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Combined pelvic and femoral reconstruction in children with cerebral palsy

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Abstract

Objective: The primary aim of this study was to determine the effect of age, femoral head migration, and ambulatory status on radiographic outcomes after combined pelvic and femoral reconstruction in children with cerebral palsy. The secondary aim was to evaluate the fate of the opposite hip after unilateral reconstruction.

Methods: A retrospective cohort study design of consecutive patients from 1995–2009 was used. The records were screened for patients who underwent varus derotational osteotomy and modified Dega osteotomy.

Results: Eighty-five hips in 71 patients were included. The mean age was 8.4 ± 3.2 years and the mean follow-up was 6.6 ± 3.1 years. The final measures were a mean migration index of $20\% \pm 15.58\%$, centre edge angle of $28.45^\circ \pm 15.98^\circ$, and Sharp's angle of $40.75^\circ \pm 8.5^\circ$. Those values were not correlated with age and the initial migration index. Nonambulatory status did not negatively affect hip stability. Final measurements of the contralateral hips were similar to the reconstructed hips, and the cumulative incidence for later reconstruction was 5.67%.

Conclusions: Regardless of age, preoperative displacement, and ambulation, the combined procedure provides durable radiographic improvement. In unilateral cases, there is a low risk of later deterioration of the opposite side.

Keywords

Cerebral palsy, pelvic osteotomy, femoral osteotomy, hip dislocation, ambulatory status, unilateral reconstruction

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Introduction

The overall prevalence of hip displacement in patients with cerebral palsy ranges from 17% to 35%. In nonambulatory patients with gross motor function classification system (GMFCS) levels IV and V, the risk of hip displacement is as high as 66%.[1–3]

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Hip instability is a concern mainly because of pain.[4] A reduced hip may ease handling for caregivers.[5] Over the last 2 decades, there has been an increased interest in hip surveillance with various protocols aiming to increase early preventive soft tissue surgery and minimise late osseous reconstructive interventions.[6,7]

Indications, timing, and the exact nature of the reconstructive procedures for hip displacement vary among practising groups. There is less controversy regarding the indications for lengthening of contracted adductor muscles and the iliopsoas tendon to relieve the deforming forces. The main indication for varus derotational osteotomy (VDRO) is a migration index (MI) greater than 40% to 60%.[8–10] Eilert and MacEwen suggested that the "golden age" for intervention is between 4 and 8 years for minimal varus remodelling and this has good potential for acetabular remodelling.[11] Later reports noted more recurrence of hip displacement in patients aged younger than 4 years.[12,13] Pelvic osteotomies have been added to VDRO to address acetabular dysplasia and resubluxation in a staged fashion.[14,15] Additionally, other authors have recommended single-staged combined procedures that include pelvic osteotomy with VDRO.[9,16] Besides a younger age, several reports have indicated that a high initial migration index and poor preoperative mobility are detrimental to the longevity of correction.[17–19] Moreover, recent studies suggested a lower threshold for intervening on the opposite side in this patient population.[20–22]

Therefore, this study aimed to evaluate radiographic parameters after VDRO combined with modified Dega osteotomy in children with cerebral palsy, taking into account age, femoral head migration, and ambulatory status. The secondary objective of this study was to examine progression of the opposite hip after unilateral reconstruction.

Patients and methods

Selection of patients

The institutional review board of the Research Institute of the McGill University Health Centre approved the study (Study Code: 11-737-PED). We performed a retrospective review of consecutive patients who underwent a single-staged VDRO and modified Dega osteotomy at Montreal Children's Hospital and Montreal Shriners Hospital for Children from May 1995 to December 2009.

The inclusion criteria were hip displacement due to cerebral palsy, combined single-staged surgery, open triradiate cartilage, absence of previous osseous intervention around the hip, and a minimum follow-up of 2 years.

Clinical parameters

The charts were reviewed for age, sex, side of surgery, and the need for open reduction. We also collected data related to the type of cerebral palsy, as well as GMFCS level. GMFCS levels II–III were called ambulatory and levels IV and V were nonambulatory. Postoperative adverse events were reviewed, as well as any additional surgical treatments. For observation of the contralateral hip, we noted subsequent interventions and whether they were planned from the beginning or whether the decision was made later, based on radiographic progression of the subluxation.

