Mid-term clinical result of femoral varus osteotomy combined with Pemberton osteotomy in treating spastic hip subluxation

Jie Wen, Hong Liu, Sheng Xiao, Xin Li, Ke Fang, Zhongwen Tang, Shu Cao and Fanling Li

Hip subluxation in ambulant children with cerebral palsy may lead to limited walking and pain. This study aimed to introduce the indications and methods of femoral varus osteotomy combined with Pemberton osteotomy in treating spastic hip subluxation to evaluate the interim clinical result and outcome and to discuss its corrective mechanism and orthopedic effect. A total of 23 children with spastic hip subluxation, who underwent femoral varus osteotomy combined with Pemberton osteotomy were selected. The clinical effects were evaluated according to the migration percentage, acetabular index, proximal femur neck shaft angle (NSA), and Melbourne Cerebral Palsy Hip Classification System (MCPHCS). The median migration percentage was 55 (50, 75) before operation, 20 (0, 30) at postoperative 1 year, and 22 (5, 32) at last follow-up. The median acetabular index was 30° (25°, 40°) before operation, 20°(15°, 26°) at postoperative 1 year, and 20° (15°, 25°) at last follow-up. The median NSA was 145 (138, 153) before operation, 117 (107, 126) at postoperative 1 year, and 118 (110, 125) at last follow-up. The MCPHCS grade 4 counts 23 (100%) before operation, grade 3 counts 20 (87.0%), grade 2 counts 2 (8.7%) and grade 1 counts 1 (4.3%) at postoperative 1 year, and grade 4 counts 1 (4.3%), grade 3 counts 21 (91.3%) and grade 1 counts 1 (4.3%) at last follow-up. Femoral varus osteotomy combined with Pemberton osteotomy is a good surgical treatment for children with Gross Motor Function Classification System levels I and II and migration percentage greater than 50%. *J Pediatr Orthop B* 29:523–529 Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc.

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Keywords: acetabular index, cerebral palsy, femoral varus osteotomy combined with Pemberton osteotomy, migration percentage, Melbourne cerebral palsy hip classification system, spastic hip subluxation

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Introduction

Children with cerebral palsy have muscle strength imbalance around hip joint and may develop a globally deficient acetabulum; therefore, they are prone to hip abnormalities. Studies have reported that the proportion of hip subluxation or dislocation in children with severe cerebral palsy varies from 2.5 to 59% [1]. Once a child with cerebral palsy has hip dislocation, the ensuing complications include pelvic tilt, scoliosis, hip pain, and others [2]. For ambulant children with Gross Motor Function Classification System (GMFCS) levels I to II, the movement ability is greatly lost and their quality of life declines significantly [3]. Therefore, the selection of an appropriate treatment in such patients in the presence of a danger signal such as hip subluxation is critical. At present, two widely accepted treatment methods are available, including soft tissue surgery and bone surgery; of which, the soft tissue surgery comprises adductor muscle lengthening or tenotomy, iliopsoas muscle lengthening or transposition, and other surgical treatments. Robert *et al*. have suggested that simple soft tissue release in children before the age of 5 years can reduce the occurrence of hip subluxation or dislocation [4]. The bone surgery includes femoral and pelvic osteotomy. The purpose of this study was to evaluate the results of iliopsoas and adductor muscle relaxation combined with femoral varus osteotomy and Pemberton osteotomy for treating spastic hip subluxation in ambulant children with cerebral palsy GMFCS I and II, as measured by changes in the migration percentage, proximal femur neck shaft angle (NSA), Melbourne Cerebral Palsy Hip Classification System (MCPHCS) and acetabular index after surgery, with a minimum 24-month follow-up.

Methods

General information

The inclusion criteria were as follows: (1) ambulant children with cerebral palsy in GMFCS levels I and II; (2) children with migration percentage between 50 and 90%; (3) children who never underwent hip surgery before (including adductor muscle relaxation); and (4) children who were followed up for at least 2 years.

A retrospective analysis of 23 children (15 males and 8 females) in GMFCS levels I and II, who underwent spastic hip subluxation in the Department of Pediatric

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Orthopedics of our hospital, between June 2011 and 2014, was conducted. The median age counts 8.3 (6.1; 12.9) years. Their migration percentage before operation was between 50 and 90%. All children underwent iliopsoas and adductor muscle relaxation combined with femoral varus osteotomy and Pemberton osteotomy, and they were followed up every 3 months for 1 year after operation, and then every 6 months. This study was approved by the ethic committee of our hospital. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was waived by the committee because of the retrospective nature of the study.

