The Remodeling of the Neck-Shaft Angle after Proximal Femoral Varus Osteotomy for the Treatment of Legg-Calve-Perthes Syndrome

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Objective: *To study the corrections of the neck-shaft angle (NSA) and the related clinical symptoms after proximal femoral varus osteotomy (PFVO) for the treatment of Legg-Calve-Perthes syndrome (LCPS).*
Material and Method: *Retrospective cohort study. Consecutive cases of LCPS treated at Lerdsin General Hospital during 1999 to 2010 were reviewed. The patients were excluded if they had less than 3 years of follow-up, there was incomplete data, and bilateral involvement. Demographic data and clinical symptoms were collected. The NSA were measured before and after PFVO.*
Results: *Twenty-two patients were treated by PFVO. The mean pre-operative NSA was 140 degrees. The mean varus angle created by PFVO was 20 degrees. The mean post-operative NSA at 6 weeks, 6 months, 1 year, 2 years and 3 years were 119, 119, 118, 120 and 120 degrees respectively. No statistical difference between the mean NSA at 6 weeks and 3 years (p = 0.65). There were 9 patients whose NSA increased more than 5 degrees at 3 years after operation. This group of patients had a more varus angulation at the early post-operative period. No physeal arrest was detected in any cases at 3 years after PFVO. No correlation between the NSA and pain or limitation of the hip abduction were observed. There were 3 patients, who had NSA less than 110 degrees after PFVO, had limping gait.*
Conclusion: *It is difficult to predict the degree of remodeling of an individual hip after proximal femoral varus osteotomy. Special attention should be paid to avoid excessive varus of the proximal femur less than 110 degrees whenever PFVO is performed.*

Keywords: *Legg-Calve-Perthes syndrome, Perthes, Neck-shaft angle, Proximal femoral varus osteotomy, Remodeling, Treatment*

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Legg-Calve-Perthes' syndrome (LCPS) is a condition which an avascular event affects the capital epiphysis of the femur. After that avascular event passed, the femoral head turns soft and susceptible to collapse. Proximal femoral varus osteotomy (PFVO) is one of the treatment options to make the femoral head contained in the acetabulum during the biological plasticity period.

The maximum degree of varus angulation and the remodeling potential of the neck-shaft angle (NSA) after PFVO is not a consensus. The amount of varus angulation should be limited to that needed to position the femoral head just under the lateral rim of the acetabulum. Talkhani(1) concluded that in the circumstances where the surgeon may have to increase the varus of the femur to less than 90 degrees to obtain containment one can still expect the femur to remodel satisfactorily. Weiner(2) allowed up to 100 degrees of post-operative neck-shaft angle. Moreover, the bone remodeling in response to surgical varus was unpredictable. Up to 90 degrees or more varization after PFVO for LCPS were able to remodel with time(3). It is questioned if the neck shaft angle remains varus and causes any long term problems.

The purpose of the present study was to focus on the corrections of the neck shaft angle and the related clinical symptoms after proximal femoral varus osteotomy for the treatment of LCPS.

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Material and Method

A retrospective cohort study was performed. Medical records and plain radiographs of the hips were reviewed. The present study population was gathered from LCPS patients treated in Lerdsin General Hospital during 1999-2010. The inclusion criteria were LCPS patients who were treated with PFVO. The patients who had followed-up less than 3 years, incomplete medical data or radiographs and bilateral involvement were excluded. Demography and clinical data were collected from medical records including age at first visit, gender, side, weight, height and clinical symptoms (pain, limping gait and range of hip abduction). The poor prognosis hips without hinge abduction in initial and fragmentation stage will received PFVO. The poor prognosis hips included: Catterall 3 and 4, Salter-Thompson B, lateral pillar C, at risk clinically and radiographically (regardless of the disease extent), age younger than 8 years with head deformity or age older than 8 years with or without head deformity (Catterall group 2, 3 and 4, with or without at-risk signs; lateral pillar B and C; Salter-Thompson B). There were 22 patients (22 hips) who were treated with PFVO. AO 90-degrees osteotomy plates were used as fixation devices in 19 hips and external fixators were used in 3 hips. All of fixation devices were removed after clinical and radiographic union.

Plain radiographs of both hips in AP view were taken with x-ray beam 60 inches from the center of both hips. The patella of both knees were pointed forward. The NSA of both affected and normal hips were measured using goniometer. Centers of the width of the neck and the width of shaft of the femur were identified. Two lines were drawn passed the centers of the width. The angle between 2 lines were measured by 2 residents (Fig. 1). The NSA was measured sequentially as followed: preoperative period, 6 weeks, 6 months, 1 year, 2 years, 3 years postoperatively and annually until the last visit.

