CLINICAL STUDY

Selective posterior rhizotomy in the treatment of cerebral palsy, first experience in Czech Republic

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Abstract

Background: **Selective posterior rhizotomy (SPR) is a surgical treatment of spasticity in patients with cerebral palsy (CP).**
Starting point: **We present the first experience with SPR in Czech Republic.**
Material and methods: **14 patients with severe spasticity were indicated for SPR during the period of 2 years (2001–2002). The indication criteria were severe spasticity with clonus, more or less symmetric impairment of lower extremities and increased H/M ratio in preoperative electromyography. SPR was performed in 13 cases, in one patient only the revision and intradural neurolysis of caudal roots was done. In all patients we used osteoplastic laminotomy L2–S1. The intraoperative EMG monitoring with selection of rootlets with abnormal response was performed. Preoperative and postoperative number of spasms, passive range of joint movements, Ashworth scale, Peacock grade and level of functional independence were assessed. The comparison of H/M ratio on EMG before and after surgery was performed.**
Results: **An evident improvement in all tested parameters was noted. The per-operative course in all cases was uneventful. Till now, no persistent complications have been observed.**
Conclusion: **SPR improves functional ability in a selected group of CP patients. Our findings regarding clinical outcomes are in agreement with those of other authors. In our experience the extrapyramidal symptoms may not be an absolute contraindication of SPR.** ***(Tab. 5, Fig. 3, Ref. 10.)***
Key words: selective posterior rhizotomy, spasticity, cerebral palsy, intraoperative electrophysiological monitoring, H-reflex.

Cerebral palsy (CP) is a disorder of movement and posture, which is caused by a central nervous system insult sustained during gestation or early childhood. Spastic CP is the most common of all forms. The loss of suprasegmentary control over the balance between inhibitory and excitatory synapses on the anterior horn cells causes a reduction in inhibition and results in spasticity (Fasano et al, 1978; Sherrington, 1898). Spasticity is defined as a velocity dependent increase in resistance to passive movement. It is associated with hyperactive tendon reflexes and gives rise to the clasp-knife phenomenon encountered during passive limb movement. Decreased range of motion of the affected limbs and clonus are frequently seen. Selective sectioning of the posterior rootlets reduces sensory input, which results in decreased muscle tone and improved motor function in children with spastic form of CP (Park and Owen, 1992; Park et al, 1993; Peacock and Arens, 1982).

A wide variety of surgical techniques for reduction of spasticity has been described. Among them, selective posterior rhizotomy has been used widely and successfully to normalize muscle tone in children with spastic cerebral palsy. A traditional treatment available for spastic form of CP and associated deformities includes physical therapy, orthopedic surgery, use of orthoses,

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walking aids, botulinum toxin A applications, oral baclofen treatment or intrathecal baclofen infusions.

Historical background

The physiology of hyperactive spinal reflexes was first described by Sherrington in the late 1800's (Sherrington, 1898). Division of posterior spinal nerve roots was shown to abolish hypertonus in decerebrate on cats. This work was applied to human spasticity in the early 1900's by Foerster, who published a large series of cases in 1913, including patients with spinal cord injury, stroke, multiple sclerosis, and cerebral palsy (Foerster, 1913). Foerster also discussed the use of posterior rhizotomy for relief of tabetic crises and intractable pain. Foerster described division of whole posterior nerve roots from L2 to S2, with sparing of L4 or L3 to preserve sensation and quadriceps tone for standing. Although he did not report major sensory losses among his patients, the procedure was practically abandoned until the 1960's, presumably because of complications of excessive deafferentation.

Gros revised Foerster's procedure to prevent sensory problems by dividing only four fifths of the rootlets at each spinal level. Difficulties with weakness and functional loss were seen in 25 per cent of the patients. The selection process for surgical candidates was not described, and spasticity persisted in some cases (Gros, 1979).

