Hip deformity is the second most common deformity in cerebral palsy (CP) patients, following equinus deformity of the foot. Usually, CP patients have normal hip anatomy at birth, then spastic adductors and iliopsoas begin to be noted at about 6 to 18 months of age. Spastic muscle imbalance fosters retention of fetal skeletal anatomy, and the absence of normal motion and weight bearing contribute to acetabular deficiency. Spastic hip flexors, adductors, and internal rotators overpower their antagonists and eventually cause muscle shortening and a fixed flexion-adduction contracture of the hip joint [1]. In general, hip subluxation in CP patients develops at about 3 years of age, and dislocation at about 7 to 8 years of age [2]. For neurologically immature, spastic, quadriplegic children, the prevalence of hip dislocation approaches 50% [3]. If left untreated, this situation can adversely influence the patient’s sitting balance or decrease sitting tolerance.
An unbalanced trunk can further compromise the patient’s upright posture and decrease the ability to use the upper extremities, necessitating custom seating modifications. Windblown posture might be acquired in severe cases. Pain is also a major issue in up to 50% of untreated hip dislocations [4]. Perineal hygiene is difficult, and pressure sores may appear, adding to the patient’s misery and the cost of care [1, 5].

Prophylactic treatment aimed at normal development of the acetabulum should be performed as soon as the deformity is diagnosed. Various kinds of surgical procedures, including soft tissue release and bone procedures [6, 7], have been advocated. Since CP patients have a wide variety of clinical manifestations depending on causative factors and timing, many procedures may be combined according to the adaptive changes that have occurred around the hip joints. The purpose of this study was to describe the results of aggressive, comprehensive treatment of subluxation and dislocation of the hips in a series of CP patients.

**Materials and Methods**

A total of 23 CP patients underwent surgery for correction of subluxated or dislocated hips at National Taiwan University Hospital during the period from 1985 to 1993. There were nine boys and 14 girls. Twenty-two patients had spastic CP, and one had mixed spastic–athetoid CP (Case 23). Eleven patients were quadriplegic, eight diplegic, and four hemiplegic. The right hip was involved in 10 patients, left in nine, and both in four. There were 15 subluxated and 12 dislocated hips. Walking ability, range of motion (ROM), and pain level were recorded preoperatively and postoperatively. Before surgery, five patients were community ambulators, six patients house-ambulators, eight patients sitters, and four patients were bed-ridden. All patients had decreased abduction and extension of the hips. Five patients had hip pain.

The preoperative and final radiographic evaluation was based on the center–edge angle (CEA), acetabular index (AI), and neck–shaft angle (NSA). For the 15 subluxated hips, the CEA was $-4^\circ$ on average (range, $-40^\circ$–$-30^\circ$), the AI was $28^\circ$ (range, $19^\circ$–$38^\circ$), and the NSA was $156^\circ$ (range, $114^\circ$–$140^\circ$). For the 12 dislocated hips, the CEA was $-78^\circ$ on average (range, $-150^\circ$ to $-35^\circ$), the AI was $33^\circ$ (range, $25^\circ$–$43^\circ$), and the NSA was $170^\circ$ (range, $150^\circ$–$197^\circ$).

Surgery was suggested when the adductor muscle contracture prohibited $30^\circ$ of hip abduction, or when $45^\circ$ flexion contracture of the hip was present, or both occurred together. The goal of the operation was to improve the hip ROM, increase abduction to at least $45^\circ$, and decrease flexion contracture to no more than $30^\circ$. The mean age of patients at the time of surgery was 7 years 5 months (range, 1 yr 8 mo–14 yr 5 mo). Release of soft tissue including adductors, iliopsoas, and hamstrings, was only used in combination with other procedures. Varus derotational osteotomy (VDO) was performed in all but two patients with deformity of the proximal femur. This procedure was indicated when a marked break in the Shenoton line, a CEA of $10^\circ$ or less, and increased coxa valga and anteversion were present, as advocated by Mubarak et al for three-level treatment for CP hips [8]. Open reduction was also performed for hips in which concentric reduction could not be obtained by closed means. In cases with high dislocation or severe joint contracture, femoral shortening was performed. The subtrochanteric osteotomy was fixed with a $90^\circ$ blade plate. Pelvic osteotomy was performed in all patients with acetabular dysplasia (AI > $30^\circ$). All but five patients underwent this procedure. The Dega procedure was used in five patients (Fig. 1), Salter osteotomy in five, Pemberton osteotomy in four (Fig. 2), and triple osteotomy in four. The choice of pelvic osteotomy was based on the age of the patient and the severity of hip deficiency; Salter osteotomy was indicated for children aged between 18 months and 6 years old, Pemberton osteotomy or Steel osteotomy for children aged 18 months to 10 years old with more than $10^\circ$–$15^\circ$ correction of AI. Dega osteotomy was indicated for older patients.