Operative methods

The children underwent general anesthesia and were placed in a supine position; a medial inguinal incision centered over the adductor was performed after routine disinfection. First, the adductor longus tendon and partial gracilis muscles were released, the iliopsoas tendon was separated, and the tense iliopsoas tendon was released; then, the intertrochanteric varus osteotomy was performed along the longitudinal incision in the upper lateral thighs, and the anteversion angle of the femoral neck and collodiaphysial angle were corrected. Bikini hip incision was performed, and the periosteum of internal and external iliac bone was stripped to the greater sciatic notch. The curved osteotomy of ilium was performed between the anterior superior and inferior iliac spine to reach the Y-shaped cartilage, and then the distal end of osteotomy was pushed distally, the autologous femoral wedge bone block was inserted in the gap caused by osteotomy on pelvis, and the stability of bone block insertion and the bone coverage of femoral head were examined. A small bone mass was resected from the femur bone. Small portions of autogenous iliac bone and allograft bone were cut and infilled into the space of ilium osteotomy. The femoral osteotomy was secured with an AO blade plate, and the goal was a NSA of 110° to 120° with 15° to 20° of antetorsion. Intraoperative fluoroscopy confirmed that the femoral head reduction was satisfactory, and then the incision was closed.

Postoperative management

After operation, prophylactic antibiotics were given for three days, and hip spica casts were used for all children, for 3 months. After the removal of the plaster, the children began to perform functional training during the day and wore hip abduction braces at night for 1 year after operation. Then, the internal fixation implant removal was performed according to the condition of bone healing at the osteotomy site.

Evaluated parameters

The evaluated parameters included the migration percentage, acetabular index, proximal femur NSA and MCPHCS on pelvic radiograph before operation, at postoperative 1 year, and at last follow-up. For measuring migration percentage on pelvic radiograph, a line was made between both sides of the apex of the inner lower margin of the acetabulum (A line), and a vertical line was made along the upper outer margin of the acetabulum (B line). Migration percentage = Femoral head outside of the B line (c)/total femoral head width (*d*) × 100% (Fig. 1). NSA measure on pelvic radiograph followed the method of Ogata [5].

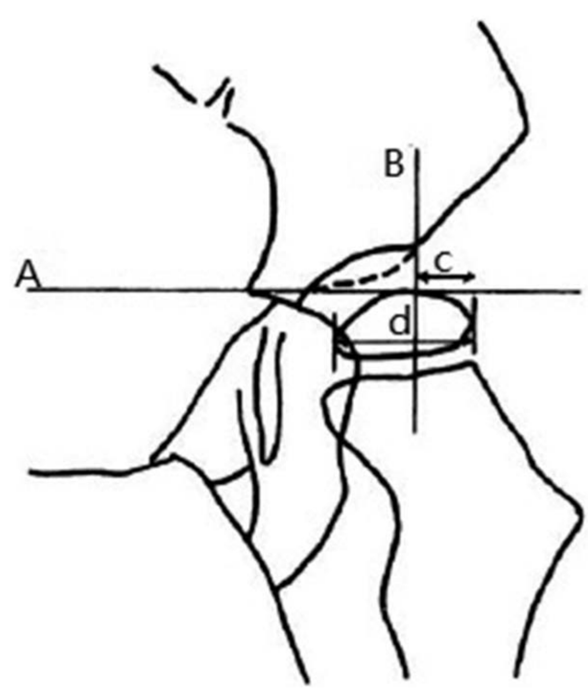
Statistical analysis

The SPSS software was used for statistical analysis. The migration percentage and acetabular index measurement data were expressed as *median values and ranges* (*min; max*). The MCPHCS measurement data were expressed as frequency as it is a categorical variable. The Wilcoxon signed-rank test was used to compare the migration percentage, acetabular index, and NSA on a pelvic radiograph of the two groups. A *P* value less than 0.05 was considered as statistically significant.

