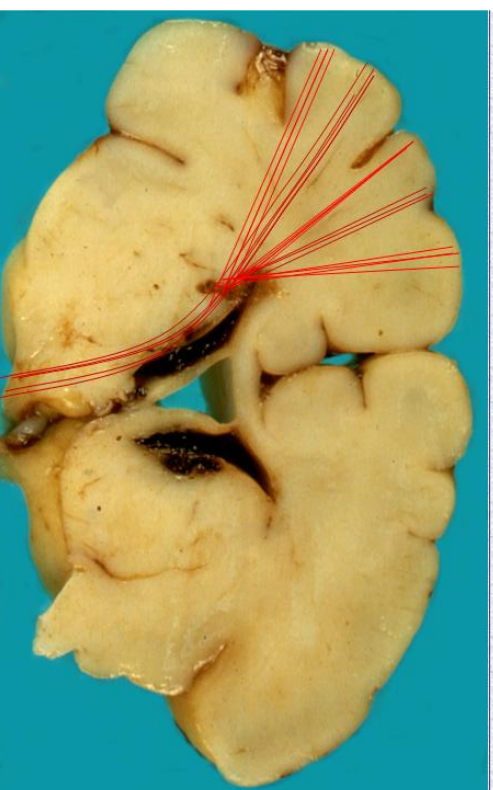


# Selective Dorsal Rhizotomy (SDR) for spastic cerebral palsy: a review

G. Tamburrini, C. Di Rocco

Pediatric Neurosurgery  
Catholic University, Rome, Italy



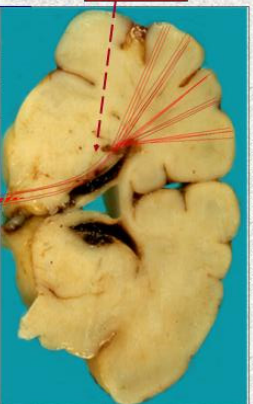
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Rationale

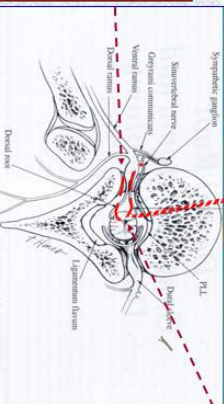
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Rationale

Decreased descending input



Excessive alpha motoneuron activity



Uncontrolled excitatory input by the afferents in the dorsal roots

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

**Why spasticity is deleterious in children with spastic cerebral palsy?**

- Loss of sarcomeres
- Reduction of muscle extensibility
- Shortening of muscles
- Inhibition of active movements
- Development of muscle contractures → bone and joint deformities

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Historical perspective



**Experimental basis:** dorsal root section relieved decerebrate rigidity after brainstem section in a cat

**Clinical series (1908 and 1913):** most patients affected by cerebral palsy and spastic diplegia

**Technique:** unselected bilateral complete section of posterior nerve roots of L2, L3, L5 and S1, *sparing L4*

**Foerster O. (1873-1941)**

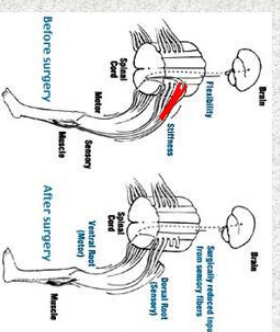
**Results:** marked improvement in spasticity and improvement in function in >70% of patients

**Problems:** recurrence of spasticity on long term, proprioceptive sensory loss, exceeding suppression of muscle tone

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Historical perspective

**Gros C et al. (1967):** non selective sectioning of 80% of each of the nerve roots from L1 to S1



**Gros C, Oudekotte G, Vlahovitch B, Fereboese P (1967) La radicostomie selective postérieure dans le traitement neurochirurgical de l'hypertonie pyramidale. Neurochirurgie 13:505-518**



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review  
Historical perspective

### Mid/Late 70's

"Sectorial rhizotomy", tailored to the clinical status of the individual patient ("disabling" vs. "beneficial" spasticity)

Selective dorsal rhizotomy (SDR) established on the responses of the sensory rootlets to IO stimulation

*Privat JM et al. (1976)* Sectorial posterior rhizotomy, a new technique for surgical treatment of spasticity. *Acta Neurochir* 35: 183-195

