Selective dorsal rhizotomy and rates of orthopedic surgery in children with spastic cerebral palsy

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If the spasticity of cerebral palsy (CP) is reduced in children at a young age by selective dorsal rhizotomy, the incidence of lower-extremity deformities requiring orthopedic surgery may be reduced; however, this has never been investigated in detail. The authors examined the effects of selective dorsal rhizotomy on rates of lower-extremity orthopedic surgery in 178 children with CP. Age at selective dorsal rhizotomy ranged from 2 to 19.3 years (mean 5.5 years) with follow-up intervals ranging from 24 to 70 months (mean 44 months). Spastic CP was classified as quadriplegia (33%), diplegia (65%), and hemiplegia (2%).

To assess the effects of early versus late rhizotomy on rates of orthopedic surgery, patients were grouped as follows: Group I underwent rhizotomy between 2 and 4 years of age (54 patients), and Group II underwent rhizotomy between 5 and 19 years of age (124 patients). Comparison of Kaplan–Meier plots of lifetime orthopedic surgery rates revealed that Group II underwent orthopedic surgery at a higher rate than Group I (p = 0.037). Analysis by procedure type revealed higher orthopedic surgery rates in Group II than Group I for heel cord releases (p = 0.0025), adductor releases (p = 0.018), and hamstring releases (p = 0.02). Orthopedic surgery rates were no higher for Group II compared to Group I for ankle/foot operations (p = 0.023), femoral osteotomy (p = 0.25), iliopsoas releases (p = 0.35), and “other” operations (p = 0.013). The data indicate that early rhizotomy reduces the need for orthopedic surgery for heel cord, hamstring, and adductor releases.

KEY WORDS • cerebral palsy • dorsal rhizotomy • orthopedic operations • spastic diplegia • spastic quadriplegia

CHILDREN with spastic cerebral palsy (CP) frequently require orthopedic surgery on the lower extremities, for example, tendon releases or lengthenings and osteotomies for contractures and bone deformities that complicate spasticity.16 Orthopedic surgery has been the mainstay of corrective surgery for children with spastic CP as far back as 1823, when Delpech’s5 described a triceps surae lengthening procedure.4,10 Abolishing muscle rigidity by deafferentation also has distant historical roots beginning with Sherrington’s20 experiments with decerebrate cats in 1898, and Foerster’s7 report of posterior rhizotomy for treatment of spasticity in 1913. It has only been in more recent decades that selective dorsal rhizotomy has been established as a surgical treatment for spasticity in 1913. It has only been in more recent decades that selective dorsal rhizotomy has been established as a surgical treatment to enable higher levels of motor functioning for children with spastic CP.4,8,13,15 In addition to improvement of ambulation in high-functioning children with spastic CP, selective dorsal rhizotomy and orthopedic surgery alleviate pain, improve sitting posture, and increase ease of nursing care in children with little motor function.13,16,23

Dorsal rhizotomy and orthopedic surgery also have a preventive value in that they may reduce the incidence of progressive orthopedic deformities that often occur in children with spastic CP.9,14,16,21,23 Decisions regarding potential surgical interventions in these children require knowledge about the natural course of orthopedic and neurological problems and how treatments currently in use interact to effect the ultimate functional outcome. Despite common use of selective dorsal rhizotomy and orthopedic surgery in current clinical practice, the effects of selective dorsal rhizotomy on the need for orthopedic surgery are not known. Thus this study was undertaken to test the hypothesis that selective dorsal rhizotomy reduces the need for orthopedic surgery in children with spastic CP.

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Preoperative clinical assessments, postoperative follow-up visits, and telephone discussions with parents and health care providers were used to document orthopedic surgery performed before and after dorsal rhizotomy. Orthopedic operations were categorized as adductor releases, heel cord releases, iliopsoas releases, hamstring releases, femoral osteotomies, ankle/foot osteotomies (for example, the Grice procedure), or “other.” “Other” operations included: peroneal muscle tendon transfers and releases, iliobibial band releases, partial patella resections, quadriceps muscle releases, and plantar fasciotomies. Operative reports were obtained from orthopedic surgeons to verify the details of the orthopedic operations.

Because the literature contains no historical control for the rate of orthopedic surgery in children with spastic CP, patients in this study were divided into two groups: Group I consisted of 54 patients (mean age 7 years at last follow-up examination, range 4.5–9.2 years) who underwent dorsal rhizotomy at a higher rate than the 54 children in Group I (p = 0.037). Group I consisted of 54 children who underwent rhizotomy at 2 to 4 years of age, and Group II consisted of 124 children who underwent rhizotomy after 4 years of age. Note: the y-axis does not begin at zero at the origin.

