Changes in hip migration after selective dorsal rhizotomy for spastic quadriplegia in cerebral palsy

ROBERT C. HEIM, M.D., T. S. PARK, M.D., GEORGE P. VOGLER, PH.D.,
BRUCE A. KAUFMAN, M.D., MICHAEL J. NOETZEL, M.D., AND MADELINE R. ORTMAN, R.N.

Departments of Neurosurgery and Neurology, St. Louis Children’s Hospital, and Division of Biostatistics, Washington University School of Medicine, St. Louis, Missouri

Selective dorsal rhizotomy is increasingly used for management of spastic quadriplegic cerebral palsy but rates of hip stability following the operation have not been reported. Determining hip stability by radiographic measurement of lateral migration of the femoral head beyond a lateral edge of the acetabulum after dorsal rhizotomy allows an objective assessment of the outcome of the operation. This prospective study examined the effect of selective dorsal rhizotomy on lateral migration of the femoral head in 45 children with spastic quadriplegic cerebral palsy. The children ranged in age from 2 to 9 years (average 5 years 1 month) and were grouped according to their ages with 23 children in the 2- to 4-year-old group and 22 children in the 5- to 9-year-old group. Postoperative follow up ranged from 7 to 50 months (average 20 months). The Reimers migration percentage (MP), a measure of the lateral migration of the femoral head, was calculated from anteroposterior hip radiographs taken prior to the operation and at the last follow-up examination. Of the 90 hips involved, 9% improved, 80% remained unchanged, and 11% worsened, yielding a radiographic stability rate of 89%. The hips with postrhizotomy worsening of the MP had an average preoperative MP of 14% (range 9% to 38%) and an average postoperative increase in MP of 18% (range 11% to 37%). Of the 45 children, four subsequently underwent unilateral derotational femoral osteotomies for persistent or worsening hip subluxation. There was a significant tendency for the MP to worsen in patients with lower prerhizotomy MP values ($\chi^2 = 20.74$, df = 4, $p = 0.001$), but the age of patients and their ambulatory status at the time of rhizotomy had no bearing on postoperative hip stability. The data indicate that selective dorsal rhizotomy prevents progressive lateral migration of the femoral head in the majority of children who undergo the operation for spastic quadriplegia.

KEY WORDS • cerebral palsy • dorsal rhizotomy • hip migration • spastic quadriplegia

HIP subluxation and dislocation are common problems in children with spastic cerebral palsy, occurring in 3% to 59% of patients.$^{16,21,23,40,43}$ The cause of these hip abnormalities is multifactorial, but predominant spasticity in the hip flexors and adductors probably plays an important role in the development of abnormalities.$^{3,14,37}$ To manage hip deformities in cerebral palsy, a variety of orthopedic operations are currently used, which primarily aim to restore a balanced muscle strength around the hip or replace the femoral head in the hip joint. In addition, a neurosurgical operation, selective dorsal rhizotomy, is utilized for management of cerebral palsy.$^{13,10,12,26}$ By decreasing spasticity, dorsal rhizotomy might be expected to decrease the incidence of hip subluxation in children with cerebral palsy. Several recent reports have indicated a decrease in spasticity and functional improvements following selective dorsal rhizotomy in patients with spastic cerebral palsy.$^{2,20,30,42,45}$ These studies, however, did not examine hip stability in cerebral palsy in general or spastic quadriplegia in particular. Spastic quadriplegia is a common subtype of cerebral palsy characterized by spastic weakness involving the trunk and all extremities.$^{17,19}$ To determine the efficacy of selective dorsal rhizotomy and its effects on hip stability in spastic quadriplegia, we prospectively investigated changes in lateral hip migration in children who underwent the surgical procedure for spastic cerebral palsy. This report focuses on children with spastic quadriplegia.