*Fassano VA et al. (1979)* Surgical treatment of spasticity in cerebral palsy. *Child Brain* 4: 289-305

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

Historical perspective

Selective dorsal rhizotomy (SDR) established on the responses of the sensory rootlets to IO stimulation

30-50 Hz: Single muscular contraction: not involved/not sectioned

30-50 Hz: Sustained synchronous activation of muscles (contralateral lower limb, upper limbs, trunk, neck) involved/sectioned

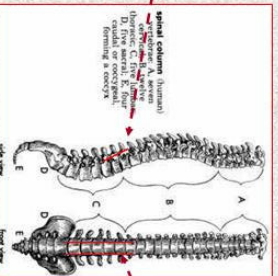
*Fassano VA et al. (1979)* Surgical treatment of spasticity in cerebral palsy. *Child Brain* 4: 289-305

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

Selective dorsal rhizotomy (SDR) established on the responses of the sensory rootlets to IO stimulation

### Approach

*Fassano VA:* approach to the rootlets at the conus level (T12-L2)



*Peacock WJ, Arenas LJ (1982):* approach to the rootlets at their exit foramina (L1-S1)

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review  
Historical perspective

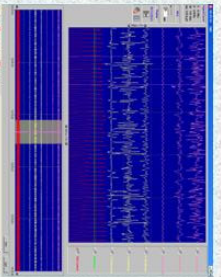
Selective dorsal rhizotomy (SDR) on originally proposed intraoperative electrophysiologic guidance (incremental stimulus: 30-50 Hz) was questioned because.....

1. No evidence that axons more involved in the spastic process are segregated together in the posterior rootlets
2. A low threshold to single stimulus and a "sustained" response to the 50 Hz stimulation might occur also in non spastic children

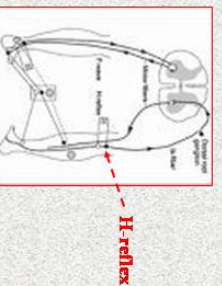
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Actually.....still controversial

Incremental/ tonic response 0.1 to 50 Hz (eventual suprasegmental responses): involved/sectioned



H-reflex recovery curve (increased recovery curve): involved/sectioned



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Grading the IO electromyographic responses

Grade	Electromyographic responses
0	Un sustained or single discharge to a train of stimuli
1+	Sustained segmental ipsilateral discharges
2+	Sustained segmental and immediately adjacent segments discharges
3+	Sustained segmental and distant levels discharges
4+	Sustained contralateral discharges



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Patients selection: Team work

1. Neurologist
2. Psychiatrist and Physiotherapist
3. Orthopedic surgeon
4. Neurosurgeon

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Patient evaluation

- Clinical history: -> perinatal, first years
- Neurologic examination: spasticity vs. rigidity, dystonia, athetotic movements...
- Previous treatments: orthopedic, ITB, neurotomy....
- Skeletic deformities: rate of reversibility and effects on motor function (with the help of the orthopedic surgeon and physiatrist/physiotherapist)
- Video-tape the patient ambulatory status (when valuable) : gait analysis
- Radiology: X-Rays of the spine and hips, MR of the L-S spine

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

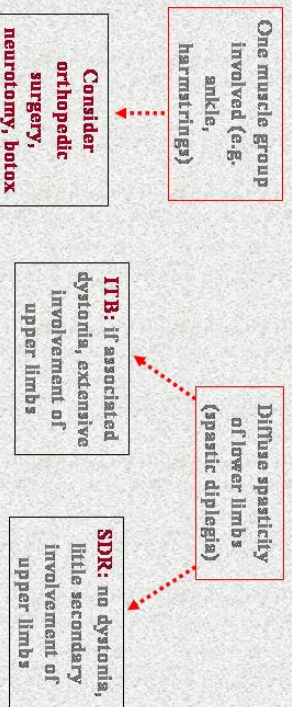
## Patient evaluation: evaluation of muscle tone

