

Surgical Results and Complications of Developmental Dysplasia of the Hip - One Stage Open Reduction and Salter's Osteotomy for Patients between 1 and 3 Years Old

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Background: Reports of the efficacy of Salter's osteotomy have often been based on groups of patients with complex disease conditions and treatment. The purposes of this study were to document the results of patients with well-defined conditions, focusing on the onset and sequelae of osteonecrosis.

Methods: The study participants consisted of 63 patients with unilateral hip dislocation who had undergone one-stage open reduction and Salter's innominate osteotomy between the ages of 1 and 3 years. The results were evaluated clinically by McKay's classification and radiologically by the modified Severin's classification. Early signs of osteonecrosis were identified by neck widening, epiphysis fragmentation, and presence of a metaphyseal growth disturbance line in the first year after the operation.

Results: After a follow-up of 10 years on average, good clinical and radiographic results were noted in 89% and 92% of the patients, respectively. Osteonecrosis occurred in 30 hips, of which 14 subsequently developed femoral head deformity. Residual dysplasia was noted in 5 hips, mostly resulting from late-onset coxa valga. Eighty-five percent of the hips without osteonecrosis and 53% of the hips with osteonecrosis ($p < 0.05$) were classified as Severin class 1. No pre-operative factors were found to be associated with the occurrence of osteonecrosis.

Conclusion: One-stage open reduction and Salter's osteotomy was an effective treatment for developmental dysplasia of the hip after walking age. However, parents must be informed of the two major complications, osteonecrosis and residual dysplasia, that can lead to long-term morbidity.

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Key words: developmental dysplasia of the hip, Salter's osteotomy, osteonecrosis

Treatment for developmental dysplasia of the hip (DDH) is early reduction and stabilization of the joint to restore physiological joint development. Although closed reduction has been recommended as

the first-line treatment modality, one study found that 66% of patients required secondary surgery for residual dysplasia.⁽¹⁾ Salter described an innominate osteotomy that redirects the acetabulum to correct

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hip dysplasia and reported good or excellent radiographic results in 92% of patients.⁽²⁾ Open reduction of the hip and Salter's osteotomy have become a popular procedure in treating late presenting DDH in a single attempt.⁽³⁻⁸⁾

The results after Salter's osteotomy are affected by the age of the patient at the time of treatment,⁽³⁾ requirement for open reduction,⁽⁴⁾ previous hip treatment,^(4,9) and bilateral hip treatment.^(3,10) However the efficacy and complications of Salter's osteotomy reported in the literature have often been based on groups of patients with a complex disease condition. Morin et al. reported 180 hips treated by Salter's osteotomy with or without open reduction. The age of the patients at the time of surgery ranged from 1 to 13 years, and the diagnosed conditions included hip dislocation, subluxation, and dysplasia.⁽⁴⁾ Given the complex data reported, it is difficult for parents to have realistic expectations regarding the outcomes and potential problems of the surgery for their child.

Osteonecrosis of the proximal femur is a serious complication that can develop after treatment of DDH. Gage and Winter reviewed 154 hips treated with closed reduction and found osteonecrosis in 51 hips (33%).⁽¹¹⁾ Morcuende et al. reported osteonecrosis in 43% of 93 hips treated with open reduction through an anteromedial approach.⁽¹²⁾ Gulman et al reviewed 52 hips treated with open reduction and Salter's osteotomy and found osteonecrosis in 33 hips (63%).⁽³⁾ The subsequent development of the hip could be significantly hindered by osteonecrosis. The factors that are associated with the occurrence of osteonecrosis require further detailed study.

The purpose of this study was to document the results of a group of late-diagnosed DDH patients with clearly defined disease conditions, age and treatment received. We also analyzed factors that may be associated with osteonecrosis and outcome following osteonecrosis.