Results

All children were followed up for an median of 38 months. Bony union at the osteotomy site was achieved in all of them (Fig. 2). The median migration percentage was 55(50,75) before operation, decreased to 20(0,30) at postoperative 1 year within follow-up, and was 22(5,32) at last follow-up. A significant difference was found in

Fig.1



Measuring method of migration percentage.

the migration percentage before operation, at 1 year, and last follow-up ($P < 0.05$), indicating that hip subluxation improved significantly after operation. Besides, no significant difference was observed in the migration percentage at postoperative 1 year and last follow-up ($P > 0.05$), indicating that the surgical effect was maintained without further aggravation. The median acetabular index was 30°(25°, 40°) before operation, decreased to 20°(15°, 26°) in the follow-up at the postoperative 1 year, and was 20°(15°, 25°) at last follow-up. A significant difference was found in acetabular index before operation, at postoperative 1 year, and last follow-up ($P < 0.05$), indicating that the dysplasia of hip joint improved significantly after operation. Besides, no significant difference was observed in the acetabular index at postoperative 1 year and last follow-up ($P > 0.05$), indicating that the improvement of acetabular development was maintained without further aggravation. The median NSA was 145 (138, 153) before operation, decreased to 117 (107, 126) in the follow-up at the postoperative 1 year, and was 118 (110, 125) at last follow-up. A significant difference was found in NSA before operation, at postoperative 1 year, and last follow-up ($P < 0.05$), indicating that the shape of proximal femur and acetabular improved significantly after operation. Besides, no significant difference was observed in the NSA at postoperative 1 year and last follow-up ($P > 0.05$). The MCPHCS grade 4 counts 23 (100%) before operation, grade 3 counts 20 (87.0%), grade 2 counts 2 (8.7%) and grade 1 counts 1 (4.3%) at postoperative 1 year, and grade 4 counts 1(4.3%), grade 3 counts 21 (91.3%) and grade 1 counts 1(4.3%) at last follow-up, the result of NSA and MCPHCS indicating that the improvement of proximal femur and acetabular development was maintained without further aggravation (Table 1).

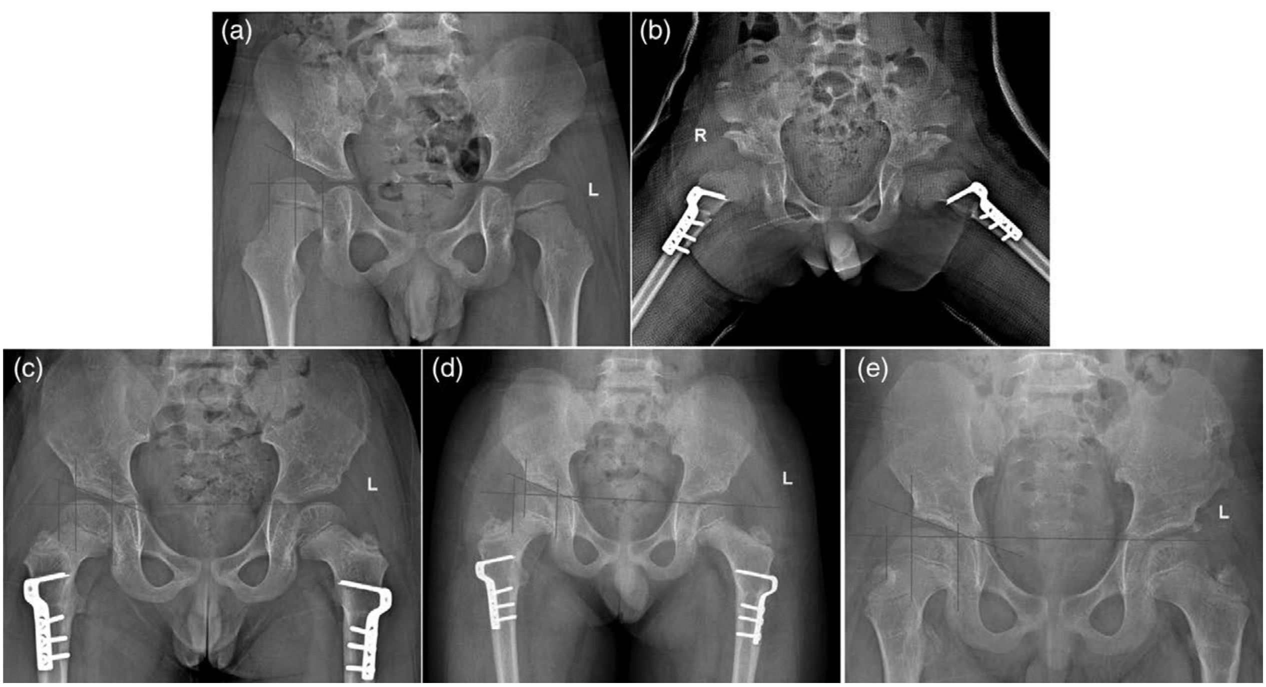
Complications

Among 23 children, one child developed avascular necrosis of the femoral head at the 2-year follow-up (Fig. 3); two children developed mild inguinal incision infection, which healed after dressing change; and three children developed pressure ulcer on the heel while removing plaster at the 3-month follow-up, which healed after dressing change and using antibiotics.