Student’s $t$-test was used to compare radiographic values before and after surgery.

**Results**

The average follow-up period was 4.8 years (range, 2.1–8.5 yr). Both clinical and radiologic results were favorable. ROM of the hip joints improved in all patients. Pain disappeared in all five patients. Walking ability improved in 10 patients. The four bed-ridden patients could all sit postoperatively. Of the eight sitters, only one did not improve; six became house-ambulators, and one became a community-ambulator. All six house-ambulators became community-ambulators. The five community-ambulators retained their good functional status after surgery.

Radiographically, in the 15 subluxated hips, the mean CEA was $32^\circ$ (range, $5^\circ$–$50^\circ$), the AI was $19.0^\circ$ (range, $5^\circ$–$30^\circ$), and the NSA was $137^\circ$ (range, $130^\circ$–$160^\circ$); the CEA and AI were significantly improved compared with preoperative values ($p < 0.005$). For the 12 dislocated hips, the CEA was $21^\circ$ (range, $0^\circ$–$65^\circ$), the AI was $21^\circ$ (range, $10^\circ$–
Fig. 1. A) Case 19: a 13-year-old boy with left hip subluxation with erosion of the femoral head. B) Varus derotational osteotomy and Dega osteotomy were performed. C) Six years later, remodeling of the acetabulum and femoral head is evident, and the boy felt no hip pain.

Fig. 2. A) Case 20: an 8-year-old boy with bilateral hip subluxation. B) Bilateral hamstring release, open reduction, varus derotational osteotomy, and Pemberton ostotomy were performed. C) Three years later, a good result is seen in both hips.

35°), and the NSA was 130° (range, 100°–152°). These changes were also all statistically significant (p < 0.001).

Complications developed in five patients. Case 4 had nonunion at the varus osteotomy site, which resolved after replating and bone grafting. Her right hip, initially normal, progressively developed dislocation 2 years later. Varus derotational osteotomy was performed to stabilize the hip. A similar situation occurred in Case 11. Redislocation of the hip developed in two patients (two hips) and resubluxation in one (one hip). Redislocation of the hip in Case 6 (Fig. 3), which happened after removal of the spica, was treated by open reduction, spica casting for 6 weeks, and an abduction brace for 3 months. Redislocation of the right hip in Case 22, which developed progressively 3 months after surgery, was treated by closed reduction, Staheli slotted acetabular augmentation, spica cast for 6 weeks, and abduction brace for 3 months. Resubluxation of the hip in Case 12 was treated by VDO, Chiari osteotomy with shelf augmentation, and spica cast for 6 weeks. All of the patients still had residual subluxation at the final follow-up.

The Table summarizes the clinical characteristics, surgical procedures, and outcomes in all patients.

Discussion

The natural course of untreated subluxated or dislocated hips in CP patients often leads to pain, decrease in walking ability, severe limitation in sitting, and increased difficulty in perineal care [4, 9, 10]. The etiology of pain is believed to be excessive pressure on
the femoral head as well as the loss of articular cartilage and deformity of the head. Patients with painful dislocated or subluxated hips have previously been shown to benefit from surgical treatment [11, 12], and this finding is supported by the results of our series.

The pathologic factors leading to hip deformity include spastic muscle imbalance, non-ambulation, coxa valga, femoral head anteversion, and acetabular dysplasia [1]. If the hip subluxation is left untreated, there is a 10% to 18% annual lateral migration of the femoral head [13]. Bagg et al reported that, if left untreated, two-thirds of their CP patients remained hip subluxated, and one-sixth of the hips became dislocated [14]. Rapid deterioration of the deformity was noted, especially when the CEA was less than 0°. Cooke et al reported that, in the radiographic evaluation of 462 CP patients, AI was the most powerful single predictor of hip dislocation [15]. They suggested that radiographic screening for CP hip dislocation should be performed by measurement of the AI at 2 and 4 years of age.