METHODS

Patients

We retrospectively reviewed medical records at our hospital of patients who underwent DDH surgery from 1991 to 1998. The inclusion criteria consisted of unilateral dislocation with Tonnis stage II or higher, one stage open reduction and Salter's innominate osteotomy as the first operation performed for DDH

for patients between 1 and 3 years of age, and a minimum follow-up time of 5 years. We excluded patients with neuromuscular disorders or associated syndromes.

Surgery

The operative procedures consisted of open reduction, capsulorrhaphy, and Salter's osteotomy with the modified Smith-Peterson anterior approach to the hip joint. No traction was applied to the hip before the operation. The adductor longus was released by percutaneous tenotomy and the iliopsoas muscle by intramuscular tenotomy at the pelvic rim. The redundant joint capsule was isolated from the surrounding gluteus muscles and the joint exposed with an incision parallel to the acetabular rim. The intra-articular soft-tissue blockage was removed, and the transverse ligament was transected to create space for the reduction. With the femoral head reduced, the joint capsule was trimmed along the acetabular margin and repaired by interrupted sutures to secure the reduction. The innominate osteotomy technique, including exposure, osteotomy, graft harvest, acetabular realignment, and fixation, was performed as described by Salter.⁽²⁾ Patients were immobilized for 6 weeks in a double hip spica cast with the hip maintained at 30° flexion and 45° abduction.

Outcome measures

Postoperatively, the patients had plain radiographs of the pelvis at 3 months, 6 months, 1 year, and annually thereafter. Pain, limping, and the range of motion of the hip were recorded at follow up visits. We used McKay's classification for clinical outcome.⁽⁹⁾ The results were rated excellent or good if hips were stable and painless with a negative Trendelenburg sign. The results were rated fair if there was a positive limp or Trendelenburg sign, or moderate limitation of hip motion. A poor result was an unstable hip and severe motion limitation. Failure was a dislocated hip.

We assessed radiographs taken in the first year after surgery for early signs of osteonecrosis of the proximal femur, including broadening of the femoral neck, fragmentation of the femoral head by Salter's criteria,⁽¹⁰⁾ and presence of a growth disturbance line in the metaphyseal region as described by O'Brien et al.⁽¹³⁾ The late consequences of osteonecrosis were classified using the system of Kalamchi and

MacEwen.⁽¹⁴⁾ Kalamchi type 1 osteonecrosis involves the femoral epiphysis only, while the other types involve the physis. Type 2 osteonecrosis interferes with lateral physis growth and results in coxa valga. Type 3 osteonecrosis interferes with central physis growth and results in coxa brevia and vara. Type 4 osteonecrosis interferes with the whole physis and epiphysis and results in coxa plana and magna.

Final follow-up pelvic radiographs were used to evaluate the outcome using the modified Severin's classification.^(15,16) An excellent result (class I) was a spherical femoral head with a center-edge angle > 19 degrees. A good result (class II) was moderate deformity at the proximal femur with a center-edge angle > 19 degrees. A class III hip had dysplasia without subluxation and a center-edge angle between 15 and 19 degrees. A class IV hip had persistent subluxation with a center edge angle < 10 degrees. A class V hip had the femoral head in a false acetabulum. A class VI hip had redislocation. We also used the acetabular index and the femoral head coverage ratio to demonstrate the effects of surgery. The femoral head coverage ratio is the percentage of the width of the femoral head metaphysis within the acetabulum divided by the width of the whole femoral head metaphysis. This ratio ranges from zero, indicating complete dislocation, to 100%, indicating that the whole femoral head is within the acetabular fossa.

Factors associated with osteonecrosis and statistics

Osteonecrosis is a major complication following surgery for DDH, hindering the subsequent development of the hip. The occurrence of early signs of osteonecrosis served as the independent variable. Factors that may be associated with the occurrence of osteonecrosis included the age of the patient at the time of operation, gender, Tonnis grading of hip displacement,⁽¹⁷⁾ preoperative acetabular index, and previous failed closed reduction. There were 4 grades of hip displacement in Tonnis grading according to the position of the capital femoral ossification center in relation to the superior acetabular rim. In grade 1 displacement, the ossification center was medial to a vertical line through the acetabular rim. In grade 2, the ossification center was lateral to the vertical line but below the acetabular rim. In grade 3, the ossification center was level with the acetabular rim. In grade 4, the ossification center was above the superior

acetabular rim.