Discussion

Cerebral palsy in childhood is often associated with viral infections at the early stages of pregnancy, physical conditions, environmental factors, and genetic factors before

Fig. 2



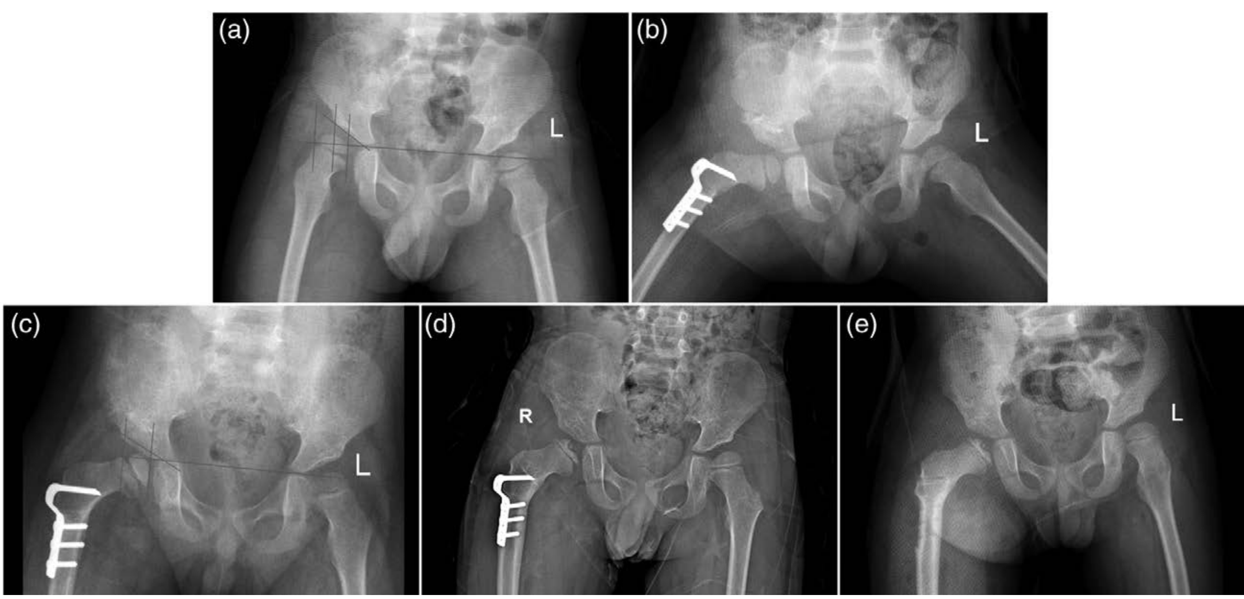
A 9.3-year-old male child. (a) The migration percentage before operation was 50%, the acetabular index was 30° and the MCPHCS was 4. (b) At 2 weeks after operation, the pelvic radiograph showed that the acetabular index of the acetabular osteotomy site reduced at 2 weeks after operation, and hip reduction was satisfactory after femoral varus osteotomy. (c) At the 6-month follow-up, bony union was achieved at the acetabular osteotomy site, and the improvement of migration percentage was better. (d) At postoperative 1 year, bony union was achieved at the acetabular and femur osteotomy site, the migration percentage decreased to 19%, and the position of the bilateral hip joint was satisfactory. (e) At the last follow-up, the femoral internal fixation was removed, the migration percentage increased to 21% in comparison with that before operation, the acetabular index was maintained at 16°, the MCPHCS reduced to 3, and the position of the hip joint was good. MCPHCS, Melbourne Cerebral Palsy Hip Classification System; NSA, neck shaft angle.