In the 1970's, Fasano and colleagues (1978) published a method of selective posterior rhizotomy in which rootlet division was based on electromyographical responses to repetitive electrical stimulation. Their technique relied on knowledge from animal experimental work, which demonstrated that monosynaptic reflex responses become depressed by rapidly repeated stimulation of afferent fibers. A one-to-one correspondence between the electrical stimulus to the afferent root and the motor response was seen at lower frequencies, but depression occurred at frequencies beyond 15 per second. This depression was believed to be caused by presynaptic inhibition.

Working at the level of the conus medullaris in spastic children, Fasano and co-workers (1979) stimulated lumbosacral posterior nerve rootlets at increasing frequencies while recording the responses in corresponding anterior roots and muscles. Single pulses were used to identify the threshold for muscle contraction, and frequencies were then increased to 30 to 50 Hz. Some rootlet responses showed the expected inhibition at higher frequencies, but others lacked this inhibition or had exaggerated motor responses (sustained discharge or spread to other muscle groups). It was postulated that abnormal interneuronal control of Ia afferents was responsible for these phenomena and that a lack of presynaptic inhibition could be involved. The rootlets associated with the exaggerated responses were divided, and the remainder was spared. In most cases, 25 to 50 per cent of the rootlets were divided. Very favorable results were described in 80 children with spastic cerebral palsy who were followed for up to 15 years postoperatively. Unfortunately, standardized measures of function were lacking for this population, making objective assessment of progress very difficult, and continued follow-up on this series of patients has not been published. Laitinen and associates used Fasano's technique for nine spastic adults, many of whom were severely disabled by multiple sclerosis. Improvements in voluntary movement torques were observed with the use of an isokinetic dynamometer (Laitinen et al, 1983).

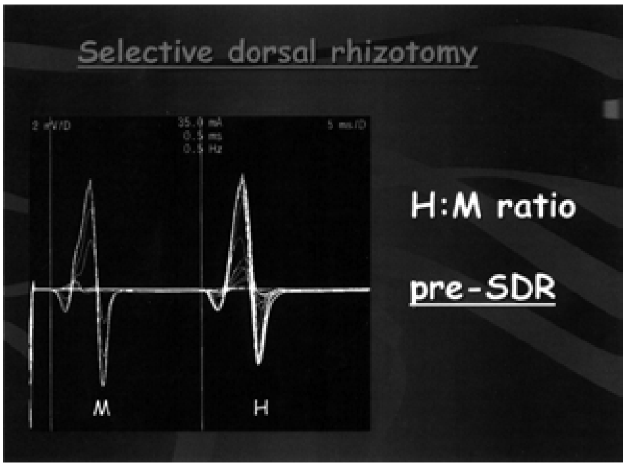

Fig. 1. Pre-SDR EMG testing H:M ratio. Superposition of individual responses shows the maximum amplitude M wave elicited by supramaximal stimulation and the maximum amplitude H wave was elicited by gradual increase of intensity of stimulation. Peak to peak amplitude were measured.

In the 1980's, an interest in Fasano's procedure led to a further change in the selective posterior rhizotomy technique. The operative site was changed to the cauda equina to positively identify and preserve S3 and S4 roots. Caution was also taken to preserve most of S2 roots. This procedure was used for children with spastic cerebral palsy, and follow-up to 7 years has been reported on 60 patients from the original Capetown series, with successful maintenance of reduced spasticity as well as functional gains (Peacock et al, 1982). Postoperative assessment of patients in Peacock's series has shown decreased muscle tone, increased range of motion and improved function, including gait, with the use of objective measurements (Peacock a Staudt, 1991). Various aspects of the surgical technique have been refined to improve its safety and efficacy, including the addition of anal sphincter monitoring.

Materials and methods

Characteristics of the patients

Our group consists of 14 patients with spasticity of different origin. The indication criteria were severe spasticity with clonus, more or less symmetric impairment of lower extremities and increased H/M ratio in preoperative electromyography (Fig. 1). The group consists of 12 non-ambulatory patients with severe quadriplegia and two ambulatory patients with diplegic form of CP. One ambulatory patient had moderate walking difficulties and second one used walking aids. One of non-ambulatory severely involved patients was 24 year old woman with progres-

Tab. 1. Assessment of spasticity by Ashworth.