An independent *t*-test was used for continuous variables, and a chi-square test was used for categorical variables to identify the factors most likely to be associated with the occurrence of osteonecrosis.

RESULTS

A total of 74 children underwent one-stage surgery for unilateral DDH from 1991 to 1998 in our hospital. Of these, 11 were not included in the study because of missed preoperative radiographs in 4 children and inadequate follow-up in 7 children. The other 63 children (5 boys and 58 girls) constituted the study population. The left hips were affected in 40 children and the right in 23 children. The average age of the patients at the time of surgery was 1 year, 9 months (range, 1 year, 6 months to 2 years, 9 months). Sixty of the 63 surgeries were performed by one surgeon. Fifteen of the 63 patients had undergone a failed attempt at closed reduction before the surgery. In these 15 patients, the failed procedure had been performed at a mean age of 15 months, and subsequent open reduction and Salter's osteotomy was performed at a mean age of 18 months. At the time of the latest follow-up, the average age of the patients was 11 years, 10 months (range, 6 years, 8 months to 15 years, 9 months), and the mean duration of follow-up was 10 years (range, 5 years to 14 years).

Table 1 lists the radiographic parameters measured pre- and postoperatively. Acetabular dysplasia as indicated by the acetabular index and hip displacement as indicated by the head coverage ratio were

Table 1. Average Radiographic Data from 63 Children with One-stage Surgery for Unilateral Developmental Dysplasia of the Hip

	Pre-Op (age 1.8 yrs)	Post-Op 6 months (age 2.3 yrs)	Post-Op 1 year (age 2.8 yrs)	Post-Op 10 years (age: 11.8 yrs)
Acetabular index (°)	35.4 (23.0)	17.0 (20.5)	17.0 (19.5)	12.6* (13.6)
Head coverage ratio (%)	0 (73)	96 (81)	95 (84)	90 (87)

*: The acetabular index was not measured in patients whose triradiate cartilage was closed. Data from the contralateral unaffected hips are in parentheses.

corrected by the operation, and the correction was maintained during an average follow-up period of 10 years. Using repeated measures ANOVA, the pre-operative data were significantly different from the three postoperative measurements ($p < 0.001$). Data from the latest follow-up were significantly different from data 6 months and 1 year after the operation. Data from 6 months and 1 year postoperatively were not significantly different (Table 1).

Fragmentation of the capital epiphysis, broadening of the femoral neck, or presence of the metaphyseal growth disturbance line was observed in 30 of

the 63 hips (48%). Sixteen of the 30 hips with early signs of osteonecrosis recovered to spherical femoral heads in 2 years and were classified as Kalamchi type 1 osteonecrosis. The other 14 hips had residual deformity of the femoral head, including coxa vara in 13 hips (Kalamchi type 3) and coxa valga (Kalamchi type 2) in 1 hip. At the latest follow-up, the 16 hips that recovered to spherical head (Kalamchi type 1) had center-edge angles > 20 degrees and were graded as Severin's I hips. The 13 hips with coxa vara and brevis were subsequently graded Severin's class II hips (Fig. 1). The hip with

