Posterior partial rootlet section in the treatment of spasticity

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Twenty-six patients were operated on using a technical modification of Förster's method of treating spasticity, which consists of a partial section of the rootlets constituting the posterior roots. Many patients had mild cerebral spastic quadriplegia or spastic diplegia: several of them were nearly independent when standing or walking, and two of them completely independent. The spastic disorders that were not made worse by voluntary movements were reduced or abolished in all but one patient, in whom rootlet section was insufficient. The spastic disorders that were made worse by voluntary movements were only partially reduced; after operation they were scarcely evident or absent in a static position, but evident during voluntary movements. No improvement was observed in one patient who suffered from spastic disorders that were evident only during voluntary movements, or in one patient suffering from dystonia. The procedure caused no sensory disorders. The operation was especially useful in patients who were acquiring or had already acquired independence when standing or walking.

Key Words • spasticity • dystonia • partial radiculotomy

Förster's method of treating spasticity has been criticized because of subsequent disorders of sensation, trophic changes, and its effects on functional reeducation. A technical modification of this method, which reduces sensation disorders and excludes the trophic changes, has been introduced by Gros, et al. It consists of a complete section of all but one or two of the rootlets that constitute the posterior roots. Another technique, which consists of a selective intramedullary section at the level of the posterior spinal cord-rootlet junction, has been proposed by Sindou, et al., for both intractable pain and spasticity.

However, such techniques are of questionable value in spastic patients who can stand or walk independently or nearly independently. In fact, we have found previously, in agreement with Gros, that the first technique does not completely preserve the proprioceptive sensations. The second technique should be limited, according to Sindou, to very seriously spastic patients, since it does not completely preserve the sensations and inevitably damages the ventrolateral perforating medullary vessels.

Very recently, the technique of "sectorial posterior rhizotomy," was proposed for the treatment of spastic patients. This operation consists of a complete section, after an intraoperative electromyographic study, of the "sectorial" rootlets that correspond to "handicapping spastic muscular groups, like hip flexor, adductores femoris, soleus." Those rootlets are preserved that correspond to "useful spastic muscular groups, like abdominal muscles, glutaeus maximus, quadriceps femoris, gastrocnemius."

Although this technique is interesting, it does not completely preserve the proprioceptive sensations. Moreover, the functional
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meaning of spasticity of any muscular group varies according to the degree of paresis and spasticity, and to various functional conditions of the muscular group itself. For instance, when there is severe spasticity in a seriously paretic quadriceps femoris, the patient so treated is handicapped when sitting, but helped when standing or attempting to walk. On the other hand, when there is a medium degree of spasticity in a moderately paretic quadriceps femoris, the patient is not necessarily helped when standing, and is handicapped when walking, since he flexes his legs with difficulty.

We have used a modification of Förster's method in 26 patients; the technique consisted of a partial section of the rootlets constituting each posterior root. We report the results of this procedure, and correlate spasticity to the degree of paresis and various functional conditions of the patients, and especially to its manifestation during voluntary movements.

Operative Technique

General anesthesia is given with N₂O, O₂, and Ethrane (2-chloro-1,1,2 trifluorethyl-difluoromethyl ether), and a laminectomy limited to T11-12 is performed. The dura mater is opened to permit observation of the spinal cord, and the laminectomy is then extended to another lamina exposing no more than the last 6 to 7 cm of the spinal cord from the origin of the filum terminale. The laminectomy usually covers three laminae; it should not be extended laterally as far as the articular facets, because it is unnecessary for the operation and may cause skeletal deformity.

The arachnoid is opened, slipped beyond the spinal cord-rootlet junction, and removed. The posterior component of L-1 is then followed from the intervertebral foramen of L-1, or, if this is not visible, from the inferior lateral region of the exposed vertebral canal as far as the junction of its rootlets with the spinal cord. From this level, the rootlets of each root are separated as far as S-1, at their junction with the spinal cord. Each root generally has four to six rootlets, 0.5 to 2 mm thick. The rootlets of S-1 are usually recognizable because they join the spinal cord at about 2 cm from the origin of the filum terminale and are usually thicker than the other lumbar or sacral posterior rootlets.