Ashworth score	Characteristics
0	No increase in tone
1	Slight increase in tone, giving a "catch" when the affected part(s) is/are moved in flexion or extension
2	More marked increase in tone but affected part(s) easily flexed
3	Considerable increase in tone, passive movement difficult
4	Affected part(s) rigid in flexion or extension

Tab. 2. Grading of gross motor function by Peacock.

Peacock grade	Gross motor function
1	No purposeful movement
2	Minimal purposeful movement
3	Sitting alone and/or crawling and/or fully supported stepping. Difficulty in assuming positions
4	Reasonably useful nonambulant locomotion (crawling, "bunny-hopping", etc.) and/or walking when assisted
5	Walking with a walking aid
6	Walking alone with a poor pattern
7	Fully independent walking with good pattern

Tab. 3. Passive range of motion in selected joints.

	Preoperatively	Postoperatively
Abduction of the hips	32±15.5	54±18.5
Popliteal angle of the knee	48.5±14	35.5±17
Dorsiflexion of the ankle	1.0±6.5	5±7.5

Tab. 4. WeeFIM Functional Independence Measure for Children.

Subscale	N	Preoperatively	Postoperatively	Change (%)
Motor	13	19.5	25.5	30.7
Cognitive	13	7.5	9.5	26

sive course of Wilson's disease who presented with unusual severe spasticity mixed with minor dyskinesia. Selective posterior rhizotomy was performed in 13 patients, in one patient a release of caudal roots was done. The reason for this limited procedure was the absence of H reflex during the intra-operative neurophysiological monitoring.

The average age was 16.5 years (range 8 – 27 years). There were 4 females and 10 males. Seven of them were children under 15 years of age. Preoperative and postoperative evaluations were performed by an experienced medical team consisting of neurologist, neurosurgeon, orthopedic surgeon and physiotherapist.

Preoperative and postoperative assessment

Lower limb spasticity (Ashworth score) (Tab. 1), passive range of motion, ambulatory function (Peacock grade) (Tab. 2) and level of functional independence were assessed. The number of spasms per day was compared. Preoperative EMG monitoring and H reflex testing was performed within the whole group and the H/M ratio was assessed. The comparisons were not performed in one case where posterior rootlets were not divided.

Intra-operative monitoring

For intra-operative EMG monitoring, surface electrodes were placed over selected muscle groups on both legs. The gastrocnemius muscle was used to identify the first sacral roots (S1); the hamstrings, the fifth lumbar roots (L5); the anterior tibialis muscle, the fourth lumbar roots (L4); the quadriceps muscle, the third lumbar roots (L3); and the hip adductors, the second lumbar roots (L2). The anal sphincter muscle was monitored for the second sacral rootlets (S2). We performed laminoplasty from L1 to L5 using a high-speed drill, followed by upper sacral laminectomy. At each level the posterior root was separated into three to four rootlets. Each rootlet was then stimulated. The EMG pattern was recorded by surface electrodes located on the appropriate leg. We used the EMG criteria established by Philips and Park to select the abnormal rootlets for transection (Park, 1992). Rootlets that demonstrated gradually decreasing or steady squared-off electrical responses were spared, but any rootlets ranked higher were cut; these may account for 50 % of all the posterior roots tested. This testing, cutting, or sparing procedure was repeated on all rootlets from S2 to L2.

Results

Important improvements in the spasticity of all tested muscles were noted after SPR. The preoperative, Ashworth scales were as follows: spasticity of hip adductors = 2.9±0.93 preoperatively, and 1.2±0.64 postoperatively; hamstring spasticity 3.1±1.37 preoperatively and 1.6±1.43, and 0.5±0.37 postoperatively; quadriceps muscle spasticity 3.3±1.5 preoperatively and 2.3±0.74 postoperatively; and ankle gastrocnemius muscle spasticity 3.6±0.94 preoperatively and 2.1±0.78 postoperatively.