Table 1 General information of selected children

					Migration percentage (%)			Acetabular index (degrees)			NSA (degrees)			MCPHCS		
No.	Gender	Age (years)	Unilateral/bilateral	Follow-up/months	BO	PO1y	LF	BO	PO1y	LF	BO	PO1y	LF	BO	PO1y	LF
1	Male	6.5	Bilateral	60	50	19	21	32	20	20	143	123	125	4	3	3
2	Male	10.1	Unilateral	48	52	21	23	35	24	25	145	122	121	4	3	3
3	Male	11.6	Bilateral	42	60	25	27	40	26	25	150	118	120	4	3	3
4	Male	8.3	Unilateral	40	50	20	21	28	21	23	140	121	123	4	3	3
5	Female	6.7	Unilateral	38	52	21	22	30	20	21	147	115	112	4	3	3
6	Female	8.2	Bilateral	38	65	30	32	28	22	22	153	113	113	4	3	3
7	Male	7.6	Unilateral	30	60	0	5	30	21	22	148	116	118	4	1	1
8	Male	9.4	Bilateral	40	58	21	25	35	22	22	142	109	110	4	3	3
9	Male	9.6	Bilateral	36	50	15	18	28	18	20	140	120	121	4	2	3
10	Female	8.2	Unilateral	38	55	20	23	39	25	25	144	119	120	4	3	3
11	Male	7.3	Bilateral	32	60	20	20	25	19	20	147	117	118	4	3	3
12	Male	12.9	Unilateral	37	75	25	28	30	16	15	150	118	115	4	3	3
13	Female	11.3	Unilateral	46	66	19	23	32	20	18	148	121	121	4	3	3
14	Male	6.8	Unilateral	50	60	17	20	34	24	25	145	126	125	4	3	3
15	Female	8.9	Bilateral	52	50	25	28	26	18	18	138	107	110	4	3	3
16	Male	8.8	Unilateral	28	70	28	32	29	18	20	150	112	112	4	3	4
17	Male	7.4	Bilateral	24	50	20	22	35	21	20	144	115	115	4	3	3
18	Female	6.1	Bilateral	36	60	20	21	32	22	24	147	117	118	4	3	3
19	Male	8.2	Bilateral	30	50	18	20	32	20	20	140	120	119	4	3	3
20	Female	9.4	Bilateral	44	55	20	21	25	16	15	143	116	118	4	3	3
21	Female	9.7	Unilateral	50	62	20	25	32	20	20	149	121	120	4	3	3
22	Male	7.4	Unilateral	38	52	15	18	28	15	17	140	116	110	4	2	3
23	Male	9.3	Bilateral	42	50	19	21	30	16	16	141	114	115	4	3	3
Median		8.3		38	55	20	22	30	20	20	145	117	118	NA	NA	NA

BO, before operation; LF, last follow-up; NA, not applicable; PO1y, post operation 1 year.

Fig. 3



A 7.6-year-old male child. (a) The migration percentage before operation was 60%, the acetabular index was 30° and the MCPHCS was 4. (b) At 2 weeks after operation, the pelvic radiograph showed that the acetabular index of the acetabular osteotomy site reduced at 2 weeks after operation, and hip reduction was satisfactory after femoral varus osteotomy. (c) At the 6-month follow-up, bony union was not achieved at the acetabular osteotomy site, the femoral head was completely in the acetabulum, and the migration percentage was 0. (d) At the 2-year follow-up, the femoral head necroses occurred. (e) At the last follow-up, the femoral internal fixation was removed, the migration percentage increased to 5% in comparison with that before operation, the acetabular index was maintained at 16°, the MCPHCS reduced to 1, and the femoral head necroses had not been fully recovered. MCPHCS, Melbourne Cerebral Palsy Hip Classification System.

and after conception [6]. Spastic cerebral palsy accounts for 60–70% of all children with cerebral palsy [7]. As children with cerebral palsy suffered from brain damage, the inhibitory disorder or abnormal control of advanced center on spinal stretch reflex caused stretch reflex to be more sensitive, resulting in muscle spasm [8]. The spasm of iliopsoas and adductor muscle, insufficiency of hip abductors, and poor coverage of the acetabulum may be characteristics of the hip in children with spastic cerebral palsy. Howard *et al.* [9] thought that the strong traction of adductor muscle spasm affected the development of hip abductor, decreased the stimulation of greater trochanter, and affected the development of greater trochanter; besides, the inclination of the femoral neck was blocked, and the femoral neck was everted. Moreover, the adductor spasm led to thigh adduction, resulting in inadequate acetabular femoral head coverage. Furthermore, the acetabulum developed poorly because of abnormal stress.