Radiographic measurements

Pre- and postoperative supine frontal pelvic radiographs were reviewed for the standard MI as described by Reimers.[8] Pelvic obliquity (PO), which was the angle between the acetabular tear drops and the horizontal reference frame, was recorded from the initial radiographs.[23] Final radiographs were examined for the MI, centre edge angle (CEA), Sharp's angle, PO, the presence of heterotopic ossification, and avascular necrosis (AVN). We also applied the Melbourne Cerebral Palsy Hip Classification System (MCPHCS) to the final follow-up radiographs. This system is a reliable, six-grade, ordinal scale.[24,25]

For the opposite side, the preoperative, postoperative, and follow-up MI, as well as the follow-up Sharp's angle and CEA, were recorded. We also documented if the patient had spinal instrumentation. All of the measurements were carried out by the first author.

Surgical procedure

The indications for the combined procedure in this study were subluxation to the MI greater than 40% to 50% in patients older than 5 years of age, and a MI greater than 60% to 70% in younger patients. These indications were regardless of previous treatments and ambulatory status. The surgical protocol was similar in all of the patients. First, the hip adductors and iliopsoas tendons were released. Second, the hip was assessed for reducibility. If concentric reduction was not possible, a standard anterior approach to the hip was used to perform open reduction and capsulorrhaphy. Third, VDRO was carried out through a lateral approach. We avoided varus to neck–shaft angles less than 100° and roughly estimated the amount of varus required by the degree of hip abduction required for a concentric reduction. The implant that was chosen for fixation of the VDRO was based on the surgeon's preference. A modified Dega osteotomy was performed as described by Mubarak et al.[9] Moulds were taken for abduction brace measurements, and a hip spica was applied for approximately 6 weeks, followed by physiotherapy and night-time splinting. In unilateral cases, the contralateral hip adductors and iliopsoas were released if contracted.

Statistical analysis

Normality and equality of variances for continuous data were assessed graphically. Correlations were performed by Pearson's method. Fisher's exact test was used for count data. For parametric values, the independent two-tailed t-test was used. For nonparametric variables, the Mann–Whitney–Wilcoxon test was applied. Two-tailed p values of < 0.05 were considered significant. We used R software for statistical analysis, version 3.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

From an initial 105 candidates, 34 were excluded because of incomplete radiographs. Therefore, a total of 71 patients (85 hips) were included in the analysis, with 57 unilateral and 14 bilateral combined procedures. There were 34 boys and 37 girls. A total of 38 hips were on the right and 47 were on the left. The mean $\pm$ SD age at the time of the procedure was 8.4 ± 3.2 years (19–201 months). The mean follow-up was 6.6 ± 3.1 years (24–177 months). There were 66 (92.9%) patients with spastic cerebral palsy, four (5.63%) had the mixed type, and one (1.4%) was hypotonic. Among the patients, 50 (70.4%) were diagnosed with quadriplegia, 17 were diplegic (23.9%), three (4.2%) had hemiplegia, and one (1.4%) was triplegic. There was GMFCS level I in no patients, level II in seven (9.8%), level III in 14 (19.7%), level IV in 11 (15.5%), and level V in 39 (54.9%).

The change in the MI over time is shown in Figure 1. The final radiographic measures were an MI of $20\% \pm 15.58\%$ (0%–71%), CEA of $28.45° \pm 15.98°$ (−27°to 68°), and Sharp's angle of $40.75° \pm 8.5°$ (14°–58°). These measures were not associated with age and the initial MI (Table 1). Although preoperative displacement was greater in nonambulatory patients, they did not have

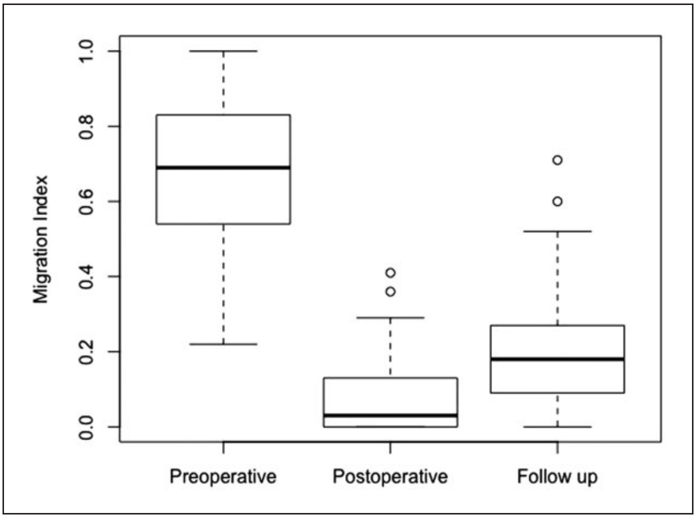

Figure 1. Evolution of the migration index for the combined procedure preoperatively, postoperatively, and at the final follow-up.

