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Surgical Treatment of Spastic Syndrome of the Lower Limbs in Children with Cerebral Palsy

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Abstract Childhood Cerebral Palsy (CP) occurs due to brain damage during the perinatal period. CP is characterized by impaired motor functions, increased muscle tone, and other symptoms. Selective dorsal rhizotomy is the most effective treatment method for spastic forms of CP. In this article, we present our experience with rhizotomy. In this article, we present our experience performing selective dorsal rhizotomy (SDR) in 18 patients. The effectiveness of our surgical technique is demonstrated by the postoperative regression of the spastic syndrome.

Keywords Childhood Cerebral Palsy, Selective dorsal rhizotomy, Spasticity, Diplegia, Tetraparesis

1. Introduction

Cerebral palsy is a serious neurological disorder in children, occurring in 2 per 1,000 newborns and leading to lifelong disability in affected individuals [1]. Among the various factors contributing to disability in patients with cerebral palsy, spasticity in the limbs plays a significant role [1,2]. This condition affects nearly 75% of patients with cerebral palsy [3,4], hindering motor tasks in daily life and leading to muscle contractures and orthopedic deformities in growing children. Selective dorsal rhizotomy (SDR) has been shown to be more effective than other interventions in reducing spasticity in patients with cerebral palsy, thereby improving motor activity and alleviating orthopedic deformities [5,6]. Since 2016, the Republican Scientific and Practical Medical Center of Neurosurgery has been performing surgical interventions on peripheral nerves to relieve limb spasticity. Since 2020, surgeries on the intradural roots of the spinal cord conus, namely SDR, have been introduced. Currently, several surgical techniques for SDR are in use [6].

2. Materials and Methods

Since 2023, we have performed selective dorsal rhizotomy (SDR) on 18 patients with cerebral palsy. Among them, 12 patients were diagnosed with spastic diplegia, while 6 had spastic tetraparesis. The group included 10 boys and 8 girls, aged from 3 to 18 years. Surgical interventions were carried out using a Carl Zeiss (Germany) operating microscope with a "face-to-face" assistant module and a 32-channel intraoperative neuromonitoring system (Inomed, Germany) with free-run EMG and bipolar stimulation-based root identification.

A crucial factor for performing SDR was the meticulous selection of patients. The primary candidates for SDR were children with spastic diplegia who had either mild spasticity in the upper limbs or none at all. During the patient evaluation, we ensured that motor impairments had originated in infancy and had shown steady improvement in early childhood rather than progressive deterioration. Preterm birth was considered a significant factor in selecting SDR candidates. Neurological examination findings determined whether spasticity was the primary and sole cause of muscle hypertonia and whether it significantly impeded motor functions such as sitting, crawling, standing, and walking. Additionally, we conducted a thorough assessment of the severity of orthopedic deformities and their impact on the patient's motor activity.

All patients underwent MRI of the brain and the conus region of the spinal cord. Spinal cord MRI was essential for determining the surgical intervention level and ruling out other pathologies. We considered SDR appropriate for children over the age of 3, as cerebral palsy type and spasticity patterns cannot be reliably diagnosed at a younger age. Dystonia and hyperkinesias accompanying spasticity were regarded as unfavorable factors, as their manifestations tend to worsen postoperatively due to reduced spasticity. Dystonia typically becomes clinically apparent by the age of 5, and in some cases by 10, with a progressive course.

Exclusion criteria included patients with severe basal ganglia damage detected on MRI, which was considered a contraindication due to associated rigidity; patients with a history of orthopedic surgery in the past six months; those with severe fixed joint deformities; and severe scoliosis, which was considered a relative contraindication. Additionally,

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children with increased muscle tone due to severe hydrocephalus, intrauterine or neonatal infections, or head trauma were excluded from the study.

3. Results and Discussion

Anesthesia Considerations. Since the surgical procedure is performed under continuous intraoperative neuromonitoring, the use of muscle relaxants and inhalation anesthetics is excluded during the main stage of the operation. These agents suppress electrical and motor muscle responses during nerve root stimulation. At this stage of the procedure, anesthesia was maintained using propofol, thiopental, and fentanyl.

Surgical Technique Features. The patient was positioned prone on the operating table with the head end slightly lower than the lumbar region. This positioning allowed cerebrospinal fluid to accumulate proximally, minimizing its loss from the surgical site in the lumbar region. Needle electrodes were placed bilaterally by neurophysiologists in the adductor muscles, anterior and posterior thigh muscle groups, tibialis anterior muscle, medial head of the gastrocnemius muscle, and plantar foot muscles in preparation for intraoperative EMG studies (Figure 1).