### Modified Ashworth scale

Score	Description of the muscle tone
00	Hypotonia
0	Normal tone, no increase in tone
1	Slight increase in tone manifested by a slight catch and release or minimal increase in resistance to joint range of motion
1+	Slight increase in tone manifested by a slight catch and minimal increase in resistance to joint range of motion for more than half of the joint range
2	More marked increase of tone through most of the whole joint range, but the affected joint is easily moved
3	Considerable increase in muscle tone, passive movement difficult but possible
4	Affected joint is stiff and cannot be moved

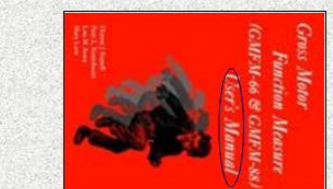
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Patients selection: spasticity of the lower limbs



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## The Gross Motor Function Measure (GMFM)

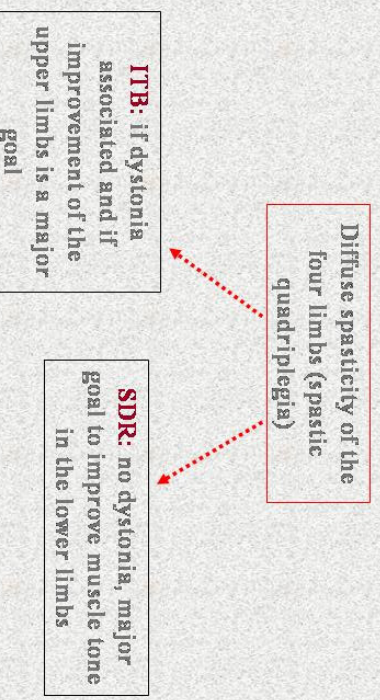


- Validated measure of functional limitations
- 88 items scored on a four point ordinal scale; five dimensions evaluated
- 1. Dimension A: 17 items performed in **lying or rolling** position
- 2. Dimension B: 20 items observed in the **sitting** position
- 3. Dimension C: **crawling and kneeling** (14 items)
- 4. Dimension D: **standing ability** (13 items)
- 5. Dimension E: **walking running, jumping** (24 items)

*Kussel DJ, Rosenbaum PL, Cadman DT, Gouland C, Hardy S, Lewis S (1989). The gross motor function measure: a means to evaluate the effects of physical therapy. Dev Med Child Neurol 31: 341-352*

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Patients selection: spasticity of the four limbs (spastic quadriplegia)





Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Patients selection problems

- Spasticity might help weight support? (3D gait analysis for the potential benefit/risk ratio)
- SDR is a permanent procedure; consider ITB (reversible) also in children with spastic diplegia?

Able to rise, to walk independently; able to crawl on knees and arms

.....→

Favourable outcome after SDR

**Consider disadvantages of ITB:** continuing long term management; proximity to medical centers with expertise in ITB administration, reoperation for battery failure, complications related to prosthetic implants

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Patients selection problems

- Cooperative and motivated patient (patients with severe cognitive impairment have a grim prognosis)
- Age. Ideal patient **2-6 years:** (a) wait until 2 because spasticity might spontaneously improve in the first two years; (b) prevent as much as possible deleterious effects of spasticity) **but.....**
- 1. **Dystonia** might become clear later (spastic quadriplegic child)
- 2. **Positive effects** documented also in **adolescents and young adults** (reduce abnormal stress on bones and muscles, joint and muscle pain...)

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### L1-S1 Technique



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Are the results of ITB and SDR comparable in spastic diplegic patients?

DATE	NO.	SEX	AGE
OPERATION	DATE	DATE	DATE

Surgical treatment of spasticity in children: comparison of selective dorsal rhizotomy and intrathecal baclofen pump implantation

Paulo Sérgio de Paula Soares<sup>1</sup>, Susanna Maria de Sá<sup>2</sup>, Soraia Siqueira<sup>3</sup>, Mariana Walter<sup>4</sup>, Fabia Kozak<sup>5</sup>

**Materials and methods:** A consecutive series of 71 children who underwent SDR for treatment of spasticity was compared with a group of 71 children matched by age and prognostic score on the Gross Motor Function Classification System (GMFCS) who underwent ITB placement. Change in GMFCS score, lower-extremity tone (based on the Modified Ashworth-Bohannon Scale), and lower-extremity passive range of movement (PROM) at 1 year as well as the need for subsequent orthopedic procedures and parents' satisfaction were selected as outcome measures.