Good remodeling was graded as increased of NSA after PFVO more than 5 degrees at 3 years post-operation, while the change of NSA less than 5 degrees was graded as poor remodeling.

Two independent observers measured all of the radiographs. The first and second measurements were done by one observer at 12 months interval to demonstrate intraobserver correlation. The other measurement was done by another observer to demonstrate interobserver correlation.

Mean, standard deviation, range were used for descriptive variables. Paired t-test was used to compare NSA at different periods of time. Pearson correlation was used for correlating the clinical symptoms and NSA. A p-value of < 0.05 was considered significant. Interobserver and intraobserver reliability analysis using the intraclass correlation coefficient were performed to determine consistency among raters. There was no external funding in the present study.

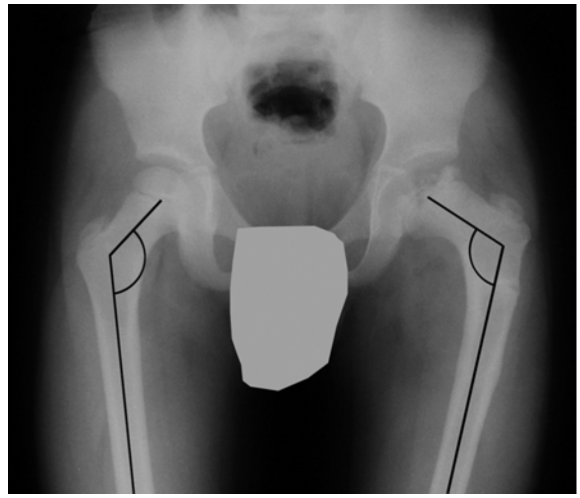

Fig. 1 AP radiograph of the hips showed neck-shaft angle

Results

There were 22 patients (22 hips) enrolled in the present study. There were 17 males and 5 females. The mean age at the first visit was 8.8 years (SD 2.6, range 4.9 to 13.9). The mean height was 130.1 centimeters (SD 16.5, range 102 to 167). The mean body weight was 32.3 kilograms (SD 12.2, range 20 to 66). The mean body mass index was 18.8 (SD 4.6, range 11.1 to 27.8). The involved hips were right side in 9 patients and left side in 13 patients. Five of 22 patients underwent PFVO during initial stage and 17 patients underwent PFVO during fragmentation stage (Table 1).

The mean preoperative NSA of the affected sides and normal sides were 140 degrees (SD 8, range 128 to 159) and 138 degrees (SD 8, range 127 to 156) respectively. The mean NSA at 6 weeks (represented early postoperative NSA after PFVO), 6 months, 1 year, 2 years and 3 years after operation of the affected sides were 119 degrees (SD 9, range 104 to 145), 119 degrees (SD 11, range 102 to 147), 118 degrees (SD 11, range 98 to 147), 120 degrees (SD 11, range 104 to 150) and 120 degrees (SD 11, range 102 to 150) respectively. The amount of varus angle created by osteotomy was measured at 6 weeks post-operatively. The mean varus angle created was 20 degrees (SD 9, range, 8 to 50). There was no statistically significant different between the mean of NSA at 6 week and 3 years postoperatively ($p = 0.65$) (Table 2).

Table 1. Demographic data

Number of patients	22
Mean age at the first visit (years)	8.8 ± 2.5 (4.9-13.9)
Male: Female	17: 5
Right: Left	9: 13
Weight (kg)	32 ± 12 (20-66)
Height (cm)	130 ± 16 (102-167)
BMI	19 ± 5 (11-28)
Skeletal age (years)	7.6 ± 3.6 (3-16)
Waldenstrom	
Initial	5
Fragmentation	17
Reossification	0
Healed	0
Catterall	
1	3
2	7
3	5
4	7
Lateral pillar	
A	1
B	11
C	10
Type of fixation: 90 degrees osteotomy plate	19
External fixator	3
Mean paternal age (years)	41.6 ± 5.9 (32-52)
Mean maternal age (years)	36.8 ± 4.8 (29-45)

Table 2. Mean of the neck-shaft angle at different periods (degrees)

	Affected hips	Normal hips
Initial	140 ± 8 (128-159)	138 ± 8 (127-156)
6 wk post-op*	119 ± 9 (104-145)	139 ± 8 (127-154)
6 mo post-op	119 ± 11 (102-147)	138 ± 9 (127-157)
1 yr post-op	118 ± 11 (98-147)	138 ± 8 (123-151)
2 yr post-op	120 ± 11 (104-150)	140 ± 9 (126-155)
3 yr post-op*	120 ± 11 (102-150)	139 ± 9 (126-155)