Because the two groups were dissimilar in age, a direct comparison of the percentage of children in each group who underwent orthopedic surgery would not be informative. To normalize for these age differences between the two groups, Kaplan–Meier plots of ages at the time of the first orthopedic surgery were generated for Groups I and II using commercially available software (Statview Survival Analysis Tools; Abacus Concepts, Berkeley, CA). At 0 years of age, 100% of the children were “nonoperated,” that is, none had undergone orthopedic surgery. At each age there was a decremental decrease in the percentage of nonoperated children. The difference in rates of orthopedic surgery for the two groups as depicted by Kaplan–Meier plots was then compared and statistical significance was assessed by the Breslow-Gehan-Wilcoxon test (Fig. 1). This method permits a comparison of orthopedic surgery rates between individuals of each group over the same age intervals. Similar Kaplan–Meier plots were then generated to compare the rates of orthopedic surgery between Groups I and II for each type of orthopedic surgery, for example, operations including hamstring release and adductor release, considered separately (Figs. 2–4). The statistical analysis used generates probability values only when each of the groups being compared contains at least one individual who underwent the event of interest (in this case, an orthopedic operation). In two of the analyses (hamstring and iliopsoas releases) statistical significance was not able to be determined because no child in Group I had undergone these operations. Further analysis for these two comparisons was accomplished with the Wilcoxon test using commercially available survival analysis software (SAS/STAT, Version 6; SAS Institute, Cary, NC).

**Results**

Table 1 summarizes the percentage of children who underwent orthopedic surgery on lower extremities before and after selective dorsal rhizotomy. Overall, at the time of last follow-up review, 68 (38%) of 178 patients in the
study had undergone at least one orthopedic operation before and/or after dorsal rhizotomy, with a rate of 22% in Group I and 45% in Group II.

Table 2 illustrates the percentage of children who underwent surgical intervention for each type of orthopedic operation, considered separately. The Kaplan–Meier plots in Figs. 1 to 4 represent the first systematic demonstration of accrual rates of orthopedic surgery for a large population of children with spastic CP. The overall orthopedic surgery rate was higher for Group II than Group I (p = 0.037, Fig. 1). Of the four patients with spastic hemiplegia in Group II, only one underwent orthopedic surgery, and this was performed when the patient was 8 years of age.

Kaplan–Meier plots calculated by procedure type revealed that the rates of orthopedic surgery were higher for Group II than Group I for the following operations: heel cord releases (p = 0.0025, Fig. 2), adductor releases (p = 0.018, Fig. 3), and hamstring releases (p = 0.02, Fig. 4). The rate of orthopedic surgery was not higher for Group II than Group I for the following operations: iliopsoas releases (p = 0.35), ankle/foot operations (p = 0.023), femoral osteotomy (p = 0.25), and “other” operations (p = 0.013).

The children who underwent multiple operations for lower-extremity orthopedic deformities are summarized in Table 3. A single operative session included all orthopedic operations performed on a single date. If a patient underwent further or repeat orthopedic operations at a later date, this was considered to be a second operative session. Thirteen children required two or more operative sessions; of those children, three required three operative sessions, and two of these three patients required four operative sessions.

Discussion

At present, the percentage of children with spastic CP who eventually require each of the different orthopedic operations remains unclear. However, there is limited information regarding the need for orthopedic operations in patients who received orthopedic treatments in the prerhizotomy era. For example, Samilson, et al.,18 noted that as many as 28% of children with spastic CP develop hip dislocations, and Majestro and Frost11 reported 194 children, of whom 20% required orthopedic operations for spastic internal femoral rotation. Others have stated that at least 25% of spastic children will develop deformities of the foot and ankle.2 Likewise, it was estimated that 20 to 25% of children with spastic CP will require heel cord release

**TABLE 1**

<table>
<thead>
<tr>
<th>No. of Children (%)</th>
<th>Pre rhizotomy</th>
<th>Post rhizotomy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (54 patients)</td>
<td>2 (4)</td>
<td>10 (19)</td>
<td>12 (22)</td>
</tr>
<tr>
<td>Group II (124 patients)</td>
<td>40 (32)</td>
<td>23 (19)</td>
<td>56 (45)</td>
</tr>
<tr>
<td>total (178 patients)</td>
<td>42 (24)</td>
<td>33 (19)</td>
<td>68 (38)</td>
</tr>
</tbody>
</table>