The natural history of dysplasia of spastic hip usually involved three stages, the risk period, progressive stage, and degeneration stage. In the risk period (6–18 months), the muscle strength imbalance of adductor and abductor muscle and the time delay of weight-bearing walking caused the femoral anteversion angle of the child to be maintained the same as at his/her birth, which failed to decrease gradually as in normal children [10,11]. In the progressive stage (2–18 years), the phenomena such as hip subluxation, muscle contracture, pelvic tilt, and flexion and adduction deformity of the hip, increased angle of femoral anteversion, and coxa valga and acetabular dysplasia with enlarged collodiaphysial angle began to appear [12]. The femoral head moved outward at an increased rate of 10–18% migration percentage per year, subluxation remained in 60% of cases, and the hip dislocation appeared in almost 18% of cases [13]. In the degeneration stage, severe pain in the hip appeared eventually, with nursing difficulties, bedsore, osteoarthritis of the hip joint, secondary femoral fracture, and even scoliosis and pelvic obliquity, leading to a serious decline in the quality of life and disability to perform activity of daily living [14,15].

Recently, many scholars have paid more attention to the correlation between GMFCS classification and dysplasia of the hip joint. Soo *et al.* [16] investigated 323 children with cerebral palsy; of these, 89.7% of children with GMFCS level V developed hip subluxation, while none with GMFCS level I developed hip subluxation. Morton *et al.* [17] showed that the possibilities of hip dislocation in children with GMFCS levels IV and V were obviously higher, which were 30 and 50% after 15 years, respectively. Howard *et al.* [9] defined acetabular dysplasia with hip subluxation as progressive, and Bagg *et al.* [18] suggested that no matter what the GMFCS level was, a possibility that the subluxation in children with migration percentage greater than 50% may progress to complete dislocation was present.

For identifying hip subluxation and dislocation, the currently accepted treatment was based on the migration percentage on pelvic radiographs. Scrutton *et al.* [19] reported that the migration percentage for normal children was within 25%, while 25–33% was a value of risk for abnormal hip joint development. Hagglund *et al.* [20] proposed to use 33% as the starting point for hip subluxation, and when migration percentage reached 52–68%, the compressive stress of femoral head led to the maximum rate and degree of acetabular distortion. An migration percentage of more than 90% can be diagnosed as a complete dislocation. In our study, the median migration percentage before operation was 55%, which decreased to 20% within 1 year after operation, indicating that iliopsoas and adductor muscle relaxation combined with femoral varus osteotomy and Pemberton osteotomy had better efficacy on the improvement of spastic hip subluxation. At the last follow-up, the median migration percentage reached 22%, and the hip joint was maintained in a better position, which was similar to the results of other studies. Gordon *et al.* [21] performed femoral varus rotational osteotomy on 48 children with hip subluxation, including 20 ambulant children. After operation, the Wiberg central-edge (CE) angle improved from 4° to 25°. Hoffer *et al.* [22] followed up 20 children with hip subluxation who underwent proximal femoral varus rotational osteotomy; among these, 15 cases were unilateral, five cases were bilateral, and only one case needed a further operation after follow-up. Canavese *et al.* [23] performed femur varus osteotomy on 27 children with spastic hip subluxation and dislocation; among these, 12 children underwent a contralateral hip operation, and the average migration percentage improved from 48.4% (before operation) to 17.9% and the average acetabular index improved from 51.8° (before operation) to 44°. Dietz and Knutson [24] performed Chiari pelvic osteotomy on 24 children with hip subluxation; at 7-year follow-up, the migration percentage decreased from 93% (before operation) to 19%. In 2006, Debnath *et al.* [25] performed femoral varus osteotomy combined with Chiari pelvic osteotomy on 11 children with painful hip subluxation and dislocation, the follow-up period was about 14 years, and the migration percentage improved from 80.6% (before operation) to 13.7%. Rutz *et al.* [26] performed femoral varus osteotomy combined with modified pemberton pelvic osteotomy on 121 GMFCS II to V patients with hip subluxation and dislocation, the follow-up period was about 7.3 years, and the migration percentage improved from 77% (before operation) to 10%, MCPHCS grade improved from 4 (before operation) to 1, and they suggest that the preoperative migration percentage was the most influential risk factor with respect to postoperative outcome. Our study takes NSA as a indicators of research, which is rare seen in other previous studies mentioned before. In their study, indicators include migration percentage index, CE angle and acetabular index but not NSA. Considering the reason, the requiment of NSA may be very hard as the existance of adduction and spastic of lower limb. All our patients are GMFCS I-II children, it is easier to receive anteroposterior pelvic radiology and lateral roentgenogram radiology than GMFCS III-V patients, but the requirement of NSA is still affected by radiology position and the coordinate degree of patients. In present study, migration percentage, acetabular index, NSA, and MCPHCS in 1 year after surgery are significantly improve than before surgery. In median 38-month follow-up, all the indicators are maintained to improve without any further aggravation.