Table 1. Correlation matrix showing the effect of age and initial MI.

	Final MI			CEA			Sharp's angle		
	r	95% CI	p	r	95% CI	p	r	95% CI	p
Age	−0.06	−0.27 to 0.16	0.60	0.13	−0.08 to 0.34	0.22	−0.16	−0.36 to 0.06	0.15
Initial MI	−0.10	−0.31 to 0.11	0.34	−0.03	−0.24 to 0.18	0.78	−0.10	−0.31 to 0.11	0.35

MI, migration index; CEA, centre edge angle; r, correlation coefficient; CI, confidence interval.

Table 2. The effect of ambulatory status.

GMFCS level	n	Preoperative MI (%)	Postoperative MI (%)	Follow-up MI (%)	CEA (°)	Sharp's angle (°)
II–III	25	58.8 ± 19.8	9.56 ± 11.03	22.85 ± 11.13	26.28 ± 15.91	45 ± 6.16
IV–V	60	72.8 ± 0.20	7.48 ± 10.32	19.56 ± 16.94	29.33 ± 16.05	38.98 ± 8.75
95% CI			−2.86 to 7.03	−03.70 to 10.28	−10.63 to 4.52	2.65 to 9.35
p			0.40	0.35	0.42	<0.01

GMFCS, gross motor function classification system; MI, migration index; CEA, centre edge angle; CI, confidence interval.

a higher amount of subluxation compared with ambulatory patients (Table 2). Moreover, PO did not improve, regardless of subsequent fusion of scoliosis to the pelvis and ambulatory status (Table 3). None of the patients had instrumented fusion for scoliosis before the combined procedure. At the final follow-up, MCPHCS was grade 1 in 23 hips, grade 2 in 10 hips, grade 3 in 33 hips, and grade 4 in 19 hips.

Table 3. Effect of reconstructive surgery on pelvic obliquity.

	n	Preoperative (°)	Follow-up (°)	95% CI	p
Group 1	58	6.22 ± 4.08	7.75 ± 6.68	−3.49 to 0.99	0.23
Group 2	13	6.31 ± 5.25	6.50 ± 8.30	−6.99 to 7.49	0.81
Group 3	21	5.66 ± 4.21	7.71 ± 7.28	−6.49 to 1.99	0.48
Group 4	50	6.48 ± 4.32	7.44 ± 6.89	−2.99 to 1.5	0.51
Total	71	6.24 ± 4.28	7.52 ± 6.96	−2.99 to 1	0.33

Group 1, combined hip procedure only; Group 2, combined hip procedure followed by scoliosis surgery; Group 3, GMFCS levels II–III; Group 4, GMFCS levels IV–V; CI, confidence interval.

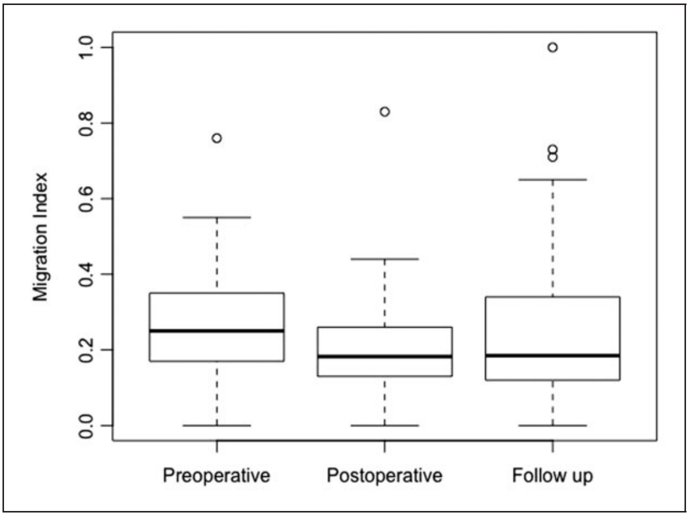

Figure 2. Migration index for the opposite side that had no osseous intervention.