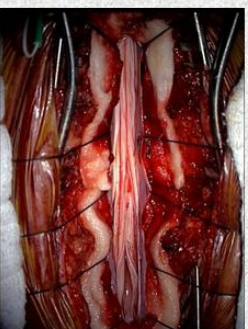
**Results:** At 1 year, both SDR and ITB decreased tone, increased PROM, and improved function. Both procedures resulted in a high degree of patient satisfaction. Compared with ITB, SDR provided a larger magnitude of improvement in tone (-2.52 vs -1.23,  $p<0.0001$ ), PROM (-4.77 vs -0.39,  $p<0.0138$ ), and gross motor function (-1.66 vs -1.08,  $p<0.0001$ ). In addition, fewer patients in the SDR group required subsequent orthopedic procedures (1/91 vs 6/71,  $p=0.0166$ ).

**Conclusions:** For children with moderate to severe spasticity, SDR and ITB are both effective surgical treatments. Our results indicate SDR is more effective in reducing the degree of spasticity and improving function than ITB is in this group of patients.

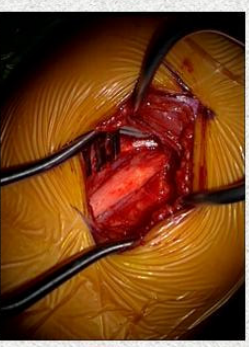
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Technique

Osteoplastic laminotomy L1-S1

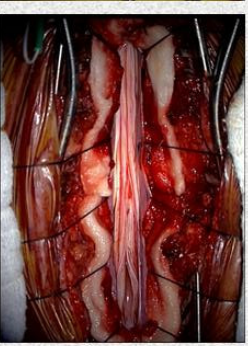


One/two levels (L1-L2) laminectomy



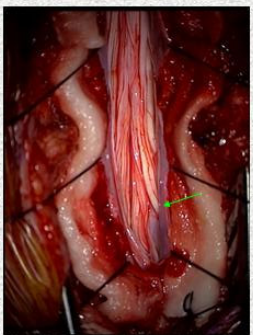
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### L1-S1 Technique

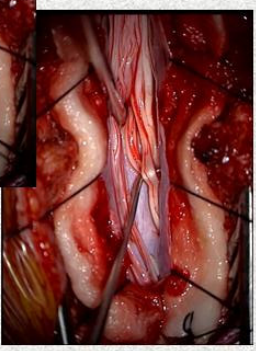
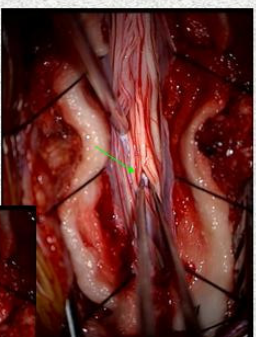




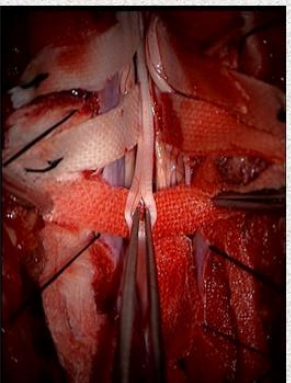
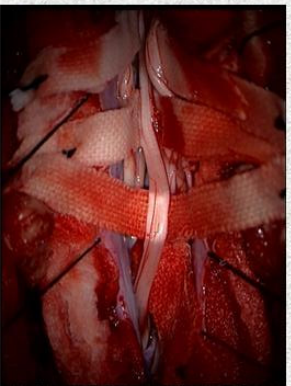
Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



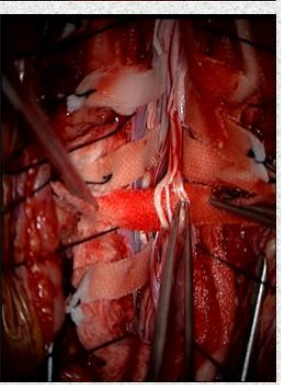
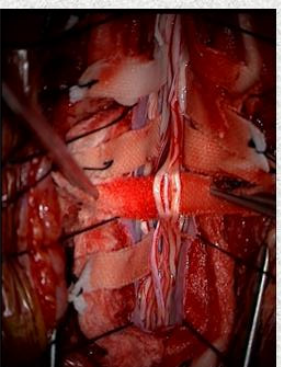
Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