* A smaller percentage of children in Group I underwent orthopedic operations as compared to the percentage of children in Group II. Group I = children who underwent selective dorsal rhizotomy at 2 to 4 years of age, and Group II = children who underwent selective dorsal rhizotomy after 4 years of age. Note: Sum total of pre- and post rhizotomy orthopedic surgery is greater than total in chart because children having both pre- and post rhizotomy orthopedic surgery were counted only once.
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<table>
<thead>
<tr>
<th>Table 2</th>
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<tbody>
<tr>
<td>Number, percentage, and mean age of children with CP who underwent orthopedic surgery by procedure type, including pre- and postrhizotomy operations</td>
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</table>

<table>
<thead>
<tr>
<th>Orthopedic Surgery</th>
<th>Group I (54 patients)</th>
<th>Group II (124 patients)</th>
<th>Total (178 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Children (%)</td>
<td>Mean Age, Yrs (range)</td>
<td>No. of Children (%)</td>
</tr>
<tr>
<td>heel cord release</td>
<td>2 (4)</td>
<td>7.2 (6.3–8.0)</td>
<td>33 (27)</td>
</tr>
<tr>
<td>hamstring release</td>
<td>0 (0)</td>
<td>NA</td>
<td>21 (17)</td>
</tr>
<tr>
<td>iliopsoas release</td>
<td>0 (0)</td>
<td>NA</td>
<td>4 (3)</td>
</tr>
<tr>
<td>adductor release</td>
<td>2 (4)</td>
<td>2.3 (2.3–2.3)</td>
<td>24 (19)</td>
</tr>
<tr>
<td>femoral osteotomy</td>
<td>3 (6)</td>
<td>6.9 (6.0–8.4)</td>
<td>8 (6)</td>
</tr>
<tr>
<td>ankle/foot</td>
<td>5 (9)</td>
<td>6.0 (4.8–8.0)</td>
<td>10 (8)</td>
</tr>
<tr>
<td>other</td>
<td>2 (4)</td>
<td>7.6 (6.8–8.4)</td>
<td>7 (6)</td>
</tr>
<tr>
<td>total</td>
<td>12 (22)</td>
<td>5.7 (2.3–8.4)</td>
<td>56 (45)</td>
</tr>
</tbody>
</table>

* Children in Group I generally underwent fewer of each of the subtypes of orthopedic operations than the children in Group II. The mean age at the time of orthopedic surgery varies considerably between Groups I and II. Group I = children who underwent rhizotomy at 2 to 4 years of age, and Group II = children who underwent rhizotomy after 4 years of age. Note: Sum total of individual operations is greater than total operations because some children had more than one type of orthopedic surgery performed at the first operative session. Abbreviation: NA = not applicable.

or lengthening for equinus deformity.3 Watt, et al.,22 who prospectively studied 74 children with spastic CP of various types, found that 45 patients (61%) had undergone orthopedic operations by 8 years of age. The anatomical distribution of orthopedic operations in their patients were as follows: 18 ankle/foot procedures, 11 hip soft-tissue procedures, two hip osteotomies, and 14 combined procedures.

Regarding age at the time of orthopedic operations, in a review of 114 children with spastic CP, Norlin and Tkaczuk12 found that lower-extremity orthopedic operations were performed between 1.5 and 18 years of age (mean 8 years). They also found that 20% of children who underwent initial orthopedic operations before 5 years of age required repeat surgery whereas only 10% of children who underwent initial orthopedic operations between the ages of 5 and 10 years needed repeat surgery. Furthermore, children who underwent initial orthopedic operations after the age of 10 years rarely needed repeat surgery.

One can see from the literature review that the average rate at which orthopedic operations are performed in children with spastic CP depends on many variables, including the distribution of CP types and the age of patients. Additional factors complicating such analysis include disagreement among orthopedists as to the optimum age for surgical intervention.16 Some prefer initial orthopedic intervention at an early age, whereas others contend that these operations should be postponed until the age of 3 years or as late as the age of 8 years. Sharrard and Burke19 argue that early adductor release prevents the progressive subluxation that commonly leads to hip dislocation by 5 to 7 years of age. Majestro and Frost16 reported the best results for release of spastic internal femoral rotation when performed before the age of 6 years. Furthermore, there is significant variation among orthopedists as to surgical indications for each of the different procedures.17 Because of these compounding factors, the literature fails to offer an acceptable historical control for the rate of orthopedic surgery for children with spastic CP.