Of the 57 patients with unilateral combined procedures, six had osseous intervention either concomitantly or shortly afterwards. Three of these six patients had VDRO on the same day as the combined procedure. Of these three patients, one required revision of VDRO to a combined procedure 1 year later. The fourth hip underwent VDRO 1 year after the index procedure. The fifth hip had an unplanned combined procedure 3 years later. The sixth hip underwent a shelf augmentation procedure 2 years after the combined procedure on the other hip. Therefore, 54 opposite hips were available for radiographic review (Figure 2). There were no significant differences in the final measurements of contralateral hips compared with reconstructed hips. In contralateral hips, the mean MI was 25.72% ± 20.94% ($p = 0.29$), CEA was 22.63° ± 27.04° ($p = 0.51$), and Sharp's angle was 42.1 ± 7.1 ($p = 0.52$). Only three osseous hip interventions of 54 (5.67%) at risk were planned after the combined procedure based on follow-up radiographs.

There were seven unplanned trips to the operating room, with a reoperation rate of 9.8% (Table 4). There were nine cases of AVN. Six of 24 hips that required

Table 4. Complications.

Morbidity	GMFCS levels II–III (n = 25)	GMFCS levels IV–V (n = 60)	Remarks/treatment
Re-dislocation	0	0	
Re-subluxation (MI ≥ 50%)	0	4 (6.6%)	One patient had a revision to a combined procedure
Nonunion	0	0	
Malunion	1 (4%)	0	Externally rotated extremity requiring anteverting osteotomy in a GMFCS level III patient.
Severe windswept deformity	0	2 (3.3%)	One patient underwent valgus proximal femur osteotomy in one hip and varus osteotomy in the other hip
Superficial skin ulcer	1 (4%)	3 (5%)	Local wound care
Deep skin ulcer	0	1 (1.6%)	Debridement in the operating room
Superficial surgical site infection	0	1 (1.6%)	Oral antibiotics
Deep surgical site infection	1 (4%)	0	Debridement in the operating room
Extremity fracture after cast removal	0	4 (6.6%)	Two patients were treated surgically
Painful implants	1 (4%)	2 (3.3%)	Two patients had non-routine implant removal
Respiratory complications	1 (4%)	3 (5%)	One patient had transient apnoea, and three patients had aspiration pneumonia
Gastrointestinal complications	1 (4%)	3 (5%)	One patient had ileus and three had upper GI bleeds requiring endoscopy
Neurological complications	4 (16%)	5 (8.3%)	Recurrence of seizures
Genitourinary complications	4 (16%)	5 (8.3%)	Three patients had urinary tract infections and one had traumatic catheterization
Blood transfusion reaction	4 (16%)	5 (8.3%)	Supportive care
Heterotopic ossification	4 (16%)	5 (8.3%)	No patients required excision Broker (Grade I = 5, Grade II = 3)
Avascular necrosis	4 (16%)	5 (8.3%)	Asymptomatic

GMFCS, gross motor function classification system; MI, migration index; GI, gastrointestinal tract.

capsulotomy developed AVN, whereas three of 61 patients without capsulorrhaphy developed AVN (odds ratio 6.27, 95% confidence interval 1.20 to 42.70, $p = 0.013$). With regard to chronic hip pain, only six of the 62 (9.7%) patients with accessible follow-up clinical records clearly indicated the presence of pain in the reconstructed hip.

Discussion

In approximately half of patients with cerebral palsy, hip instability is associated with pain.[4] Hip reconstruction reduces pain and improves subjective measures, such as ease of care and parental satisfaction. Up to 86% of parents would recommend surgery to another parent.[26,27] Recently, DiFazio et al.[28] found a strong correlation between the Child Health Index of Life with Disabilities score and the MI.

Correction attained with the combined procedure appears to be stable over time. In our study, the mean final MI was 20% ± 15.58%, which is comparable with similar reports.[9,23,29] The final mean CEA and Sharp's angle were 28.45° ± 15.98° and 40.75° ± 8.5°, respectively. The lowest normal CEA of Wiberg reported by Tonnis was 19°, and Sharp considered measurements between 39° and 42° to be within the upper limit of normality.[30,31]