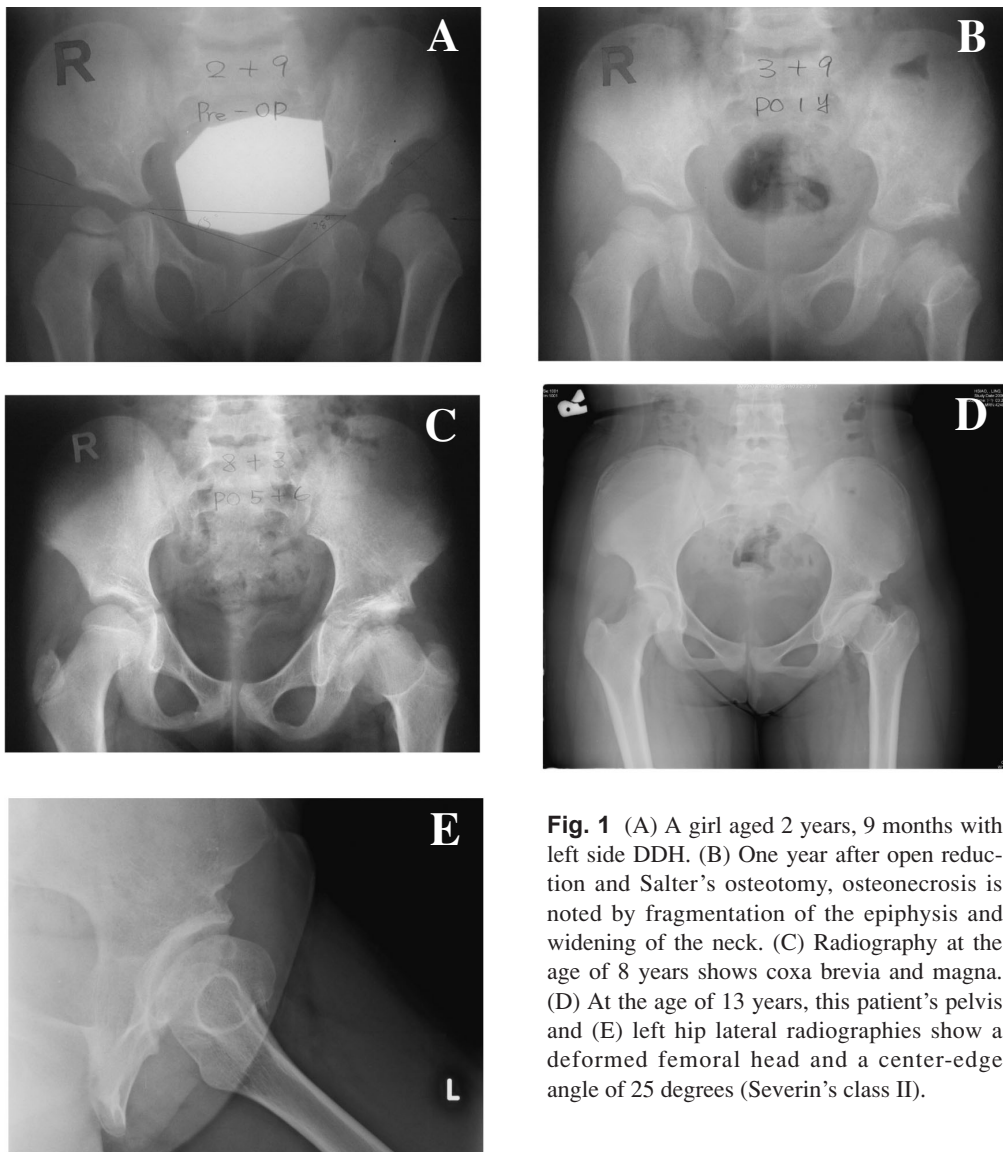


Fig. 1 (A) A girl aged 2 years, 9 months with left side DDH. (B) One year after open reduction and Salter's osteotomy, osteonecrosis is noted by fragmentation of the epiphysis and widening of the neck. (C) Radiography at the age of 8 years shows coxa brevia and magna. (D) At the age of 13 years, this patient's pelvis and (E) left hip lateral radiographies show a deformed femoral head and a center-edge angle of 25 degrees (Severin's class II).

coxa valga developed subluxation and was classified as Severin's class III.