Under the operating microscope one-half or two-thirds of each rootlet is cut, approxi-
we preferred to partially cut the T-12 posterior roots at the intervertebral foramens.

**Summary of Cases**

Between January, 1973, and March, 1975, we operated on 26 patients by posterior partial rootlet section. The patients ranged in age from 6 to 16 years. Their clinical syndromes consisted of the usual perinatal pathology, such as asphyxia, difficult labor, and encephalitis, except for one patient who had suffered from spinal cord trauma in childhood. All patients had undergone physiotherapy for many years and had stable clinical pictures.

Ten patients had cerebral spastic diplegia and 14 had cerebral spastic quadriplegia, one patient had posttraumatic spastic paraplegia, and one dystonia. These syndromes were not very serious in any of the patients. Many were nearly independent when standing or walking, and two were completely independent. Moreover, all patients had normal or moderately reduced mental development.

The results of the operation were evaluated on the basis of several criteria. The objective difference between the pre- and postoperative sitting position, standing position, and walking was documented in most patients by photographs and in some cases also by cinematography. The difference between pre- and postoperative stretch reflexes, in the subjective judgment of the patient, his family, and physiotherapist, was also assessed.

In Tables 1 and 2, the functional results obtained in the 26 patients are reported. These results were recorded within the first days or weeks of the operation, before the patients had recommenced physiotherapy. Of the 13 patients suffering from spastic disorders not made worse by voluntary movements, seven (Cases 1, 3, 5, 8, 10, 11, and 13) improved markedly, two (Cases 4 and 6) moderately, and three (Cases 7, 9, and 12) slightly (Table 1). Most patients improved when sitting, standing, or walking, because of the abolition or reduction of the spastic disorders of the lower limbs, such as hyperadduction or crossing, hyperextension, medial rotation, and equinism. The only patient in this group who did not improve (Case 2) showed a recurrence of the increased lower limb stretch reflexes after 3 months, presumably caused by an insufficient section of the rootlets.

On the other hand, as shown in Table 2, of the 12 patients suffering from spastic disorders made worse by voluntary movements, not one improved markedly, two (Cases 21 and 22) improved moderately, and nine (Cases 15–22, 23–25) improved slightly (Table 2). In this group the spastic disorders were either scarcely evident or absent postoperatively when the patient was in a static position, but were always evident during voluntary movements. The two patients who improved moderately showed spastic disorders that were made only slightly worse by voluntary movements. The one patient who showed spastic disorders only during voluntary movements (Case 14) did not improve after the operation, nor was improvement observed in the patient suffering from dystonia (Case 26).

Hyperextension and arching of the trunk were reduced, especially if the operation involved the T-12 level. Moreover, according to other observations and to our previous experience, in all cases of tetraspasticity an improvement of the mobility of the upper limbs was observed, even if only slightly. In three patients there was a slight improvement of speech; and in one, mastication was improved.

In all cases the increase of the stretch reflexes was markedly reduced or, more often, abolished. In only two cases did the stretch reflexes reappear pathologically in a muscular group: in one patient, the clonus of the feet reappeared after 3 months at the same time as equinism; in the other, increased hip and knee stretch reflexes reappeared 3 months postoperatively, concurrently with the reappearance of hyperadduction of the thighs and hyperextension of the legs.

Exteroceptive sensations appeared normal clinically in all patients but one, in whom hypesthesia in the dorsal regions of the feet was observed. This deficit lasted for 3 months postoperatively, during which time the patient also had paresthesia limited to the same regions but not described as distressing. Even though most patients exhibited overactive lower limb response to exteroceptive stimuli, this occurred only during the first few days after the operation and was not accompanied by paresthesia.