In a previous study, only one of the 18 hips that underwent the combined procedure using a modified Dega osteotomy and soft tissue lengthening developed subluxation after a minimum follow-up of 3 years and 8 months.[9] McNerney et al.[32] reported 104 hips in 92 patients who underwent a single-stage combined procedure. In their study, the mean follow-up was 6.9 years. Pelvic osteotomy was mostly a modified Dega osteotomy, but Pemberton and Salter osteotomies were also used. A total of 31% of patients required subsequent surgery to maintain reduction. A total of 95% of the hips remained reduced and there were no redislocations. Braatz et al.[33] reported the outcomes after the combined procedure in 72 hips in patients with cerebral palsy. In their study, at a mean follow-up of 7.7 years, 89% of hips had an MI less than 30%, which is similar to a another previous report.[29]

We did not find a significant correlation between the patients' age and the final radiographic measurements. In a long-term study by Brunner et al.[13] the minimum follow-up was 11 years, and there were smaller CEAs in patients with cerebral palsy who had femoral procedures before the age of 4 years. The authors concluded that femoral osteotomy alone did not maintain sufficient acetabular coverage. The MI was not measured in Brunner et al.'s[13] study. Another femoral reconstruction only cohort study was performed by Noonan et al.[17], with an average follow-up of 5.2 years. Using the MI, the authors found less hip subluxation in patients who were operated on before 6 years old (18%) than in children who were older (33%) at the time of reconstruction. They also found a 28% overall risk of later displacement. They concluded that in older children, pelvic osteotomy should be considered in addition to femoral varus osteotomy and muscle balancing procedures. Recently, Mallet et al.[29] found no difference during skeletal maturity after the combined procedure between patients who were younger and older than 8 years at the time of reconstruction, which is similar to a finding by Settecerri et al.[19] Rutz et al.[27] did not find an association in a multivariate analysis between age at the time of surgery and final MI in a long-term study of 168 hip reconstructions that included transiliac osteotomy.

Several studies have found worse long-term outcomes in patients with more preoperative displacement.[17,19,27] Only a few patients in these reports had pelvic osteotomies, and even fewer had modified Dega osteotomies. In our study, there was no association between the preoperative MI and later displacement, which is similar to a previous report on the combined procedure.[26] Moreover, in a study of 144 reconstructed hips by Bayusentono et al.[34], nonambulatory patients had more deterioration in the MI, but only 80 hips in the cohort had pelvic osteotomy. Recently, in a study of 57 hips reconstructed with femoral and pelvic osteotomies, Reidy et al.[35] did not find a difference in the final MI between walkers and non-walkers. In the present study, nonambulatory status was not associated with poor radiographic results. Additionally, there was no positive effect on PO after the combined procedure. This finding is similar to that by Abousamra et al.[36] who studied 12 unilateral hip displacements treated with the combined procedure in ambulatory children.

Treatment of the opposite hip remains controversial. Carr and Gage warned against unilateral soft tissue hip surgery in nonambulatory patients with cerebral palsy because it may induce subluxation in the contralateral hip.[37] In another study, only nine of 35 untreated hips remained nondisplaced after 4.2 years of follow-up.[20] In a previous study, only two of 48 nonoperated hips had femoral osteotomies for progressive subluxation.[19] Canavese et al.[21] found a 44% risk of later bony reconstruction of well-seated non-operated contralateral hips in patients with GMFCS levels III–V when reviewed at skeletal maturity. In a study of 35 unilateral hip reconstructions, Shukla et al.[38] noted progressive contralateral hip subluxation in 17 patients, and it was less in hips that had soft tissue release. In our unilateral osseous reconstructions, spasticity in the contralateral hip was addressed surgically prior to or during the combined procedure. We found that the incidence of subsequent contralateral reconstruction was 5.67%.

The probability of adverse events associated with hip surgery in patients with cerebral palsy is high.[39-41] More than half of the patients in our study had at least one complication. Root et al.[42] showed that the risk of AVN was 22.9% after routine capsulotomy. A total of 10.6% of hips developed AVN in our study, and this rate was higher after open reduction. A total of 9.7% of our patients indicated the presence of hip pain at the final follow-up, which is similar to a previous finding by Baraka et al.[43] and Braatz et al.[44]

This study was retrospective with no comparison group. Radiographic measurements were used as a surrogate for important outcome measures. Ideally, accurate assessment of pain, function, and quality of life is preferred. In conclusion, the combined procedure provides predictable radiographic results, regardless of age, preoperative hip migration, and ambulatory status. In the unilateral combined procedure, there is a low risk for future displacement on the contralateral unreconstructed hip.

Declaration of conflicting interest

The Authors declare that there is no conflict of interest.

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