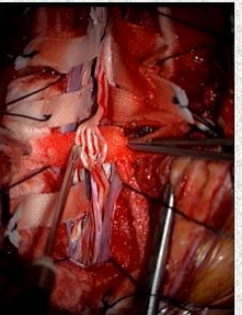
Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



Selective Dorsal Rhizotomy for spastic cerebral palsy: technique

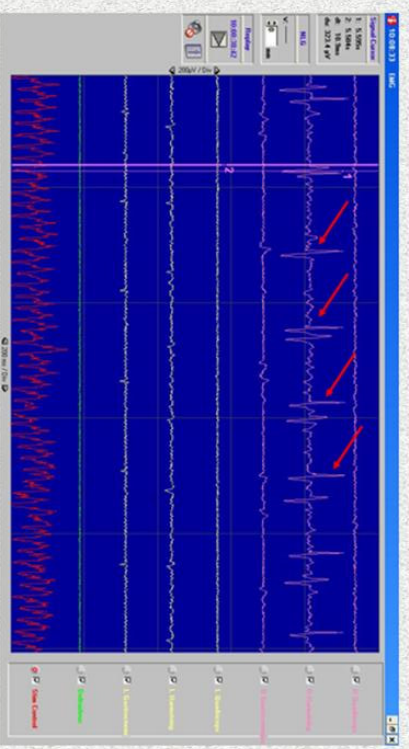
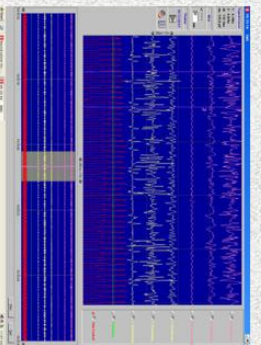


Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

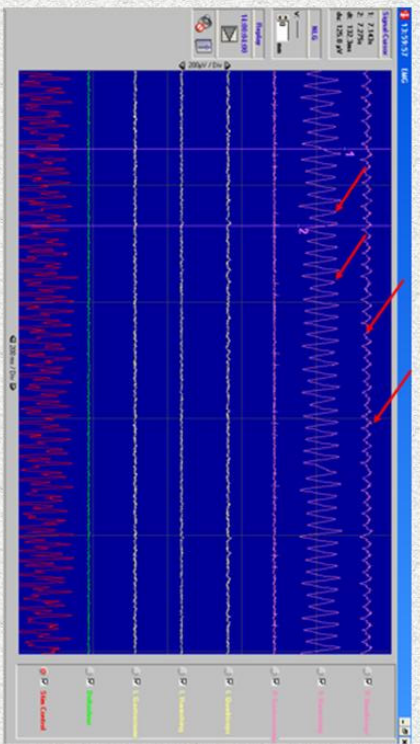
**Grading the IO electromyographic responses**





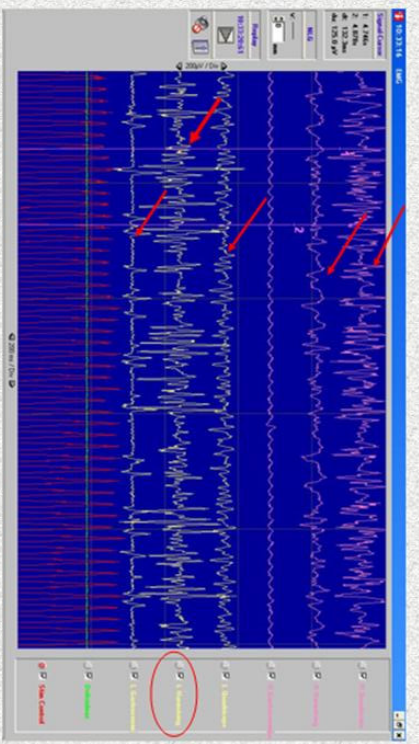
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Grading the IO electromyographic responses