Proprioceptive sensations, like position sense of the lower limbs or of the individual toes, tactile discrimination, and pallesthesia,
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### TABLE 1

**Functional results in 13 spastic patients not made worse by voluntary movements**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Syndrome*</th>
<th>Functional Condition Before Surgery</th>
<th>Bilat. Rootlet Section</th>
<th>Functional Results After Surgery</th>
<th>EC &amp; PC Sensations†</th>
<th>Follow-Up Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>ICD</td>
<td>stood independently, thighs hyperadduced &amp; medially rotated, legs moderately flexed, feet equine; walked independently, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked independently, thighs not hyperadduced, legs more extended, feet not equine; residual medial rotation in rt thigh</td>
<td>normal</td>
<td>2 yrs</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>ICD</td>
<td>stood nearly independently, thighs hyperadduced, legs hyperextended, feet slightly equine; on walking, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked nearly independently, feet slightly equine; hyperadduction &amp; hyperextension recurred after 3 mos</td>
<td>normal</td>
<td>1 yr</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>ICD</td>
<td>stood independently, thighs hyperadduced, feet equine; walked independently, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked independently, thighs not hyperadduced, feet not equine</td>
<td>normal</td>
<td>2 yrs</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>ICD</td>
<td>stood nearly independently, thighs hyperadduced, feet equine; on walking, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked nearly independently, thighs not hyperadduced, rt foot not equine, lt slightly equine</td>
<td>normal</td>
<td>20 mos</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>ICD</td>
<td>stood nearly independently, thighs hyperadduced, feet equine; on walking, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked nearly independently, thighs not hyperadduced, feet not equine</td>
<td>normal</td>
<td>14 mos</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>ICQ</td>
<td>stood with help, thighs hyperadduced, legs hyperextended, feet equine; trunk hyperextended; difficult mobility of arms &amp; speech; on walking, disorders unchanged</td>
<td>T12-S1</td>
<td>stood &amp; walked with help, thighs not hyperadduced, legs not hyperextended; lt foot not equine, rt slightly; trunk not hyperextended; mobility of hands slightly improved</td>
<td>EC sensations normal; PC sensations non evaluable</td>
<td>2½ yrs</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>ICQ</td>
<td>stood with help, thighs crossed, feet equine; difficult mobility of arms; on walking, disorders unchanged</td>
<td>L1-S1</td>
<td>stood with help, thighs slightly hyperadduced; recurrence of equinism in both sides after 3 mos; mobility of arms slightly improved</td>
<td>normal</td>
<td>21 mos</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>ICQ</td>
<td>stood nearly independently, thighs hyperadduced, feet equine; difficult mobility of arms &amp; speech; on walking, disorders unchanged</td>
<td>L1-S1</td>
<td>stood &amp; walked nearly independently, thighs not hyperadduced, feet not equine; mobility of arms &amp; speech slightly improved</td>
<td>normal</td>
<td>20 mos</td>
</tr>
</tbody>
</table>