Deformity of the hip joint has been studied by computerized tomography (CT). Using three-dimensional (3-D) images, Abel et al found that acetabular roof development is the factor most strongly associated with the degree of hip subluxation [16]. They demonstrated that the majority of CP hips, especially among non-ambulatory quadriparetic patients, were subluxating in a posterosuperior direction in association with flexion and adduction contracture of the femur. They recommended that acetabular reconstructions designed to obtain anterior coverage (eg, Salter or double osteotomy) should not be employed. However, some authors found otherwise. Gugenheim et al reported that an anterior deficiency in the acetabulum in congenital and paralytic hip instability was demonstrated by transpelvic CT [17]. Kim and Wenger found, using a 3-D CT technique, that the location of acetabular deficiency in patients with neuromuscular disease was posterior (37%), anterior (29%), midsuperior (15%), and mixed (19%) (anterosuperior, posterosuperior, and global) [18]. They concluded that the choice of pelvic osteotomy depended on the nature of the acetabular deficiency, which should be confirmed by 3-D CT or arthrographic methods. Salter osteotomy did not cause any complication in any of our five patients. This procedure is contraindicated only when the acetabular deficiency is in a posterosuperior direction, because it was designed to obtain better anterior coverage. As mentioned earlier, Pemberton osteotomy is being increasingly used in our hospital; although its technical demand is equivalent to that of Salter osteotomy, more angular correction can be achieved, and k-wire fixation is not needed, which means fewer pin-related problems.

In this series, mild subluxation of the hip joints was treated by combined soft tissue release and VDO. Soft tissue release alone was not used because it leads to recurrence of dislocation or subluxation in many patients, especially in quadriplegic patients [12, 19]. Better results are obtained when corrective surgery is done before the development of acetabular dysplasia. Sharrard et al reported that, of 49 patients with subluxated hips, 12 remained subluxated after a soft tissue procedure, and only 13 were normal. Moreover, three of four dislocated hips remained subluxated [12]. Samilson et al reported that 25% of patients who had adductor release later experienced hip dislocation [5]. However, when the hip was already dislocated prior to soft tissue release, they found the results were consistently unfavorable, as did Sherk et al [19].

For our patients, severe hip instability was stabilized by aggressive, combined procedures that included soft tissue release, VDO, and pelvic osteotomy. Houkom et al found that hip dislocation in children younger than 6 years old is best treated with combined soft tissue release, open reduction, varus derotational osteotomy, and Pemberton osteotomy were performed. C) Progressive hip subluxation is noted 2 months after operation; a second operation was performed with open reduction, hip spica, and prolonged abduction brace. D) Eight years later, a satisfactory result was observed. The plate was then removed.
### Table. Clinical characteristics, surgical procedures, and outcomes

| Sex | Age (yrs + mos) | Side | Type | Hip status | Walking ability | Pain | Ad | Fle | Ham | OR | VDO | Pelvic | Duration | Complication | Subsequent operation | Walking ability | Pain |
|-----|----------------|------|------|------------|----------------|------|----|-----|-----|----|-----|--------|---------|---------------|-----------------|------------------|-----------------|------|
| M   | 5+6            | R, L | Quad |            |                |      | N  | B   | B   | N  | B   | N      | 7+2     | N             |                 | N                | Sit             | N               |
| F   | 5+7            | R    | Quad |            |                |      | N  | B   | N   | N  | R   | N      | 26+1    | N             |                 | N                | Sit             | N               |
| M   | 6+10           | R    | Quad |            |                |      | N  | R   | R   | N  | R   | Salter | 6+7     | N             |                 | N                | N               | House ambul     |
| F   | 6+8            | L    | Di   |            |                |      | N  | B   | L   | L  | N   | Nonunion| 5+4     | N             |                 | VDO (80.05)      | Ambul           |
| F   | 1+8            | L    | Quad |            |                |      | N  | N   | N   | L  | N   | Salter | 5+3     | N             |                 | N                | N               | House ambul |
| F   | 8+3            | L    | Di   |            |                |      | N  | B   | B   | L  | L   | Pemberton| 8+6     | N             |                 | Redislocation    | Open reduction (76.04) | Comm ambul |
| M   | 9+9            | L    | Quad |            |                |      | N  | N   | N   | L  | N   | Pemberton| 5+10    | N             |                 | N                | N               | House ambul     |
| F   | 3+4            | L    | Quad |            |                |      | N  | N   | N   | L  | L   | Salter | 4+2     | N             |                 | N                | N               | House ambul     |
| F   | 9+3            | L    | Di   |            |                |      | N  | N   | N   | L  | L   | Triple  | 7+10    | N             |                 | R dislocation    | N               | Comm ambul     |
| M   | 7+5            | L    | Quad |            |                |      | N  | N   | N   | L  | L   | Triple  | 4+1     | Subluxation    |                 | N                | N               | Comm ambul     |
| F   | 7+1            | R    | Quad |            |                |      | N  | R   | N   | N  | R   | Triple  | 4+1     | N             |                 | N                | N               | House ambul |
| M   | 1+7            | L    | Di   |            |                |      | N  | B   | B   | B  | N   | Pemberton| 5+2     | N             |                 | N                | N               | Comm ambul |
| M   | 9+1            | R    | Hemi |            |                |      | N  | R   | R   | N  | N   | Dega    | 4+1     | N             |                 | N                | N               | House ambul     |
| F   | 1+5            | R    | Di   |            |                |      | Y  | R   | N   | N  | R   | Dega    | 3+1     | N             |                 | N                | N               | Comm ambul     |
| F   | 8+9            | R    | Hemi |            |                |      | N  | N   | N   | R  | R   | Dega    | 3+10    | N             |                 | N                | N               | Comm ambul |
| F   | 9+10           | L    | Hemi |            |                |      | Y  | L   | N   | N  | N   | Pemberton| 5+7     | N             |                 | N                | N               | Comm ambul     |
| M   | 8+6            | R    | Di   |            |                |      | Y  | N   | N   | B  | B   | Pemberton| 3+10    | N             |                 | N                | N               | Comm ambul     |
| F   | 6+10           | R    | Hemi |            |                |      | N  | R   | R   | N  | R   | Salter | 2+3     | N             |                 | N                | N               | Comm ambul     |
| F   | 13+10          | R    | Quad |            |                |      | Y  | B   | B   | N  | B   | Dega    | 2+1     | N             |                 | R redislocation | Closed reduction, Staheli (82.01) | Comm ambul |
| F   | 11+8           | L    | Di   |            |                |      | Y  | L   | L   | N  | N   | Triple  | 2+2     | N             |                 | N                | N               | Comm ambul |

