicable.

Author Contributions

All authors participated in the design of the study. YL and ZXD collected the data. ZXD set up the dataset and performed the analysis. YL was a major contributor in writing the manuscript. All authors participated in revising the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Independent Chi-square test compares the baseline variable of the two groups.

Variable	Groups		χ^2	P Value
	NCE group n(%)	CE group n(%)		
Gender				
Male	13(92.9)	13(92.9)	0.000 ^a	1.000 ^b
Female	1(7.1)	1(7.1)		
Reduction				
Close	11(78.6)	10(71.4)	0.190 ^a	0.663 ^b
Open	3(21.4)	4(28.6)		
Delbet Type				
0	10(71.4)	9(64.3)	0.164 ^a	0.686 ^b
1	4(28.6)	5(35.7)		
YES	0(0.0)	1(7.1)		
Anesthesiology				
GA	1(7.1)	0(0.0)	1.037	0.309
LA	13(92.9)	14(100.0)		
ICU stay				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
Laboratory parameters				
Low HGB(12g/dL)				
NO	8(57.1)	11(78.6)	0.655 ^a	0.418 ^b
YES	6(42.9)	3(21.4)		
Low HCT(<30%)				
NO	7(50.0)	9(64.3)	0.583	0.445
YES	7(50.0)	5(35.7)		
Low WBC count (<4500/mcL)				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
High WBC count(>10,000/mcL)				
NO	10(71.4)	9(64.3)	0.164	0.686
YES	4(28.6)	5(35.7)		
Low platelets(<150,000/mcL)				
NO	8(57.1)	9(64.3)	0.150	0.699
YES	6(42.9)	5(35.7)		
High INR >1.1				
NO	4(28.6)	3(21.4)	0.190 ^a	0.663 ^b
YES	10(71.4)	11(78.6)		
High BUN(>30 mg/dL)				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
High Creatinine (>1.3 mg/dL)				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
Low ALB(<34g/L)				
NO	13(92.9)	13(92.9)	0.000 ^a	1.000 ^b
YES	1(7.1)	1(7.1)		
High Bilirubin(>32.49umol/L)				
NO	14(100)	12(85.7)	0.538 ^a	0.463 ^b
YES	0(0.0)	2(14.3)		
High sodium>145mmol/L(>145 mEq/L)				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
Low sodium<135mmol/L(<135 mEq/L)				
NO	13(92.9)	14(100.0)	1.037	0.309
YES	1(7.1)	0(0.0)		

* P< 0.05 was considered statistically significant. a.The chi-square test of continuous correction was used, and the expected count of the cell was less than 5 and greater than 1 . b Continuous correction chi of square test significance(2-sided).

Table 2. Independent-Samples T-Test analysis for two groups with the normal distribution.

Variables	Groups		t	P Value
	NCE group [Mean±SD]	CE group [Mean±SD]		
Age	15.14±0.95	15.14±0.86	0.000	1.000
BMI	17.47±1.86	17.23±1.87	0.345	0.733
Laboratory parameters				
Creainine	56.21±9.97	56.81±13.66	-0.133	0.895
Bilirubin	17.64±5.30	20.90±10.63	-1.026 ^a	0.314 ^b
Sodium	139.11±2.33	138.78±2.37	0.370	0.714

* P < 0.05 was considered statistically significant.

a. Equal variances not assumed, t' test was used, value is t'. b t' test significant (2-sided).

Table 3. Wilcoxon rank-sum test for two groups without normal distribution.