Three of the other 33 hips without early signs of osteonecrosis were treated successfully but developed coxa valga 4 to 6 years later and were graded Severin's class III (Fig. 2) One hip stayed in a subluxated state after the operation (class III). One hip developed chondrolysis when the patient was 11 years old, resulting in a Severin's class II hip. Except for the above 1 class II hip and 4 class III hips, the other 28 hips developed spherical heads and stable hips and were classified as Severin's class I. Thus 85% of the 33 hips without osteonecrosis were classed as Severin's class I, significantly higher than the 53% (16 of 30) of hips with early signs of osteonecrosis (Pearson's $\chi^2 = 10.31, p = 0.001$).

At the time of the latest follow-up, 56 of the 63

patients (89%) had good or excellent hip function according to McKay's classification. Hip function was fair in 7 patients because of limited motion, mainly involving internal/external rotation of the hip. Femoral head deformity was observed in the 7 patients. In terms of the radiological results, 44 hips were classified as Severin's class I; 14, class II; and 5, class III. Good or excellent radiographic results were noted for 58 of the 63 hips (92%). No re-dislocation of the hip occurred. A second Salter's osteotomy was conducted in 2 of the 5 Severin class III hips and the other 3 hips remained in the symptomless dysplastic state.

Since the osteonecrosis was significantly associated with the latest Severin's grading, factors that have been reported to affect the outcome of DDH were analyzed for association with iatrogenic