* No statistical different between the neck-shaft angle at 6 week postoperative period and 3 year postoperative period (p = 0.65)

There were 15 patients whose NSA at 3 years postoperatively increased compared with NSA at 6 weeks postoperatively. The mean NSA change was 7 degrees (SD 5, range 1 to 18). There were 9 patients whose NSA increased more than 5 degrees and were defined as good remodeling group. The mean age was 9.2 (6.2-12.8) years old and there were 8 males and 1 female in this group. The rest of the patients were defined as poor remodeling group. The NSA were not increased in 7 patients. Physeal arrest might be a cause of poor development of the proixmal femur. There was no physeal arrest of the proximal femoral physis detected in all cases at 3 years postoperatively (Fig. 2).

Concerning the mean NSA of the good and poor remodeling group in the early post-operative period, the mean NSA of the good and poor remodeling groups at 6 weeks post-operation were 115 degrees (SD 8, range 104 to 135) and 122 degrees (SD 13, range 114 to 145) respectively. There were statistical significance between the two groups (p = 0.04). The good remodeling group had a more varus angulation at the early post-operative period (Table 3).

The number of patients who had clinical symptoms decreased over time. Pain was initially represented in 16 patients (73%). Only 1 patient (5%) had pain at 3 years after operation. Limping was initially found in 19 patients (86%) and the number decreased to 9 (41%) at 3 years. Compared to normal hip, the affected hip initially had a smaller arc of abduction in 20 patients (91%). Only 5 patients (23%) were found to have limitation of abduction at 3 years of followed up (Table 4).

There was a patient who had thigh pain accompanying with limping at the affected side at 3 years postoperatively. This patient initially presented with pain and limping. The initial radiographs showed the femoral head was in fragmentation stage, Catterall group 3, and Pillar B. The 2 head-at-risk signs were calcification lateral to physis and lateral subluxation of the femoral head. The patient had a pain free period for 1 year before the pain started, not at the beginning. The pain was mild and the patient did not need any medication to relieve the pain. The pain aggravated by strenuous activities. The patient had no difference in the neck shaft angle of the affected and the normal sides at 3 year-postoperative period. There was 30 degrees difference in the hip abduction between the affected and the normal sides.

At 3 years after operation, most of patients had equal hip abduction of the affected and the normal side. There were 5 patients who had hip abduction on the affected side less than that of the normal side. The hip abduction different was in the range of 15 to 30 degrees. The mean NSA at 3 years after operation of the full range of hip abduction group and the limited hip abduction hip group were 118 and 127 degrees respectively. There was no statistical different of the mean NSA of these 2 groups ($p = 0.27$).

It was hard to correlate the persisting clinical symptoms at 3 years after operation and the large amount of varus of the proximal femur. Pain, limping and limited hip abduction in the group of patients with NSA less than 110 degrees was not statistically significant from the rest of the patients at 3 years follow-up (pain; $p = 0.25$, limping; $p = 0.68$, limited hip abduction; $p = 0.63$) (Table 5). Despite the statistically insignificance, there was a remark on the limping symptom. All of the 3 patients who had NSA less than 110 degrees had limping. Meanwhile only 6 of 19 patients who had NSA not less than 110 degrees had this problem.

The reliability of radiographic measurements of the present study showed good agreements. The intraobserver reliability for the raters was found to be 0.80 $p < 0.01$, 95% CI (0.59, 0.91). The interobserver reliability for the raters was found to be 0.78 $p < 0.01$, 95% CI (0.54, 0.90).

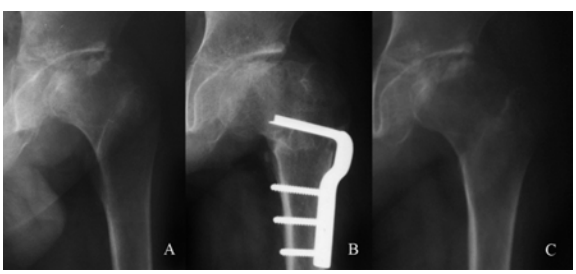

Fig. 2 Radiographs of a hip showed gradual changed of the neck-shaft angle. (A Before surgery, B 6 weeks after PFVO, C 3 years after PFVO)

Discussion

Containment is currently one of the treatment options for Legg-Calve-Perthes syndrome. The proximal femoral varus osteotomy had been claimed to make hips permanently contained without worrying about time to discontinue the containment treatment. The amount of varus that is needed to make the hip contain depends on the severity of the involvement. The adverse consequences of a varus hip are questionable.