Variables	Groups		Mann-Whitney U	P-Value
	NCE group Median (P ₇₅ -P ₂₅)	CE group Median (P ₇₅ -P ₂₅)		
Length of stay(Days)	11.79(5.89) ^a	10.50(6.00)	95.0	0.890
Admission Delay(Days)	1.00(5.12)	1.00(2.77)	82.0	0.457
Surgical Delay(Days)	5.50(10.30)	6.00(7.30)	84.5	0.532
Revision-surgery	0.00(0.00)	0.00(0.00)	90.0	0.494
Transfusion				
Blood [U]	17.95(3.23)	17.60(3.60)	92.0	0.608
Plasma (ml)	0.00(0.00)	0.00(0.00)	91.0	0.317
Laboratory parameters				
RBC	4.46(0.73)	4.62(0.32)	80.5	0.421
HGB	132.00(24.75)	135.50(12.00)	73.5	0.260
HCT	0.40(0.07)	0.40(0.04)	82.5	0.472
WBC	7.98(4.25)	9.24(2.35) ^a	89.5	0.696
Platelets	168.00(125.75)	176.00(64.72) ^a	97.0	0.963
INR	1.17(0.26)	1.15(0.08) ^a	93.5	0.836
BUN	4.33(2.55)	4.02(1.62)	93.5	0.836
ALB	43.45(6.58)	45.10(6.52)	82.0	0.462

* P < 0.05 was considered statistically significant. a. Satisfying normal distribution, using $Mean(S_D)$.

Table 4. Independent Chi-square test compares the complications of the two groups

Variable	Groups		χ^2	P Value
	NCE group n(%)	CE group n(%)		
Complications				
YES	9(64.3)	12(85.7)	0.762 ^a	0.383 ^b
NO	5(35.7)	2(14.3)		
Superficial Infection				
NO	13(92.9)	14(100.0)	1.037	0.309
YES	1(7.1)	0(0.0)		
Deep Infection				
NO	13(92.9)	14(100.0)	1.037	0.309
YES	1(7.1)	0(0.0)		
Osteonecrosis				
NO	12(85.7)	13(92.9)	0.000 ^a	1.000 ^b
Yes	2(14.3)	1(7.1)		
PPC				
NO	14(100.0)	10(71.4)	2.625 ^a	0.105 ^b
Yes	0(0.0)	4(28.6)		
Overgrowth				
NO	14(100.0)	14(100.0)	0.000	1.000
YES	0(0.0)	0(0.0)		
Coxa Vara				
NO	12(85.7)	14(100.0)	0.538	0.463
YES	2(14.3)	0(0.0)		
Non-union				
NO	12(85.7)	13(92.9)	0.373 ^a	0.541 ^b
YES	2(14.3)	1(7.1)		
Delay Union				
NO	14(100.0)	13(92.9)	1.037 ^a	0.309 ^b
YES	0(0.0)	1(7.1)		
YES	1(7.1)	0(0.0)		

* P < 0.05 was considered statistically significant. a. The chi-square test of continuous correction was used, and the expected count of the cell was less than 5 and greater than 1. b. Continuous correction chi of square test significance (2-sided).