*ICD = infantile cerebral diplegia; ICQ = infantile cerebral quadriplegia.
†EC = exteroceptive and PC = proprioceptive sensations.
**TABLE 1 (Continued)**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Syndrome*</th>
<th>Functional Condition Before Surgery</th>
<th>Bilat. Rootlet Section</th>
<th>Functional Results After Surgery</th>
<th>EC &amp; PC Sensations</th>
<th>Follow-Up Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>15</td>
<td>ICQ</td>
<td>stood nearly independently, thighs hyperadducted &amp; medially rotated, legs slightly flexed, feet equine; on walking, disorders unchanged; difficult mobility of arms &amp; speech</td>
<td>L1–S1</td>
<td>normal</td>
<td>17 mos</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>ICQ</td>
<td>stood with help, thighs hyperadducted, legs hyperextended, feet equine; difficult mobility of arms; on walking, disorders unchanged</td>
<td>L1–S1</td>
<td>normal</td>
<td>16 mos</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>16</td>
<td>ICQ</td>
<td>stood nearly independently, thighs hyperadducted, feet equine; difficult mobility of arms &amp; speech; on walking, disorders unchanged</td>
<td>L1–S1</td>
<td>normal</td>
<td>16 mos</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>ICQ</td>
<td>stood with help, thighs hyperadducted, legs hyperextended, feet equine; difficult mobility of arms; on walking, disorders unchanged</td>
<td>T12–S1</td>
<td>hypesthesia in dorsal regions of feet and slight reduction of position sense of legs for 3 mos</td>
<td>14 mos</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>16</td>
<td>ICQ</td>
<td>stood with help, thighs crossed, legs hyperextended, feet equine; walking impossible; difficult mobility of arms &amp; speech</td>
<td>T12–S1</td>
<td>normal</td>
<td>13 mos</td>
<td></td>
</tr>
</tbody>
</table>

*ICD = infantile cerebral diplegia; ICQ = infantile cerebral quadriplegia.
†EC = exteroceptive and PC = proprioceptive sensations.

Discussion

We were not satisfied with the results of our experience with stereotaxic dentatolysis or pulvinolysis for the treatment of spasticity. Förster's method of treating spasticity, however, has been very encouraging, particularly in those patients in whom postural spastic disorders did not markedly increase during voluntary movements. After this experience with posterior partial rootlet section, we can confirm the usefulness of such a method in patients who show spastic disorders while in a static position, without showing an evident increase of them in voluntary movements.

Moreover, in these patients we have noticed that the reduction of the spastic dis-

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were evaluated in 21 of the 26 patients. In all cases but one they appeared normal on the clinical level. No patient had ataxia; only one showed a reduction of the position sense of the lower limbs, which was no longer present after 3 months. No general complications were observed.
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TABLE 2

Functional results in 12 spastic patients made worse by voluntary movements and in one patient with dystonia

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Syndrome*</th>
<th>Functional Condition Before Surgery</th>
<th>Bilat. Rootlet Section</th>
<th>Functional Results After Surgery</th>
<th>EC &amp; PC Sensations†</th>
<th>Follow-Up Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>7</td>
<td>ICD</td>
<td>stood with help, no evident spastic disorders; on walking, thighs crossed, legs hyperextended, feet equine</td>
<td>L1–S1</td>
<td>unchanged</td>
<td>normal</td>
<td>3 yrs</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>ICD</td>
<td>stood nearly independently, thighs hyperadducted, feet equine; on walking, disorders increased</td>
<td>L1–S1</td>
<td>stood nearly independently, thighs not hyperadducted, feet not equine; on walking, thighs moderately hyperadducted &amp; feet equine</td>
<td>normal</td>
<td>15 mos</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>ICD</td>
<td>stood with help, thighs hyperadducted, legs hyperextended, feet equine; on walking, disorders increased</td>
<td>L1–S1</td>
<td>stood with help, thighs not hyperadducted, legs not hyperextended, feet slightly equine; on walking, thighs slightly hyperadducted, legs slightly hyperextended, feet equine</td>
<td>normal</td>
<td>13 mos</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>ICD</td>
<td>stood with help, thighs hyperadducted, feet equine; on walking, disorders increased, thighs crossed</td>
<td>L1–S1</td>
<td>stood with help, thighs not hyperadducted, feet not equine; on walking, thighs moderately hyperadducted, feet equine</td>
<td>normal</td>
<td>10 mos</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>ICD</td>
<td>sat with thighs medially rotated &amp; hyperadducted; during attempts at movements, disorders increased; permanently retracted legs; Lt foot equine, rt retracted in permanent equinovarism</td>
<td>L1–S1</td>
<td>sat with thighs not hyperadducted &amp; slightly medial rotated; during attempts at movements, thighs moderately hyperadducted &amp; medial rotated; legs passively more extensible, Lt foot slightly equine</td>
<td>normal</td>
<td>10 mos</td>
</tr>
<tr>
<td>19</td>
<td>7</td>
<td>ICQ</td>
<td>sitting impossible because of arching of trunk; thighs medially rotated &amp; crossed, legs hyperextended; very difficult mobility of arms &amp; speech; disorders increased during attempts at movements</td>
<td>T12–S1</td>
<td>sitting possible because arching reduced; crossing, medial rotation &amp; hyperextension absent when immobile, but present during attempts at movements; mobility of arms &amp; speech slightly improved</td>
<td>EC sensations normal; PC sensations nonevaluable</td>
<td>2 yrs</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
<td>ICQ</td>
<td>sitting impossible because of arching of trunk; thighs crossed, legs hyperextended; difficult mobility of arms &amp; speech; disorders increased during voluntary movements</td>
<td>T12–S1</td>
<td>sitting possible because arching reduced; thighs slightly hyperadducted &amp; legs flexed; during voluntary movements, moderate hyperadduction &amp; hyperextension; mobility of hands slightly improved</td>
<td>EC, sensations normal; PC sensations nonevaluable</td>
<td>21 mos</td>
</tr>
</tbody>
</table>