All patients showed an overall improvement (over 95 %) in the ranges of abduction of the hips and dorsiflexion of the ankles, a decrease in the contractures, and almost normal popliteal angles. The results of the range of motion for each tested parameter are summarized in (Tab. 3).

The functional independence was measured according to Functional Independence Measure for Children (WeeFIM). Improvements were noted in the self-care and mobility domains, see (Tab. 4).

The rate of spasms per day was on average 5.7±2.3 and decreased to 0.8±0.32 after the surgery.

Improvement of gross motor function was measured by Peacock grading system (Tab. 5).

Tab. 5. Grading of gross motor function by Peacock. Preoperative and postoperative grade.

Preoperative Peacock grade	Postoperative Peacock grade						
	1	2	3	4	5	6	7
1 (n=0)							
2 (n=7)		1	3	3			
3 (n=2)				2			
4 (n=2)				1	1		
5 (n=1)						1	
6 (n=1)							1
7 (n=0)							
N total=13							

The comparison of electrophysiological findings shows significant decrease of H:M ratio, that means ratio between maximal H reflex (Hoffmann reflex) amplitude elicited by gradual increase intensity stimulation of afferent Ia fibers compared to maximal M wave (compound muscle action potential) amplitude evoked by supramaximal stimulation of motor fibers in peripheral nerve (Fig. 2 and 3).

Transitory urinary retention was seen in 3 cases. Neither CSF leak nor infection was observed. We noticed in one case a moderate aggravation of extrapyramidal symptoms. No sensory losses were reported. Acute pneumothorax developed in one patient after central venous catheter insertion.

Discussion

The considerations for surgical candidacy in a young CP patient must take into account numerous physiological, psychological, and social features.

Children who are selected for surgery tend to fall into two groups: severely involved non-ambulatory quadriplegic patients with minimal or no independent function, and spastic diplegic children who are walking with or without support (Peacock and Arens, 1982). In the first group, goals include improvement of comfort, positioning, and handling as well as facilitation of orthopedic management. In the second group, spastic diplegic individuals who undergo rhizotomy are expected to improve functional skills, including gait. Some severely involved spastic quadriplegic children who rely on reflex extensor tone to stand for transfers are not good candidates for rhizotomy, although many individuals who have intense scissoring (lower extremities posture due to increased tone of adductor muscles) and equinus that precludes transfer activities can benefit from the procedure. Ambulatory patients who have poor trunk control or who lack evidence of lower extremity antigravity control are unlikely to benefit from the procedure. The most suitable candidate is believed to be a bright spastic diplegic child of 4 to 6 years of age who walks independently with an abnormal pattern because of excessive hip adduction, a flexed hip and knee posture, limited range of hip and knee motion, and an equinus posture of the foot and ankle (Peacock and Staudt, 1991). These children usually have significant spasticity, but they also have relatively good trunk control, balance, and antigravity strength and some evidence of selective motor control. Because spastic cerebral palsy is a multifaceted disorder, the advantages and disadvantages of reduction of spasticity must be evaluated for each child and explained to the patient and family.

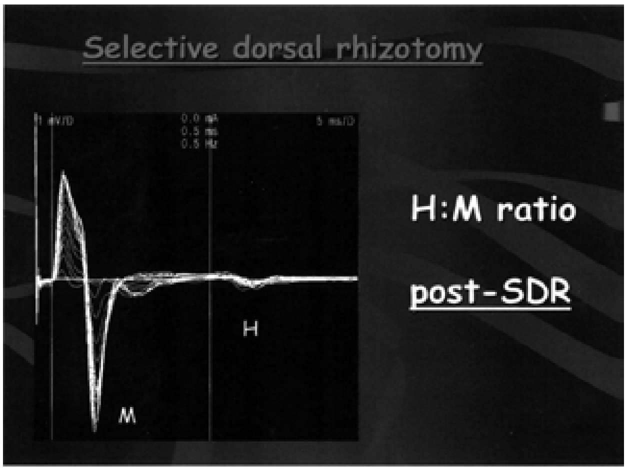

Fig. 2. Post-SPR EMG testing of H:M ratio. In comparison with pre-surgery testing, the superposition of responses illustrates a significant decrease of H:M ratio.