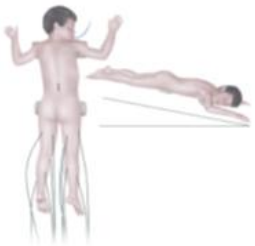

Figure 1. Plantar foot muscles in preparation for intraoperative EMG studies

Figure 2. Ultrasound verification of the conus position after laminectomy

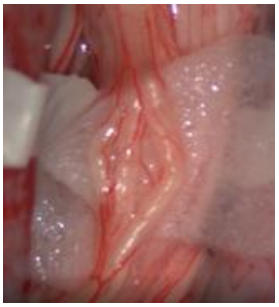

Figure 3. The suspected sensory root bundles were suspended on a rubber cushion on each side

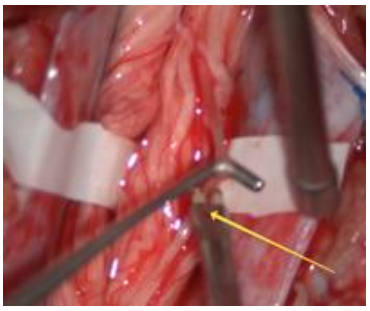

Figure 4. A probe stimulator delivered single continuous rectangular pulses of 0.1 ms duration at 2 Hz with a current intensity of 0.1 mA (up to 0.4 mA) to individual roots

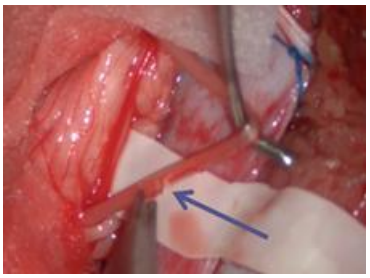

Figure 5. Grade 1 indicated that root transection was unnecessary

1. Prone positioning of the patient.
2. Laminectomy at the level of the lower border of the conus.
3. Placement of sensory nerve roots on a silicone cushion.
4. Direct bipolar stimulation using a probe.
5. Partial transection of the sensory root after determining the severity according to the Grade scale.

According to MRI data, the conus medullaris typically terminates between the T12 and L2 vertebral levels. To limit the laminectomy to one or two levels, preoperative fluoroscopic marking was performed, followed by ultrasound verification of the conus position after laminectomy (see Figure 2). The laminectomy was required to expose at least 5 mm of the conus to ensure the safe manipulation of the dorsal roots. After hemostasis of epidural veins and bone structures, we performed a dural incision. Special attention was given to opening the dura mater without damaging the arachnoid membrane. This was achieved by longitudinally tearing the arachnoid without using cutting instruments.

The subsequent arachnoid dissection was performed gradually, allowing controlled decompression of the intrathecal pressure. This approach prevented turbulence and mixing of nerve roots, which could otherwise complicate anatomical and topographical orientation. Preserving the anatomical arrangement of the conus roots after opening the meninges facilitated the surgical procedure. The next steps were carried out under microscopic magnification and intraoperative EMG monitoring.

Although EMG analysis allowed for differentiation of the nerve roots, we always confirmed this data with visual identification. For example, the L2 spinal roots were identified at their exit point due to the surgical access at this level. The

L3 and L4 roots were located medially to the L2 root and typically consisted of two or three naturally separated fascicles. The L5 and S1 roots were positioned medial to the L4 root and were the largest of all lumbosacral roots, typically consisting of three or four naturally separated fascicles. The S2 root usually appeared as a single bundle. Sensory and motor L2 roots were traced back to the conus medullaris until a natural separation between them was identified.

The sensory S2 root could be bulky, especially in patients with a post-fixed lumbosacral plexus. However, a distinct and noticeable decrease in size was always observed in the S2 root. The individual S2–S5 spinal roots appeared as thin filaments, usually emerging centrally from the conus. At this level, sensory and motor roots were closely packed, leaving no separation between them, so all S2–S5 spinal roots were left intact. The S3–S5 roots, including sensory ones, were always thinner than the others. In the final identification of the roots, intraoperative EMG played a decisive role.

For better separation, the suspected sensory root bundles were suspended on a rubber cushion on each side (see Figure 3). A probe stimulator delivered single continuous rectangular pulses of 0.1 ms duration at 2 Hz with a current intensity of 0.1 mA (up to 0.4 mA) to individual roots (see Figure 4). A motor response indicated that the root was motor. If no evoked muscle response was detected, further stimulation was applied with tetanic bursts at 50 Hz and a current intensity of 1 mA (up to 2 mA). A positive response identified a sensory root and simultaneously determined its involvement in spasticity (Grade assessment).

- Grade 1 indicated that root transection was unnecessary (see Figure 5).
- Grade 2 required a 25% root transection if the identified nerve root corresponded to a myotome with increased tone.
- Grade 3 required a 50% root transection.
- Grade 4 required a 75% root transection.

After completing the rhizotomy, the intradural space was irrigated with saline. Any bleeding from transected roots was controlled using pinpoint bipolar coagulation. The dura mater was sutured with a continuous 4/0 Prolene suture, and the wound was closed in layers.

After surgery, patients remained in the intensive care unit overnight. Early mobilization began on postoperative day 3, with the initiation of rehabilitative physical therapy. Patients were typically discharged home between postoperative days 5 and 7.

4. Conclusions

1. In spastic diplegia, observed in 18 of our patients, the surgical outcome was complete elimination of lower limb spasticity without a decline in muscle strength. In contrast, partial recurrence of spasticity (up to 2 points on the Ashworth scale) was noted in six patients with spastic quadriplegia after six months.
2. The combination of selective dorsal rhizotomy (SDR) and appropriate rehabilitation significantly improves motor skills within 3–6 months after surgery.
3. The proposed surgical technique does not require extensive laminectomy and does not lead to spinal instability in the long-term postoperative period.
4. Potential complications, such as transient dysesthesia in certain lower limb dermatomes, were temporary and did not affect the timing of motor recovery.

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