*ICD = infantile cerebral diplegia; ICQ = infantile cerebral quadriplegia.
†EC = exteroceptive and PC = proprioceptive sensations.

(continued on following page)
TABLE 2 (Continued)

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Syndrome*</th>
<th>Functional Condition Before Surgery</th>
<th>Bilat. Rootlet Section</th>
<th>Functional Results After Surgery</th>
<th>EC &amp; PC Sensations†</th>
<th>Follow-Up Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>9</td>
<td>ICQ</td>
<td>stood nearly independently, thighs hyperadducted, feet equine; on walking, disorders slightly increased; difficult mobility of arms &amp; speech</td>
<td>L1-S1</td>
<td>stood nearly independently, no spastic disorders of thighs; on walking, thighs slightly hyperadducted; mobility of hands slightly improved</td>
<td>normal</td>
<td>18 mos</td>
</tr>
<tr>
<td>22</td>
<td>8</td>
<td>ICQ</td>
<td>stood nearly independently, thighs hyperadducted, feet equine; difficult mobility of arms &amp; speech; on walking, disorders slightly increased</td>
<td>L1-S1</td>
<td>stood nearly independently, thighs not hyperadducted, feet not equine; on walking, thighs slightly hyperadducted; mobility of hands slightly improved</td>
<td>normal</td>
<td>16 mos</td>
</tr>
<tr>
<td>23</td>
<td>14</td>
<td>ICQ</td>
<td>sitting impossible because of arcing of trunk; thighs crossed, legs hyperextended; very difficult mobility of arms &amp; speech; disorders increased during attempts at movements; chewing food impossible</td>
<td>T11-S1</td>
<td>sitting possible because of reduced arcing; legs flexed and thighs slightly hyperadducted; during nonevaluable attempts at movements, thighs markedly hyperadducted and legs slightly hyperextended; mobility of arms slightly improved; chewing food just possible</td>
<td>EC sensations normal; PC sensations</td>
<td>14 mos</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>ICQ</td>
<td>supine, thighs crossed, especially during attempts at movement; partially retracted legs; feet retracted in permanent equinovarism; very difficult mobility of arms &amp; speech; very difficult to dress</td>
<td>T12-S1</td>
<td>supine, thighs not crossed, but moderately hyperadducted during attempts at movement; legs slightly flexed; less difficult to dress; mobility of arms slightly improved</td>
<td>EC sensations normal; PC sensations</td>
<td>12 mos</td>
</tr>
<tr>
<td>25</td>
<td>16</td>
<td>Post-traumatic paraplegia</td>
<td>sat with thighs hyperadducted and legs hyperflexed; voluntary movements present only in feet; during attempts at movements, thighs more hyperadducted &amp; legs more flexed</td>
<td>L1-S1</td>
<td>sat with thighs not hyperadducted &amp; legs less flexed; can flex &amp; extend legs, even if thighs hyperadducted</td>
<td>normal</td>
<td>11 mos</td>
</tr>
<tr>
<td>26</td>
<td>9</td>
<td>dystonia</td>
<td>stood with help, slight dyskinetic disorders; on attempting to walk, muscular spasms of the neck, trunk &amp; all limbs; trunk arching &amp; hyperextension &amp; crossing of legs</td>
<td>T12-S1</td>
<td>unchanged</td>
<td>normal</td>
<td>1 yr</td>
</tr>
</tbody>
</table>