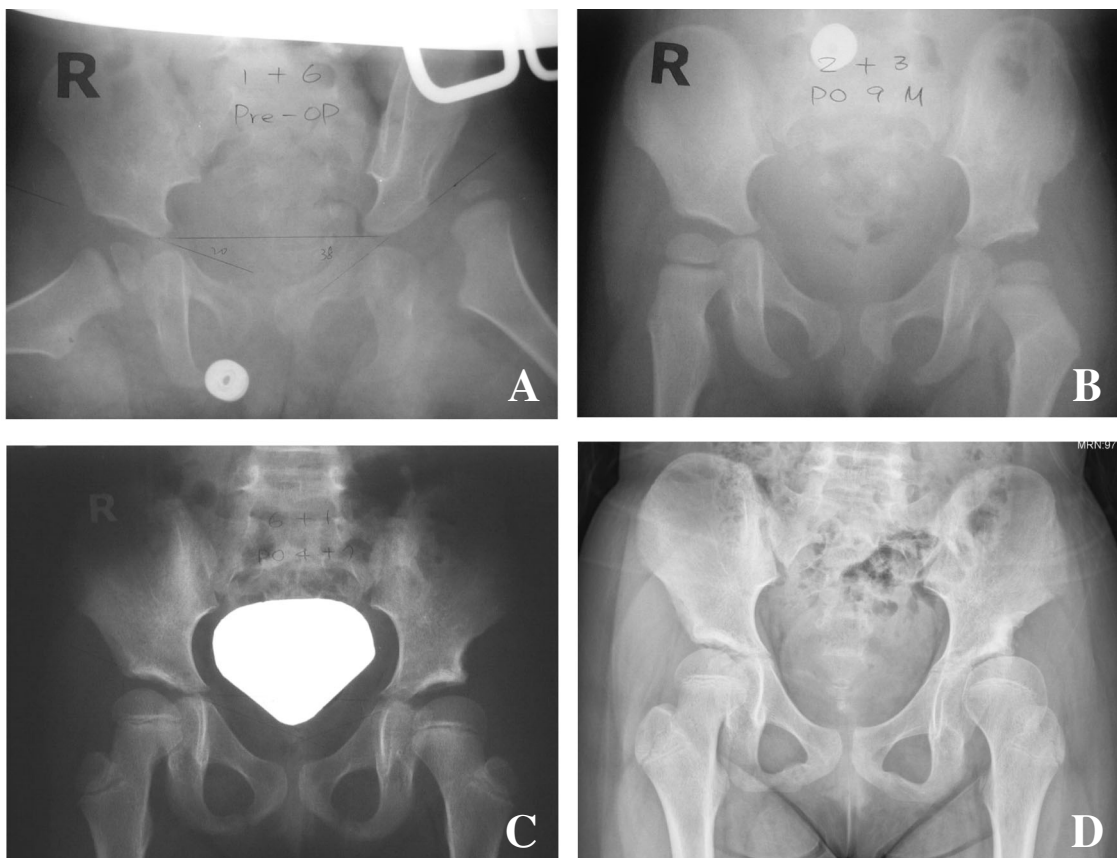


Fig. 2 (A) A girl aged 1 year, 6 months with left hip redislocation after closed reduction and casting. (B) Nine months after open reduction and Salter's osteotomy, there is no evidence of osteonecrosis. (C) Radiography at age 6 years (4.5 years after operation) shows mild coxa valga of the left hip. (D) Radiography at age 11 years shows hip dysplasia from an initially successful operation (Severin class III).

osteonecrosis. The patient's age at the time of operation, gender, severity of hip displacement, preoperative acetabular index, and failed closed reduction were not associated with the occurrence of osteonecrosis (Table 2). Interestingly we found osteonecrosis occurred in 5 of the 15 hips (33%) that had failed closed reduction before the surgery, compared with 25 of the 48 hips (52%) that underwent one stage surgery as the first attempt at treatment. Thus revision surgery was associated with less osteonecrosis than primary surgery, but the difference was not statistically significant (Pearson's chi-square test = 1.44, $p = 0.20$).

DISCUSSION

This study showed good or excellent clinical and radiographic results in 89% and 92% of hips, respectively, at an average of 10 years of follow-up. The results were comparable to previous reports showing that one surgery is an effective treatment.^(3,6) However, two major complications occurred. Residual deformity of the proximal femur, mainly coxa vara and coxa brevia, was noted in 47% of the hips with early signs of osteonecrosis. Those hips remained

stable with a good center-edge angle, but early degeneration resulting from a nonspherical femoral head might occur in the future.⁽¹⁸⁻²⁰⁾ In a group of hips without early signs of osteonecrosis, coxa valga developed 4 to 6 years later, resulting in dysplasia. This could be classified as Kalamchi type 2 growth disturbance, but it was not directly related to the iatrogenic osteonecrosis noted in the first postoperative year.⁽²¹⁾ Together, the complications of residual deformity and residual dysplasia affected 30% of the patients, limiting the longevity of the hip and reducing the value of the DDH treatment.

Osteonecrosis has been thought to result from excessive pressure over the femoral head or vascular insult.^(22,23) It has been postulated to be associated with patient age, degree of displacement, inadequate pre-reduction traction, position of immobilization, and methods of treatment.^(3,11,12,24) Because patient age, unilateral dislocation, and treatment were controlled in this study, no factor was recognized as significantly associated with osteonecrosis.

Repeated reduction of a dislocated femoral head is believed to increase the risk of osteonecrosis.^(4,9) Interestingly, in this study osteonecrosis occurred less often in hips that underwent surgery after a failed attempt at closed reduction. A possible explanation is that one-stage surgery moves the femoral head a long distance and might apply excessive pressure over the cartilaginous capital epiphysis.

The excessive pressure by the one-stage surgery might be relieved by pre-operative traction or femoral shortening, which were not included in our treatment protocol. Haidar et al. used skin traction for 2 weeks before simultaneous open reduction and Salter osteotomy.⁽⁶⁾ Only 3 of 37 hips had femoral head deformity from osteonecrosis and 4 hips had temporary mottling of the femoral epiphysis (19%). Gulman et al., who did not use preoperative traction, reported osteonecrosis in 33 of 52 hips (63%) treated with one-stage open reduction and Salter's osteotomy.⁽³⁾ Comparison with previous reports indicates that preoperative traction may be useful in reducing the rate of osteonecrosis. Further comparative study is required to prove the effectiveness of pre-operative traction in preventing osteonecrosis.