Clinical Material and Methods

The investigation included 45 children with spastic quadriplegia who underwent selective dorsal rhizotomy between August 1987 and November 1990. An additional 15 patients underwent the same operation but were excluded from the study because of inadequate radiographs or incomplete follow-up information. Nine of those 15 patients did not receive orthopedic surgery, and the status of the operations performed could not be determined for the remaining six. Twenty-three of the patients were girls and 22 were boys. Their ages ranged from 2 to 9 years (average 5 years 1 month), with 23 patients between 2 and

J. Neurosurg. / Volume 82 / April, 1995 567
4 years of age and 22 patients between 5 and 9 years. Preoperatively, 30 (67%) were nonambulatory, 14 (31%) were ambulatory with the aid of a walker, and one (2%) walked independently. Postoperative follow up ranged from 7 to 50 months (average 20 months). Prior to dorsal rhizotomy, nine patients had undergone operations for treatment of orthopedic deformities. The operations included bilateral adductor release (five patients), adductor release and obturator neurectomy (two patients), bilateral femoral osteotomy (one patient), and bilateral hamstring releases (one patient).

In keeping with our prospective protocol, hip radiographs were obtained for all patients preoperatively, and follow-up radiographs were obtained at each postoperative evaluation, which was scheduled at 6 weeks, 7 months, and annually thereafter. The migration percentage (MP) developed by Reimers was computed on anteroposterior hip radiographs with an image analysis system.\(^2\)\(^8\) to touch the visible tips of the bilateral ilia on anteroposterior hip radiographs.

Hip migration was assessed in all patients by comparing the preoperative MP with the MP obtained at the last follow up. Evaluation of MP before the last follow up showed no significant trend toward improvement or worsening. The criteria described by Kalen and Bleck\(^1\) were used to assess the changes in preoperative to postoperative values of the MP, with “improved” defined as greater than 10% decrease, “worsened” as greater than 10% increase, and “unchanged” as less than 10% increase or decrease.

Two methods of statistical analysis were used to examine the data. The first method was a chi-square analysis of the data classified into a limited number of discrete groups. The postrhizotomy outcome classifications of improved, unchanged, or worsened were contrasted with three variables. First, age was split into two categories: younger (< 5 years of age) and older (≥ 5 years of age). Second, prerhizotomy MP was separated into three groups (0% to 14%, 15% to 33%, and > 33%). Finally, prerhizotomy gait status was classified as no walking, assisted walking, and independent walking. The second statistical method used was multiple regression analysis with which outcome, expressed as a quantitative change in MP, is predicted by the quantitative predictor variables. In all cases the interpretation of the results was the same regardless of the statistical technique used.

In the analyses, each hip was treated as an independent variable. This approach ignored the potential dependency between the hips within individuals. Preliminary analyses of migration and outcome based on laterality indicated no group differences in mean or variance as a function of laterality, and analyses of the left and right sides separately showed no differences in the results. Thus, the two sides were analyzed together to simplify the presentation of the results.

**Results**

**Overall Outcome**

Of the 90 hips treated in 45 children, 9% (eight hips) improved, 80% (72 hips) remained unchanged, and 11% (ten hips) worsened (Table 1). This yielded a radiographic stability rate of 89%. Of the 45 children, four have subsequently undergone unilateral derotational femoral osteotomies for persistent or worsening hip subluxation. These four children had preoperative MP values of 11, 29, 38, and 50 (average 32), compared to an average preoperative MP of 26 in the children who did not undergo any orthopedic hip operation after the rhizotomy. An additional five children required hamstring release for knee flexion deformities.

Of the nine children who had postrhizotomy worsening of the MP, the average preoperative MP was 14% (range 9% to 38%), which increased an average of 18% (range 11% to 37%) postoperatively. Eight of these children could not walk preoperatively, but five of them could ambulate with the aid of a walker postoperatively. Only one child in this series demonstrated bilateral worsening of the hip MP after the rhizotomy; all others showed unilateral worsening.

**Age at Rhizotomy and Outcome.** The children were divided into two age groups, 2 to 4 years (23 children) and 5 to 9 years (22 children), and surgical outcomes for the groups were compared (Table 1). Among the younger 23 children, 13% improved, 72% remained unchanged, and 15% worsened. The improved hips in this group had MP decreases of 11% to 23%; the worsened hips had MP increases of 13% to 27%. Among the older 22 children, 4% improved, 89% remained unchanged, and 7% worsened. The improved hips had MP decreases of 10% and