It is controversial if the NSA will change after varization of the proximal femur. According to Heikinnen[4], results of varus rotation osteotomy with

Table 3. Comparison the mean of neck-shaft angle at 6 week postoperative period between the good and poor remodeling group

	*Good remodeling	+Poor remodeling	
Number (percentage)	9 (41)	13 (59)	
Mean of NSA (degrees)	115 (104-128)	122 (114-145)	p = 0.04

* Good remodeling was defined as increased of NSA more than 5° after osteotomy
+ Poor remodeling was defined as no increased or increased of NSA 1° to 5° after osteotomy

Table 4. Number (percentage) of patients with clinical symptoms at different periods

Symptoms	Initial	At 3 years of follow-up
Pain	16 (73)	1 (5)
Limping	19 (86)	9 (41)
Decreased abduction	20 (91)	5 (23)

Table 5. Numbers of patients with clinical symptoms and neck-shaft angle at 3 years after operation

NSA (deg)/Symptoms	< 110	≥ 110	p-value
Limping	3*	6	0.25
No limping	0	13	
Pain	0	1	0.68
No pain	3	18	
Limit abduction	1	4	0.63
No limit abduction	2	15	

*Remark: all patients with NSA less than 110 degrees had limping gait

follow-up ranging from 2 to 8 years in 65 patients were studied. Remodeling was 10 degrees in average and the optimal postoperative NSA was 100-110 degrees. Talkhani[1] reported 16 patients with a mean follow-up of 7 years. Patients who had smaller postoperative NSA showed better remodeling potential. Up to 90 degrees or more varization after surgery was thought to be able to remodel with time. Contrary, in the present study of 52 LCPS patients, Karpinski[5] reported that the greater the surgical varus, the less likelihood that the NSA return to within 10 degrees of what it was before surgery. Only about one third (38%) of that study did the NSA return to normal. The bone remodeling in response to surgical varus was unpredictable. In the present study, there was only one hip that had postoperative NSA less than 110 degrees. The 6 weeks post-operative NSA was 104 degrees and it remodeled to 111 degrees at 3 years after surgery. The NSA remained the same when this patient reached skeletal maturity at 7 years post-operatively.

There might be many factors related to the remodeling potential of the proximal femur. There was a wide range of correction of the varus angle of the proximal femur. Though two third of the hips in the present study had correction of the varus angle from 1 to 18 degrees, only 9 of 22 hips had a substantial correction more than 5 degees. The 6 weeks post-operative NSA of the good remodeling group had more varus angle after surgery than the poor remodeling group. Since the operation did not directly disturb the proximal femoral physis or the femoral neck, the changing mechanics to the proximal femur might stimulate the proximal femur to restore its original anatomy[5,6].

Proximal femoral physeal arrest may be a cause of growth disturbance of the proximal femur. There was no physeal arrest detected in both good and poor remodeling groups in the present study. The poor remodeling potential was less likely related to the growth disturbance of the proximal femoral physis. Physeal arrest alone may not be the sole cause of poor remodeling.

Age at diagnosis and at operation might not directly relate to the remodeling potential. Talkhani[1] found that the remodeling process was independent of the patient's age of diagnosis and age at surgery. Karpinski[5] found that there was no relationship between the residual surgical varus and the age of the patient at operation. Though the mean age at diagnosis of the good remodeling group was slightly older than that of the poor remodeling group (9.2 vs. 8.5 years) in the present study, there was no statistical different of this number.

It had long believed that female patient had a poorer outcome due to a shorter time for the hip to remodel before patient reached skeletal maturity[8]. Though, there was small proportion of female patients in the present study, 4 of 5 patients fell into poor remodeling group. The mean age of the female was not different from the male patients (8.7 and 8.8 years old respectively). The longer period of remaining growth might not be the substantial cause of poor prognosis in female patients.

It is interesting how long the remodeling process would continue. Herceq[9] studied NSA of 124 LCPS patients after upper femoral varus osteotomy. He found that the NSA was gradually corrected. The average amount of the NSA remodeling was 41% of the post-operative NSA within the first 3 years. And the final amount of remodeling was 65% at 7 years postoperatively. Most of remodeling process appeared within 3 to 4 years. The mean NSA at the second and third year of the present study was almost constant.

It is important to bear in mind that the correction of the NSA could not be predicted in an individual hip. More than half of the hips in the present study had a very small amount of remodeling. In a study of Kim[3], about one third of the patients (19 of 52 patients) had no improvement of the varus angulation. The effect of the surgery to the affected hip and the long term consequences of the permanent deformity should be balanced.