Figures

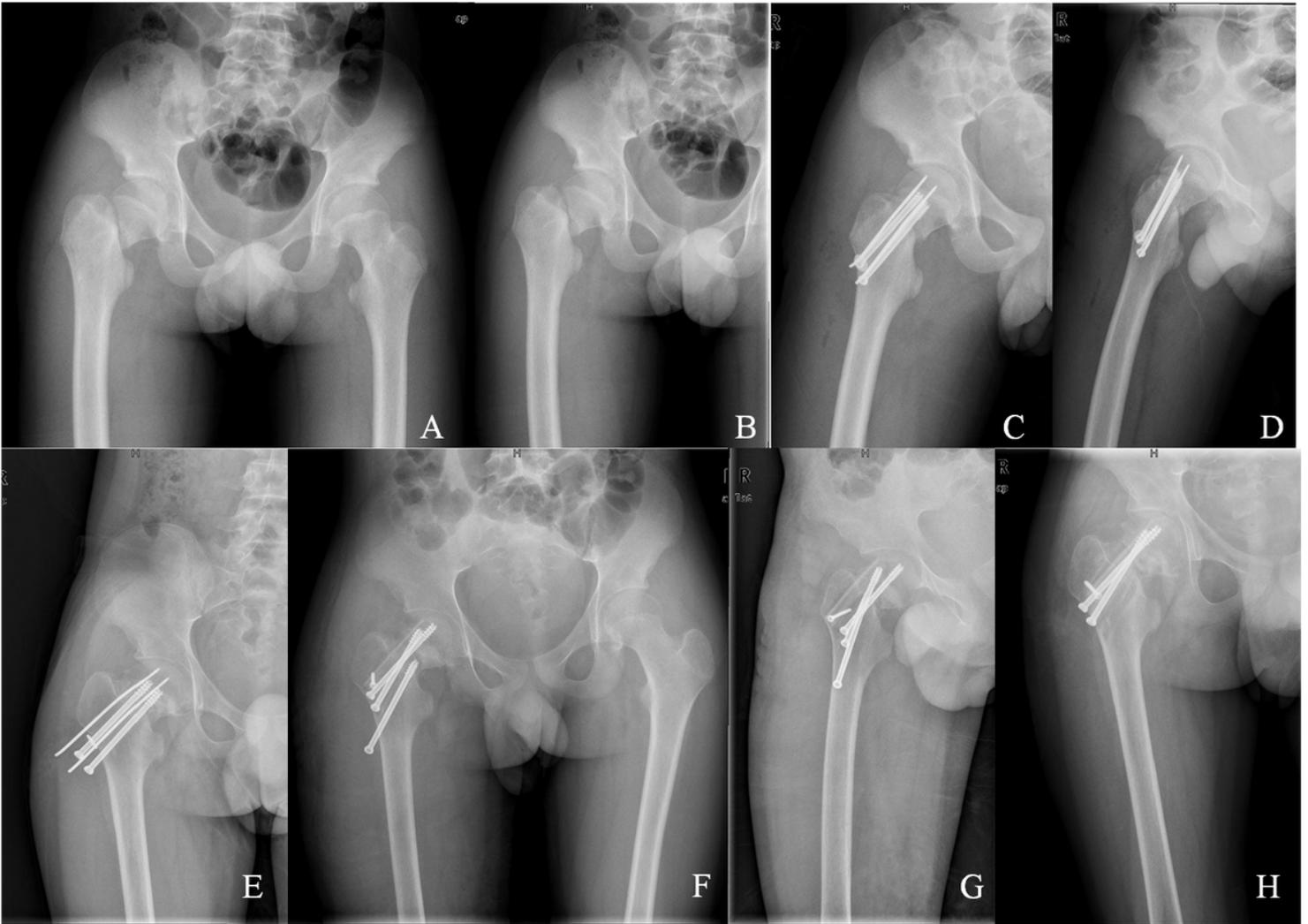


Figure 1

Radiographic series of a 14-year-old boy with a Delbet Type II, and Pauwels type III fracture after fall from walking. (A) and (B) An AP radiograph of pelvis and AP radiograph of right hip show transcervical fracture of right hip. (C) and (D) Closed reduction and internal fixation were performed with two 6.5-mm cannulated screws (not cross epiphyseal) combination with two K-wires cross epiphyseal. The quality of reduction is accepted. (E). Six months after index surgery, the patient presented non-union of femoral neck fracture associated with implants back-out. (F) and (G) Reversion surgery was performed with removal implants and free vascularised fibular grafting, re-internal fixation with three cancellous screws (two screws cross the epiphyseal). (H) One months after revision surgery, the distal cancellous screws was removed due to loosening.