Ad = adductor release; Fle = flexor release; Ham = hamstring release; OR = open reduction; VDO = varus derotational osteotomy; M = male; R = right; L = left; Quad = quadriplegia; D = dislocation; S = subluxation; N = no; B = bilateral; F = female; ambul = ambulatory; Di = diplegia; Comm = community; Hemi = hemiplegia.
release and bone reconstruction [20]. Based on the study of the anatomy of hip deformity in CP patients, Bleck advocated a combined approach consisting of bilateral adductor release, obturator neurectomy, iliopsoas release, open reduction, VDO (with femoral shortening as necessary), and iliac osteotomy [11]. He cautioned that the articul cartilage of the femoral head must appear satisfactory at the time of capsulotomy in order to proceed with relocation of the femoral head. For patients younger than 10 years old, he recommended a Pemberton osteotomy; for older patients, a Chiari osteotomy. Samilson et al also found the Chiari osteotomy to be beneficial for older patients with acetabular dysplasia [5], but Sheret et al warned that hip extension contracture or knee flexion contracture must be corrected or the results could be compromised [19]. Hips with severe, globally insufficient acetabulum may be better treated with a shelf augmentation or a combined Chiari and shelf procedure because of the greater flexibility in covering the femoral head [21]. Song and Carroll suggested that the incidence of resubluxation or redislocation is related to the preoperative lack of coverage of the femoral head, and the unstable hip with a lack of coverage of greater than 70% needs a combined VDO and acetabular procedure [22]. The Staheli acetabular augmentation is not intended to be used as a prophylactic procedure, nor is it for the hip-at-risk or mildly subluxated hip in very young patients [23]. Pelvic osteotomy must be selected in accordance with the deformity and dysplasia of the acetabulum [18, 24].

Because of asymmetric involvement or muscle imbalance, dislocation of the contralateral hip may develop, as was the case in two of our patients. Another interesting finding of Carr and Gage was that unilateral soft tissue release should be avoided due to the deleterious effect on the contralateral hip [9]. However, in our series, soft tissue release was performed when the joint contracture became the major concern, so contralateral soft tissue release was not routinely performed, and further investigation of its effect on the contralateral hip is needed. We believe that redislocation and residual subluxation are due to inadequate correction and existing dysplasia. Reviewing the possible reasons for postoperative complications in our series, we found that in Case 22, inadequate VDO and more severe acetabular dysplasia of the right hip was noted when compared with the left side. A fluoroscopic examination during surgery would have enabled us to avoid this complication. We think that the development of postoperative hip subluxation in one patient was mainly due to inadequate postoperative protection, because the immediate postoperative radiographic evaluation was satisfactory. In short, overcorrection or hypercontainment may be beneficial. However, there is still controversy about the efficacy of prolonged bracing or casting. Miller et al found a much lower incidence of postoperative fracture if patients were mobilized by physical therapy immediately after surgery [25]. In conclusion, when hip subluxation or dislocation is confirmed, early adequate soft tissue release and combined bone reconstruction procedures are necessary to maintain hip stability, which helps to improve the functional status of CP patients.

References