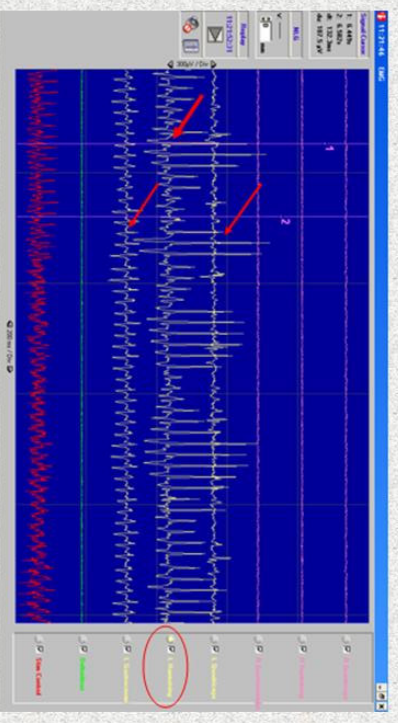
Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Grading the IO electromyographic responses

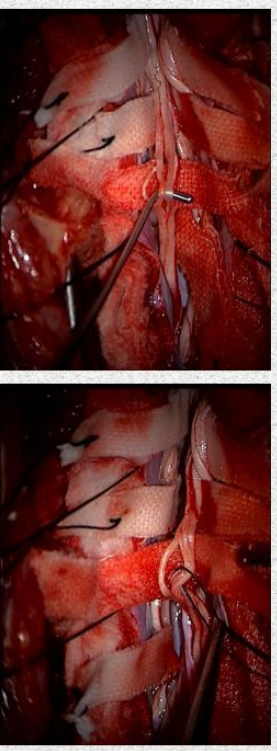


Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

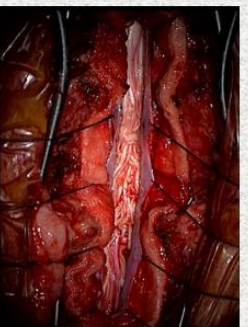
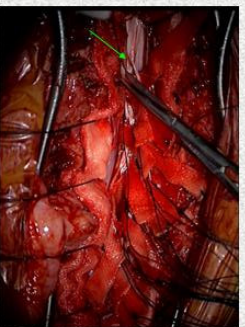
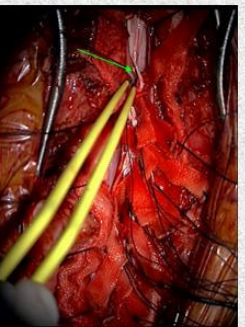
### Grading the IO electromyographic responses



Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



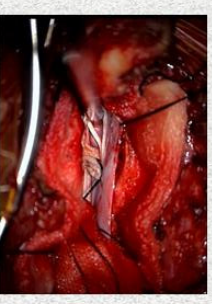
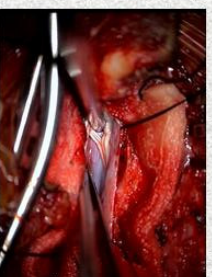
Selective Dorsal Rhizotomy for spastic cerebral palsy: technique



Around 50-70% (range 20-70%) of each dorsal root (bilaterally) is coagulated and cut

Selective Dorsal Rhizotomy for spastic cerebral palsy: technique

### The vertical course of L2





Selective Dorsal Rhizotomy for spastic cerebral palsy: technique

## What to do with S2?

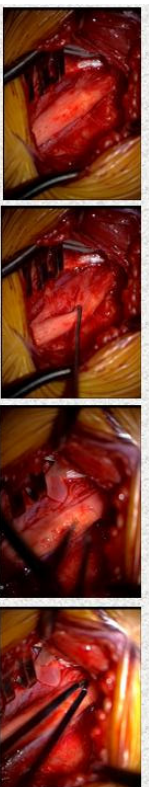


- In case of marked spasticity of ankle plantar flexors partial S2 rhizotomy might be considered (less than 35% of the posterior S2 root is cut: bladder dysfunction)
- Perineum area monitoring

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Technique

### One/two levels (L1-L2) laminectomy



- Identification of the L1 level (counting, IO XRay's)
- Intraoperative ultrasonography (axial) to identify the conus through the interlaminar space/laminotomy of lower L1 (hypodense triangle)
- Removal of the lamina overlying the conus

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Technique

### Osteoplastic laminotomy L1-S1

#### Advantages:

1. root level easily identified
2. easy identification of the dorsal from the ventral root at each level
3. easy tailoring of the procedure to the clinical status
4. apical cord at lower risk of damage
5. procedure easily completed with magnifying loupes or no magnification