To the authors knowledge, no study had concluded about the relationship between the NSA and the pain, limping and hip range of abduction. Since the number of hips included in the present study was small, the numbers of patients with pain, limping and limited range of hip abduction were limited. There was no correlation between the above mentioned clinical symptoms and the NSA or the amount of the remodeling could be detected. But there was a remark on the limping symptom. All of the patients with NSA less than 110 degrees at 3 years of follow-up had limping. From this evidence, it might imply that the NSA less than 110 degrees at the time of surgery should be cautious.

There were some limitations of the current study. Firstly, a common radiographic measurement error was related to the standardization of the position of the hips. The NSA was best measured in neutral rotation. However, the margin of error might be narrow. A cadaveric study by Kay et al provided that a measurement of the NSA was relatively stable between the arc of 20 degrees of external rotation and 50 degrees of internal rotation[10]. The range of acceptable arc of rotation was wide and had small effect to the results. Secondly, the geometry of the proximal femur was irregular and might affect the reliability of the measurement method. However, the intraclass correlation coefficient for both intra- and inter-observer showed good agreements. Thirdly, the continuation of the remodeling process might last until skeletal maturity, a longer period of observation might be needed.

In conclusion, it is difficult to predict the degree of remodeling of an individual hip after proximal femoral varus osteotomy. Special attention should be paid to avoid excessive varus of the proximal femur less than 110 degrees whenever PFVO is performed. If the PFVO alone could not make the femoral head contain enough in severe case, additional surgical procedures on the pelvic side such as innominate osteotomy or shelf arthroplasty should be considered.

Acknowledgement

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Potential conflicts of interest

None.

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***การปรับเปลี่ยนของมุม** neck-shaft angle **ของกระดูกขาส่วนต้นภายหลังการผ่าตัด** proximal femoral varus osteotomy **เพื่อรักษาโรค** Legg-Calve-Perthes syndrome*

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วัตถุประสงค์: *เพื่อศึกษาว่า neck-shaft angle (NSA) ของกระดูกขาส่วนต้นมีการปรับเปลี่ยนหรือไม่ และมีความสัมพันธ์กับอาการทางคลินิกอย่างไร หลังการผ่าตัด proximal femoral varus osteotomy (PFVO) เพื่อรักษาโรค Legg-Calve-Perthes syndrome (LCPS)*

วัสดุและวิธีการ: *เป็นการศึกษาย้อนหลังในผู้ป่วยซึ่งมารับการรักษาที่โรงพยาบาลเลิดสินระหว่างปี พ.ศ. 2542-2553 ผู้ป่วยซึ่งมาติดตามการรักษาไม่ถึง 3 ปี, มีข้อมูลไม่สมบูรณ์ และเกิดโรคในสะโพกทั้ง 2 ข้าง จะถูกตัดออกจากการศึกษา ข้อมูลด้านประชากรทั่วไป ข้อมูลทางคลินิก และค่าของมุม NSA ได้รับการบันทึกทั้งก่อนและหลังการผ่าตัด*

ผลการศึกษา: *มีผู้ป่วย 22 คน ได้รับการผ่าตัด PFVO มุม NSA เฉลี่ยก่อนการผ่าตัด 140 องศา การผ่าตัดทำให้มุมนี้ลดลงเฉลี่ย 20 องศา มุม NSA เฉลี่ยหลังการผ่าตัด 6 สัปดาห์, 6 เดือน, 1 ปี, 2 ปี, 3 ปี เท่ากับ 119, 119, 118, 120 และ 120 องศาตามลำดับ ค่ามุมเฉลี่ย NSA ที่ 6 สัปดาห์ และ 3 ปีไม่แตกต่างกันทางสถิติ มีผู้ป่วย 9 ราย ที่มีค่าเฉลี่ยมุม NSA เพิ่มมากกว่า 5 องศา ในผู้ป่วยกลุ่มนี้มุม NSA ช่วงต้นหลังผ่าตัดลดมากกว่าผู้ป่วยกลุ่มที่เหลือ ไม่พบการหยุดการเติบโตของ physis ภายหลังการผ่าตัด 3 ปี ไม่พบความสัมพันธ์ระหว่างค่ามุม NSA และอาการปวดหรือการกางข้อสะโพกลำบาก ผู้ป่วย 3 รายที่มีมุม NSA น้อยกว่า 110 องศามีการเดินกะเผลก*

สรุป: *การพยากรณ์การปรับเปลี่ยนมุม NSA ภายหลังการผ่าตัด PFVO ทำได้ยาก หากมีการผ่าตัดดังกล่าวพึงระวังไม่ให้เกิดการ varus ของกระดูกขาส่วนต้นน้อยไปกว่า 110 องศา*