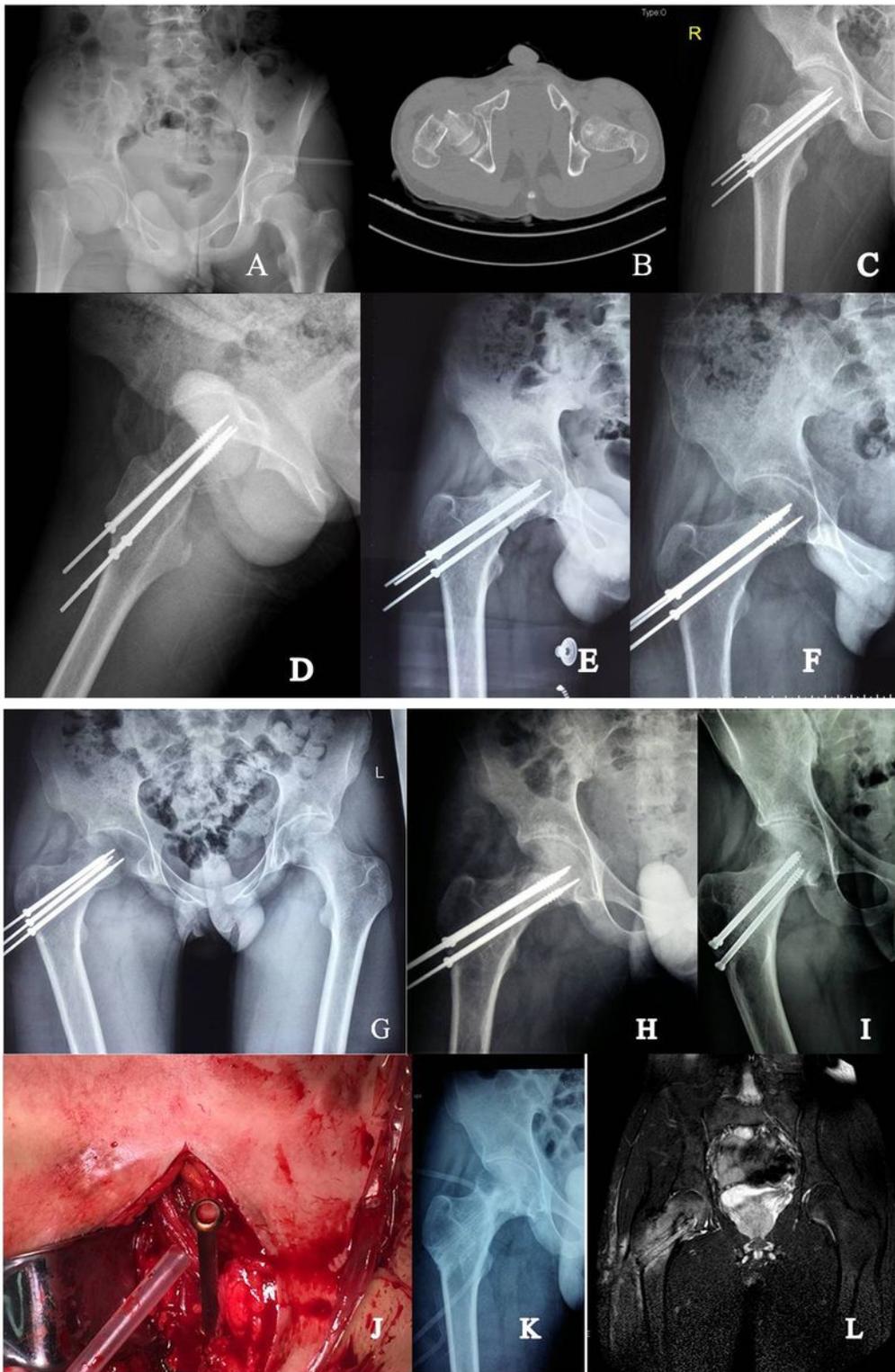


Figure 2

(A-F). (A) A 15-year-old boy fall from standing and sustained proximal femoral fracture and CT scan (B) demonstrated that the fracture is classified as Delbet type II. (C) and (D) Postoperative radiograph. Closed reduction and internal fixation were performed with three 6.5-mm cannulated screws (not cross epiphyseal) combination with three K-wires cross epiphyseal. The quality of reduction and fixation is good. The tip of k-wire were left outside of the skin. (E) Three months of postoperative radiograph