---

**Fig. 1.** Drawing displaying the source of values used to determine the Reimers migration percentage (MP). The MP is equal to A/B × 100. A = the portion of the femoral head extruded beyond the lateral edge of the acetabulum; B = the width of the femoral head; H = Hilgenreiner’s line drawn through the acetabulum so as to touch the visible tips of the bilateral ilia on anteroposterior hip radiographs.
Dorsal rhizotomy and hip migration in spastic quadriplegia

### Table 1

**Surgical outcomes of lateral hip migration in 45 children who underwent selective dorsal rhizotomy for spastic quadriplegia**

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Age of Patients (yrs)</th>
<th>No. of Hips Involved</th>
<th>Lateral Hip Migration†</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>2-4</td>
<td>46</td>
<td>Worsened 7</td>
</tr>
<tr>
<td>22</td>
<td>5-9</td>
<td>44</td>
<td>Worsened 3</td>
</tr>
<tr>
<td>45</td>
<td>totals</td>
<td>90</td>
<td>Worsened 10</td>
</tr>
</tbody>
</table>

* A chi-square analysis of the two age groups and a stepwise multiple regression analysis using age as a continuous measure showed no difference in outcome.

† Categories are based on the Reimers' migration percentage: Worsened = >10% increase, Improved = >10% decrease, Unchanged = <10% change.

11%, respectively; the worsened hips had MP increases ranging from 10% to 25%. There was no statistical difference in outcome between the two groups (χ² = 4.06, df = 2, p = 0.131).

**Preoperative Hip Migration and Outcome.** The hips were arbitrarily divided into three groups based on their preoperative MP values (Fig. 2). Hips with preoperative MP values less than 15 (nine hips) were 44% unchanged and 56% worsened after rhizotomy. Hips with preoperative MP values of 15 to 33 (55 hips) were 11% improved, 82% unchanged, and 7% worsened. Hips with preoperative MP values greater than 33 (26 hips) were 8% improved, 88% unchanged, and 4% worsened. An analysis of the three groups indicated a significant tendency for MP worsening in those patients who had lower preoperative MP values (χ² = 20.74, df = p < 0.001).

**Preoperative Ambulatory Function and Outcome.** At the time of rhizotomy, 32 children were nonambulators (Fig. 3); postoperatively 14% of their hips worsened, 13% improved, and 73% remained unchanged. Twelve children were able to ambulate with assistance preoperatively; in this group, 4% of the hips worsened and 96% remained unchanged. None of the hips in this group showed improvement in MP. There was only one patient who was an independent ambulator preoperatively. This child had no change in the MP of either hip postoperatively. There was no significant difference in outcome based on preoperative ambulatory function (χ² = 6.21, df = 4, p = 0.184).

During postoperative follow-up evaluations, no child showed deterioration in ambulatory ability. Sixteen of the 32 children who were nonambulators at the time of rhizotomy progressed to being assisted ambulators and one was able to ambulate independently by the last follow up. Three of the 12 children who were assisted ambulators preoperatively improved enough to walk with crutches. In the 2- to 4-year-old age group, 12 were assisted ambulators, one ambulated unassisted, and 10 remained nonamb-
bulators postoperatively. This represented a significant increase in the number of young children who were able to ambulate postrhizotomy compared to preoperative gait function ($\chi^2 = 12.05, df = 2, p = 0.002$). In the 5- to 9-year-old age group, 17 were assisted ambulators, one ambulated unassisted, and four remained nonambulators postoperatively.

**Discussion**

Hip subluxation and dislocation occur in up to 59% of children with spastic quadriplegic cerebral palsy. In nonambulatory patients, progressive hip deformity causes a painful condition affecting sitting posture and making perineal hygiene difficult, and hip dislocation predisposes to decubitus ulcer formation and lower-extremity fracture. In ambulatory patients, hip subluxation contributes to abnormal gait patterns; thus, these hip deformities are of significant clinical import, which is reflected in their extensive appearance in the literature of spastic cerebral palsy.

The cause of these hip deformities is considered to be multifactorial, with spasticity of the hip adductors and flexors among implicated factors for development of hip subluxation. It has been demonstrated that spasticity of the adductor and iliopsoas muscles causes a shift in the axis of rotation of the femur from the center of the femoral head to the lesser trochanter. This shift forces the femoral head against the posterior rim of the acetabulum, producing deformation of the rim and stretching of the hip capsule. The resulting acetabular dysplasia, along with persistence of coxa valga, femoral anteverision, pelvic obliquity, and absence of normal weight bearing are significant in the development of hip subluxation in patients with spastic cerebral palsy.