Our study provides the first systematic analysis of the rates of orthopedic surgery for a large population of children with spastic CP. Kaplan–Meier plots of orthopedic surgery on the lower extremity present more clearly the rates and time intervals at which these procedures are performed. The data show that children undergoing selective dorsal rhizotomy at a younger age are less likely to require certain types of orthopedic operations, indicating that selective dorsal rhizotomy may reduce the need for these operations. In the Kaplan–Meier plots for Group I versus Group II for overall operative rates (Fig. 1) the trend is for the two plots to merge together. This, in part, reflects the fact that some of the operations were typically performed at a later age for Group I compared to Group II (Table 2). Additionally, this may reflect some clinicians’ decision to postpone orthopedic surgery until the child’s outcome from dorsal rhizotomy is more clearly defined. Hence, the overall rates of orthopedic surgery may not be lower for Group I but merely postponed until later in the life of the child. Further follow-up studies will be necessary.
to resolve this issue; however, the tendency for Kaplan–Meier plots to merge was not demonstrated for the individual operations (heel cord releases, hamstring releases, and adductor releases) that were performed at a greater rate for Group II compared to Group I.

We observed that of our 178 patients who underwent dorsal rhizotomy, 17% had undergone orthopedic surgery after dorsal rhizotomy by the last follow-up review. The rate of orthopedic surgery in our patients is much lower than that described previously. Arens, et al.,1 mentioned that 24 of 53 children in South Africa required orthopedic surgery after dorsal rhizotomy, and an additional nine were awaiting surgery, for a total of 66% requiring orthopedic surgery after dorsal rhizotomy. In that study population, there were 28 muscle releases or tendon lengthenings (mainly hip adductors, hamstrings, and triceps surae), three derotational osteotomies, one open hip reduction, and one Grice procedure. The distribution of these orthopedic operations by type of disability (such as quadriplegia or diplegia) was not documented. The authors believed that the high rate of postrhizotomy orthopedic surgery was likely related to the fact that most patients were older children and already had significant orthopedic deformities before dorsal rhizotomy. Other factors such as differences in clinical approaches would certainly account for results that differ from ours. Nevertheless, their observation is in accordance with our data indicating that selective dorsal rhizotomy performed at an early age may reduce the number of later orthopedic operations.

Fifty-seven (50%) of our 114 patients who were 8 years of age or older at last follow-up review had undergone at least one orthopedic operation. This indicates that, in general, our patients who have undergone selective dorsal rhizotomy for spastic CP require fewer orthopedic operations on the lower extremity compared to the population evaluated by Watt, et al.22 Eight percent of the older children in our study underwent ankle/foot operations, which compares favorably to the rate reported by Bassett and Baker.2 Eight percent of the same patients required femoral osteotomies, considerably fewer than reported by Samilson, et al.18 Thirty-one of the same patients (27%) required heel cord releases or lengthenings, a rate comparable to the estimation by Bennet, et al.3

Another significant finding of our study is that early dorsal rhizotomy reduced the rate only for certain orthopedic operations of the lower extremity. When compared between younger (Group I) and older (Group II) children, the rate of operations on gastrocnemius/soleus, adductors, and hamstrings was significantly lower in Group I than in Group II. Most likely this finding is related to persistent and profound reduction of spasticity in the muscle group following dorsal rhizotomy. In contrast, the rates of ankle/foot operations (other than heel cord releases) and femoral osteotomies were not significantly reduced by early dorsal rhizotomy. This is not a surprising finding because these procedures are used for treatment of fixed bone deformities that often persist despite reduced spasticity after rhizotomy. The Kaplan–Meier plots for iliopsoas releases demonstrate that Group II patients underwent this operation at a higher rate than those in Group I, but this difference did not attain statistical significance (p = 0.35). Iliopsoas releases were the most infrequently performed type of orthopedic surgery in our study population (Table 2), and therefore, longer follow-up intervals and/or a larger study population would be needed to demonstrate a significant difference in the rate of performance of this operation between Groups I and II. The “other” category of orthopedic surgery also was not reduced by early dorsal rhizotomy. The reason for this is difficult to determine, but it may be that the arbitrary grouping of the 10 different varieties of operations included in this category does not lend itself to an interpretable result.

Conclusions

In 178 children with spastic CP receiving follow-up care for at least 2 years after rhizotomy, those who underwent selective dorsal rhizotomy at an early age had lower rates of orthopedic surgery than those who underwent selective dorsal rhizotomy at a later age. This was particularly true for certain operations, such as heel cord, hamstring, and adductor releases, rather than for orthopedic procedures on the bone and joint. These findings indicate that selective dorsal rhizotomy, when performed at a younger age, may decrease the need for later orthopedic operations for some segment of the spastic CP population. Thus it seems appropriate that children with spastic CP should undergo evaluation for potential selective dorsal rhizotomy before orthopedic procedures are performed.

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