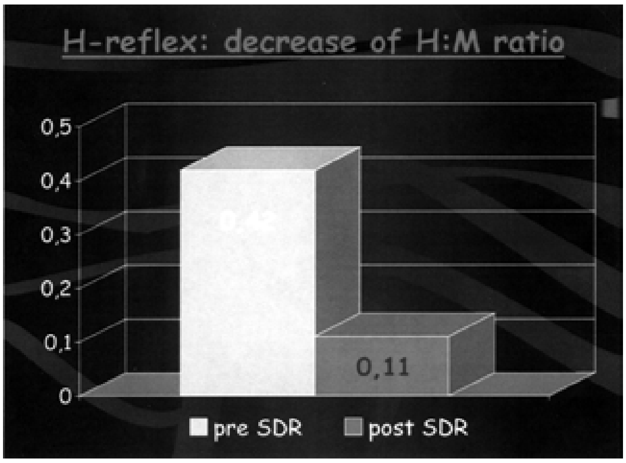

Fig. 3. Pre-operative and post-operative EMG testing of H:M ratio. In group of 13 patients a significant decrease of H:M ratio was detected. Initial average value 0.42 changed to 0.11 shortly after the surgery.

Unfortunately in our series only two patients were ambulatory, in both the walking pattern improved significantly after the surgery. In the remainder of the group the ability of purposeful movement has increased importantly. In all quadriplegic patients the reduction of spasticity interfering with care has influenced positively the quality of patients lives and led to improvement of comfort of patients and their caregivers.

The dystonia and movement disorders are considered as a contraindication of SPR (Park et al, 1993; Peacock and Arens 1982). The SPR by reduction of spasticity usually aggravates extrapyramidal symptoms. One of our patient was a 24 years old female with progressive course of the Wilson's disease who evolved spastic quadriplegia within 5 years and was sent for SPR to reduce the number of spasms, very painful to the patient. Postoperatively her extrapyramidal symptoms (choreatic movements) slightly worsened but an important reduction of spasms was attained and her functional status improved markedly. The role of extrapyramidal symptoms in quadriplegic patients may not be the absolute contraindication for surgical procedure to reduce the spasticity.

Potential long-term complications of selective posterior rhizotomy include a motor loss, sensory loss, bowel or bladder dysfunction, sexual dysfunction, and spinal instability or deformity. Surgical complications such as bleeding, infection, or dural leak are possible, in addition to general anesthesia complications such as pulmonary problems. Although there are specific considerations for surgical treatment of children with cerebral palsy, general anesthesia complications are reported to be minimal. A high incidence of urinary tract complications was also noted and was later eliminated after a change in technique. In many cases moderate hypesthesia is frequently found but it has no clinical consequences. It is minimized by adequate section of the rootlets.

Careful coordination of patient management and follow-up with an orthopedic surgeon is highly recommended. Preexisting structural deformities are not influenced by rhizotomy, and children with musculoskeletal deformities should have regular orthopedic follow-up.

In our series we observed 3 cases of transitory urinary retention that regressed after intermittent catheterization and cut-off intravenous opioids administration. Neither leak of CSF nor wound infection was observed. We noticed in one case a moderate aggravation of extrapyramidal symptoms as described above, but we do not consider this as a complication per se. It might be related to the progression of the primary disease.

SPR improves functional ability in a selected group of CP patients. Our findings regarding functional outcomes are in agreement with those of other authors. In our experience the extrapyramidal symptoms may not be an absolute contraindication of SPR.

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