presented high dense in the fracture site. (F) Nine months of postoperative radiograph demonstrated that the fracture achieved union. Continued G-L. (G-L) cont'd. (G) Ten months after surgery, the patient suddenly presented groin pain after fever. The AP pelvis radiograph shows right hip subluxation. (H) The emergency manual reduction under anesthetic was performed. After administered high doses of vancomycin for one week, the K-wires were removed. (I) Eighteen months after first surgery, the radiograph demonstrated the fracture was healed associated with premature physeal closure (PPC) of right hip. (J) In the third procedure, the implants was removed. An intraoperative photograph illustrates the screw tract tissue with purulent exudates. (K) The postoperative radiograph demonstrate that implants were completed removal. (L) After removal the screws, the MRI demonstrated edema of screw tract without evidence of avascular necrosis of femoral head.

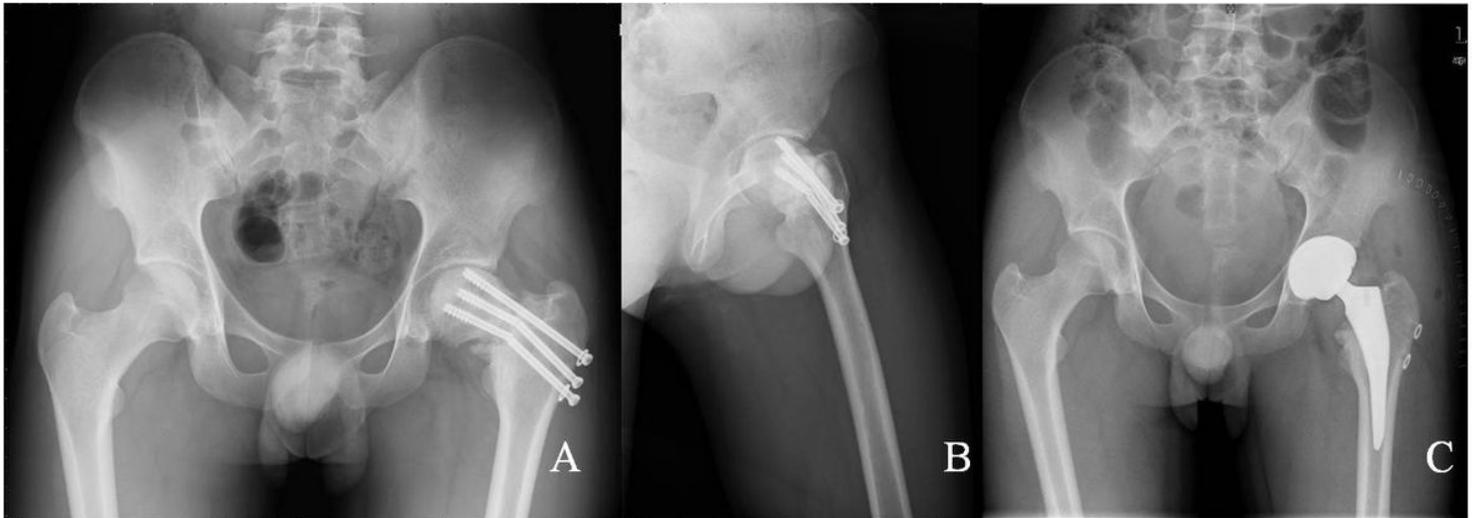


Figure 3

A 17-year-old boy fall from running and sustained Delbet type II fracture. Closed reduction and internal fixation were performed with three 6.5-mm cannulated screws cross the epiphyseal. (A) and (B) One year after surgery, the postoperative radiograph demonstrate the screws broken secondary to non-union of femoral neck fracture. (C) In the revision surgery, after partial removal the implants, the THA(Total Hip Replacement) was performed. Unfortunately, two washers of screws were left.