Lateral hip migration in growing children with cerebral palsy tends to be progressive. Vidal, et al., who studied 158 children with various subtypes of cerebral palsy, determined that without surgical intervention, the MP increased approximately 5.5% per year until age 5 in children with the potential to ambulate, whereas it increased 7% per year in children lacking the potential to ambulate. In light of the natural history of hip migration in cerebral palsy, any treatment is regarded as successful in stabilizing the hip if it halts or lessens hip migration. A variety of orthopedic operations have been used for treatment of hip deformities associated with cerebral palsy. In children at risk to develop hip subluxation, soft-tissue procedures such as adductor myotomy and tenotomy, iliopsoas release, and adductor transfers have been recommended. Although the operations successfully prevent hip subluxation, they are not effective once the hip has subluxated or dislocated. Thus, for treatment of hips already subluxated or dislocated, bone reconstructions such as derotational femoral osteotomy or acetabular augmentation are employed, but the efficacy of bone reconstructive procedures has been debated.

Nearly all reports on the orthopedic operations, however, evaluate surgical results based on the severity of the preoperative hip deformity rather than on the subtypes of cerebral palsy, that is, spastic quadriplegia or diplegia. This makes a direct comparison of our results with previous reports difficult. Fortunately, there is a report on a series of children with total body cerebral palsy that provides help in this regard. Herndon, et al., who evaluated hip stabilization in 32 patients undergoing proximal femoral osteotomy combined with obturator neurectomy and iliopsoas and adductor release reported “good or fair” results in 89% of the hips. Their results compare favorably to the 89% radiographic stability observed in our series. Their report also noted that the hips displaying the most femoral head coverage preoperatively had better radiographic results postoperatively; this contrasts with our results, which showed a tendency toward progression of the MP after dorsal rhizotomy in patients with lower preoperative MP values.

Previous reports on orthopedic operations for hip deformity indicated a better outcome in children who are ambulatory preoperatively than in those who are nonambulatory: our results do not corroborate these findings. In the present group of spastic quadriplegic children we saw no difference in outcome based on preoperative ambulatory function. A similar observation was made in our earlier review of children with spastic diplegia. It should be noted, however, that of the 10 hips that exhibited worsening of the MP postoperatively, nine occurred in children who were nonambulatory preoperatively. Of the 13 children who were ambulatory preoperatively, only one child developed worsening of the MP in one hip after dorsal rhizotomy.

Greene and colleagues have raised the possibility of progressive hip migration following dorsal rhizotomy in their report on six children with cerebral palsy. Five of the children had spastic quadriplegia and one had spastic diplegia. During a follow-up period that ranged from 6 to 13 months, seven of the 12 hips examined were found to exhibit progressive hip subluxation after dorsal rhizotomy. The authors believed that the hip subluxation observed was rapid and attributed this to muscle hypotonia following the dorsal rhizotomy combined with preexistent hip dysplasia. Their study gave no details about the total patient population, so the frequency of progressive hip migration after dorsal rhizotomy in children with spastic quadriplegia cannot be determined. In the present study a relevant finding is that only 11% of the hips examined had worsening of MP after the rhizotomy, yielding an 89% hip stabilization rate, and only four of the 45 patients underwent orthopedic surgery for persistent or worsened hip subluxation. Our data thus suggest that children with spastic quadriplegia undergoing dorsal rhizotomy are certain at risk of developing progressive hip subluxation postoperatively, but the risk is small. To ensure timely orthopedic treatment for patients after dorsal rhizotomy, however, radiographic assessment of hip stability at regular intervals is necessary.

**References**

Dorsal rhizotomy and hip migration in spastic quadriplegia


Manuscript received November 10, 1993. Accepted in final form June 24, 1994.
Address for Dr. Heim: Department of Neurosurgery, Bethesda Naval Hospital, Bethesda, Maryland 20814.
Address reprint requests to: T. S. Park, M.D., Department of Neurosurgery, St. Louis Children’s Hospital, One Children’s Place, St. Louis, Missouri 63110.