*ICD = infantile cerebral diplegia; ICQ = infantile cerebral quadriplegia.
†EC = exteroceptive and PC = proprioceptive sensations.
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orders was associated with the reduction of
the increase of the stretch reflexes, and the
abolition of the spastic disorders with the
abolition of the increase of the reflexes
themselves. The recurrence of the increase of
the stretch reflexes was associated with the
recurrence of the spastic disorders. Therefore,

it seems likely that the increase in stretch
reflex is a quantitative measure of this type of
spasticity, which has been already defined by
one of us as “tonic” spasticity.2

On the contrary, the abolition of the in-
crease of the stretch reflexes was not
associated with the abolition of those spastic
disorders that were evident in postural con-
ditions but more severe in voluntary
movements. The patients showed only a slight
reduction of spasticity during voluntary
movements. Also it should be noted that the
abolition of the increase of the stretch reflexes
in the one patient who exhibited spastic dis-
orders only in voluntary movements was not
associated with abolition or reduction of
spasticity itself. Therefore, it seems likely
that the increase of the stretch reflex is no
measure of the type of spasticity that is
strictly associated with voluntary movement.
This type of spasticity clearly differs from
dystonia, because it concerns only the anti-
gravitational muscles, and one of us has
already defined it as “phasic” spasticity.2

The ideal treatment, from a theoretical
point of view, would abolish the increase of
the stretch reflexes, by selectively cutting the
Ia fibers which constitute the afferent arches
of the stretch reflexes. This aim is not realized
by posterior partial rootlet section, nor is it
possible surgically, since it is well known that
the large myelinated Ia fibers and other
similar large myelinated fibers responsible for
deep sensations are not located in the
peripheral portion of the posterior rootlets.
However, our experience demonstrates that
the aim of any operation for spasticity on
posterior roots, that is, the interruption of the
afferent arches of the stretch reflexes, can be
achieved by partially cutting the posterior
rootlets. Recent anatomical studies13 indicat-
ing that all the large myelinated fibers tend to
occupy the center of the rootlet at the spinal
cord-rootlet junction confirm that it is not
necessary to cut the posterior rootlets com-
pletely to interrupt the Ia fibers.

The absence of clinical disorders of ex-
teroceptive sensations caused by cutting one-
half or two-thirds of the rootlets from the
dorsomedial to the ventrolateral site of each
rootlet can be explained by the fact that the
fibers responsible for exteroceptive sensa-
tions are situated peripherally and especially
in the ventrolateral part of the rootlet.13

Meanwhile, the clinical preservation of
proprioceptive sensations could be explained
by the hypothesis that the fibers responsible
for deep sensations are situated eccentrically
toward the ventrolateral part of the rootlet.

Finally, we were not surprised to observe
only a slight improvement in speech and
mobility in the arms in the cerebral spastic
quadriplegic patients. This had already been
reported by other authors7 and by ourselves4
after operations on posterior lumbar roots. It
is likely that a reduction of peripheral stimuli,
even if at a subclinical level, can reduce the
hyperexcitability of supraspinal structures
responsible for tetraspasticity.

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