We limited the patient age at the time of surgery to less than 3 years to ensure that the patient disease condition was well defined. A nationwide survey of DDH using the Taiwan National Health Insurance

Table 2. Comparison between Patients with and without Early Signs of Osteonecrosis

	Hips with osteonecrosis (n = 30)	Hips without osteonecrosis (n = 33)	<i>p</i> value
Age at the time of surgery (months)	20.5	20.5	0.99
Sex			
Female	27	31	0.56
Male	3	2	
Tonnis grading			
II	15	18	0.94
III	7	7	
IV	8	8	
Pre-operative acetabular index (degrees)	36.0	34.8	0.46
Previous closed reduction			
Yes	5	10	0.20
No	25	23	

databank showed that 75% of surgically treated patients were between 1 and 3 years of age.⁽²⁵⁾ We focused on this age range to document the results and complications for children with late-diagnosis DDH, who constitute the majority of DDH patients.

A limitation of this study was that all the patients were not followed to skeletal maturity. The good results reported in this study would probably not be sustained with an increasing follow-up period, especially for those patients with Severin's class II hips.^(18-20,26) However, the occurrence of osteonecrosis in the first year after the operation constitutes solid data not affected by the length of follow-up. The fate of a femoral head following osteonecrosis and factors associated with the occurrence of osteonecrosis have clinical significance.

Residual deformity of the proximal femur, mainly coxa vara and coxa brevia, was noted in half of the hips with early signs of osteonecrosis. Those hips remained stable with good center-edge angles, but early degeneration of the hip might occur in the future. Another group of hips without early signs of osteonecrosis developed coxa valga years later, resulting in Severin's class III hips. Both complications limited the hip longevity. Although one stage open reduction and Salter's osteotomy can successfully treat dislocation and dysplasia in DDH after walking age, parents must be informed of the two major complications, osteonecrosis and residual dysplasia, which occurred in 30% of the patients in this study and could lead to long-term morbidity.

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We would like to acknowledge Dr. Zon-Liou Lee, our long-time friend and colleague, whose tireless work, intellect, and dedication were invaluable to the success of our study. Dr. Lee passed away on the January 5, 2010 of a tumor in his brain stem. Throughout his three-year battle with cancer, he inspired us with his resolve to continue his work and his tireless commitment to the field of medicine. A large number of the subjects in this study were his patients, and we are eternally grateful for his contributions.

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先天性髖關節脫位的手術結果及併發症——開放復位合併 Salter's 切骨術施行於 1 到 3 歲的兒童

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- 背景：** Salter 切骨術的療效報告往往基於一群複雜病情的患者，而且接受不同的治療方式，本研究收集一群定義清楚的髖關節脫位且接受相同治療的患者，報告手術長期結果及股骨頭壞死的併發症情形。
- 方法：** 回顧研究 63 位單側髖關節脫位的病患，且於 1~3 歲之間接受開放復位及 Salter 切骨手術。臨床結果評估使用 McKay's 分類，X 光結果以 Severin's 分類作為評估。股骨頭壞死的診斷標準為術後一年內發生股骨頸變寬、骺端粉碎及出現生長阻滯線。
- 結果：** 經過平均十年的追蹤，89% 的病人的臨床結果良好，而 92% 的病人有良好的 X 光結果。30 位病患的股骨頭部發生壞死的情形，其中 14 位後來有殘存的股骨變形。5 位病患有殘存的髖關節發育不良，多來自於後期發生的股骨頸外翻。Severin 第一級的結果發生於 85% 沒有股骨頭壞死的髖關節，而有股骨頭壞死的髖關節僅有 53% ($p < 0.05$)。未發現和股骨頭壞死的發生有關術前因子。
- 結論：** 開放復位合併 Salter 切骨手術能有效治療行走年齡後的髖關節發育不良。但父母應被告知股骨頭壞死及殘存發育不良為此手術兩個主要的併發症，二者會造成長期的關節病變。
- (長庚醫誌 2011;34:84-92)

關鍵詞： 髖關節發育不良，Salter 切骨手術，股骨頭壞死