Whether to perform a unilateral or bilateral operation for unilateral hip abnormalities has been controversial. Silver *et al*. [27], Reimers [28], and Samilson *et al*. [29] suggested that the coverage of contralateral hip was worse after the unilateral operation. Therefore, they recommended performing bilateral operation even if unilateral subluxation or dislocation was present. However, among 27 children who were followed up by Canavese *et al*. [23], 12 children underwent an operation on the contralateral hip at stage 2; and among 48 children who were followed up by Gordon *et al*. [21], only one child underwent an operation on the contralateral hip at stage 2. The follow-up results showed that 32 children adhered to the rehabilitation treatment after operation, although the average migration percentage at last follow-up was 24%. Compared with the migration percentage within 1 year after operation, it had decreased to 21%, and they were both within the normal range. Besides, no child developed poor coverage of contralateral hip. In present study, 11 children underwent a unilateral operation and 12 underwent a bilateral operation, and during the follow-up period, no child who had undergone a unilateral operation required an operation on the contralateral hip. The main reason was that all selected children were with GMFCS levels I and II, that is, they had better walking ability. Therefore, their degree of participation in rehabilitation training was high, and their lower limb spasticity was less severe than those with GMFCS levels III and V. In the study by Canavese *et al*. [23], 12 children needed a secondary operation because they were all with GMFCS levels III and V having severe lower limb spasticity and no walking ability. Therefore, the chances of abnormalities in the contralateral hip were high.

The complications of treatment in spastic hip subluxation included bone nonunion, hip pain, avascular necrosis of the femoral head, hip dislocation, pelvic tilt, scoliosis, and others [30]. Jóźwiak *et al*. [30] believed that the main reason for avascular necrosis was the muscle strength imbalance around acetabulum. Therefore, he suggested adding a muscle strength adjustment operation while performing osteotomy. However, other scholars reported that the proportion of recurrent dislocation or subluxation of hip joint after operation accounted for 5–17% [31–33]. In present study, one case developed avascular necrosis of the femoral head, which might be related to the extent of soft tissue release and insufficient shortening of femur. All cases had good bone healing during the follow-up period; however, three patients developed pressure ulcer on the heel while removing the plaster. Considering the heel was the pressure accumulation point, the heel was padded with a multilayer tissue paper for protection when conducting postoperative plaster fixation, but the pressure ulcer on the heel still appeared. Therefore, at 2 weeks after plaster fixation, the plaster on the heel was opened regularly for checking the skin condition. If the condition was good, the plaster was fixed again, which was helpful in preventing pressure ulcers in children.

In conclusions, femoral varus osteotomy combined with Pemberton osteotomy was a surgical treatment with good clinical result at mid-term follow-up for children with GMFCS levels I and II and migration percentage greater than 50%. The migration percentage, acetabular index, NSA, and MCPHCS improved significantly after operation. During an median of 38-month (24, 60) follow-up, the operation effect was maintained without further aggravation.

Acknowledgements

This study was approved by the ethic committee of Hunan Provincial People's Hospital, the First Affiliated Hospital of Hunan Normal University. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was waived by the committee because of the retrospective nature of the study. Informed consent was waived by the committee because of the retrospective nature of the study.

S.X. conceived and coordinated the study and designed. J.W. performed and analyzed the experiments and wrote the paper. H.L., X.L., K.F., and J.W. did the follow-up with the patients. Z.T. and S.C. did the data analysis; F.L. carried out the data collection and revised the paper. All authors reviewed the results and approved the final version of the manuscript.

Conflicts of interest

There are no conflicts of interest.

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