#### Disadvantages:

1. extensive skin incision and muscles dissection
2. multiple level laminotomy/laminectomy
3. possible damage to the ventral roots
4. postoperative pain

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Technique

### One/two levels (L1-L2) laminectomy

#### Advantages:

1. small skin incision
2. small amount of muscles dissection
3. decreased number of laminiae cut
4. lower postoperative pain
5. avoidance of ventral roots (separated from dorsal roots at the level of the conus)

#### Disadvantages:

1. procedure more demanding (microscope needed)
2. root levels less easy to identify
3. more difficult tailoring of the procedure to the clinical status
4. higher risk of damage to the conus

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Results

NCBI PubMed

Search:  for selective dorsal rhizotomy

1-3 of 3 results

Rank	Author	Title	Year
1	Beal T, Goshal A, Asher A, Brown D, Green B, Green W, Simeoni S, Walker M, Kishida J	Surgical treatment of spasticity in children: comparison of selective dorsal rhizotomy and intrathecal baclofen pump implantation. PMID: 17985547	2007
2	Baroni D, Simeoni S, Aiello M	Selective dorsal rhizotomy in the treatment of spasticity related to cerebral palsy. PMID: 17645249	2007
3	Hendrick TR, Duncanson J	Orthopedic management of spasticity in cerebral palsy. PMID: 19613975	2009

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Resuming clinical results

- Consistent evidence in retrospective (six) so as prospective (three) studies of a significantly higher decrease of lower limbs spasticity (Ashworth/modified scales) after SDR and physiotherapy if compared with physiotherapy alone. The effect is stable at up to 12 years of follow-up

- Range of movement (goniometry) at lower limbs joints significantly improved in eight prospective series and 2 randomized control trials (maintained up to five years after surgery)



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Resuming clinical results

- Variable effect on strength: prospective studies show either no change or increased strength
- Gait analysis: analyzed in 9 prospective studies and 1 randomized controlled trial; consistent improvement in the range of movement at the knee, hip and ankle, but variable effect on gait velocity and pelvic tilt
- Electrophysiologic parameters: decreased lower limb H reflex to M response ratio and improved EMG

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Resuming clinical results

- Sitting ability: improved in more than 70% of the cases after SDR (qualitative and quantitative assessment: **GMFM**)
- Ambulation: improved level in 50-78% of patients with "room for improvement" (variability of grading scales); the rate for improvement on **GMFM** scales ranges between **3.2 and 12.1%** (*significant improvement=>6%*)

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Resuming clinical results

- Activities of daily living (ADL): improvements after SDR significantly better in diplegics than in quadriplegics
- Suprasegmental effects: improvement in upper limbs function (qualitative and quantitative analysis: scales) in 70-80% of the cases with improvement reported also for upper limbs fine motor skills
- Avoidance of orthopedic procedures in at least **35%** of cases

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Resuming clinical results

- Cognitive function: preliminary data document improvement in visual attention, visual-auditory tasks, speech
- Factors negatively affecting outcome:*
- preoperative clinical status (dystonic limbs, opisthotonic posturing) and intellectual delay (cooperation during rehabilitation programs)

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Complications

#### Intraoperative Complications

- Intraoperative bronchospasm: favouring factors pre-existing respiratory distress syndrome, gastro-esophageal reflux. Change in anesthetic agents (propofol), more strict patients selection and premedication with H2 blockers -> less than 1%

Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

### Complications

#### Early postoperative complications

- Cerebrospinal fluid leak: 1-5%
- Transient urinary retention: 1.25-24% (pudendal monitoring and < than 35% sectioning of S2)
- Transient dysesthesias: 2.5-40% (permanent=0-6%)



Selective Dorsal Rhizotomy for spastic cerebral palsy: a review

## Complications

### Long term complications

- **Hip subluxation: progressive in less than 20% of patients followed up for more than five years after SDR (lower than in non operated patients !?). Improvement in 9-38% of the cases**
- **Back pain: 4-7% of patients**
- **Worsening scoliosis (laminoplasty): in 25% of the cases (primarily in nonambulatory spastic quadriplegic patients)**