Palliative single-level selective dorsal rhizotomy for children with spastic cerebral palsy Gross Motor Function Classification System level IV and V: a case series and systematic review of the literature

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OBJECTIVE Single-level selective dorsal rhizotomy (SDR), typically indicated for ambulatory patients, is a controversial topic for severe spastic cerebral palsy (CP) with Gross Motor Function Classification System (GMFCS) level IV or V. The objective of this case series and systematic literature review was to outline the indication and outcome of palliative SDR for nonambulatory patients with CP and GMFCS level IV and V, focusing on improvement of spasticity and of patient and caregiver reported quality of life assessment.

METHODS A retrospective case series of patients with CP and GMFCS level IV or V who underwent single-level SDR at the authors’ institution is presented. Furthermore, two databases (PubMed and Embase) were searched and a systematic review with a search string based on the terms “selective dorsal rhizotomy,” “cerebral palsy,” and “outcome” was conducted. The primary outcome was the reduction of spasticity based on the modified Ashworth scale (MAS). Secondary outcomes were change on the Gross Motor Function Measure-66 (GMFM-66), evaluation of patient-reported outcome measures (PROMs), surgical morbidity, and mortality.

RESULTS Eleven consecutive children under the age of 25 years undergoing palliative single-level SDR were included. All patients showed a reduction in MAS score (mean 1.09 ± 0.66 points) and no surgical morbidity and mortality occurred. For the systematic review results from our case series, in addition to 4 reports, 274 total patients were included. Reduction of spasticity based on MAS score was noted in all studies (mean range 1.09–3.2 points). Furthermore, in 2 studies spasticity of the upper extremities showed a MAS score reduction as well (range 1.7–2.8 points). The GMFM-66 score improved in 72% of the patients, while bladder function improved in 78% of the patients. Based on the PROMs, 92% of the patients/caregivers were satisfied with the outcome and their quality of life after the procedure. Two wound infections (2.7%) and one CSF leak (1.3%) occurred, while no surgery-related deaths were described.

CONCLUSIONS This analysis showed an improvement in spasticity, daily care, and comfort for patients with CP and GMFCS levels IV and V. Larger cohorts analyzing the outcome of palliative single-level SDR, based on the MAS, GMFM-66, and PROMs, are still needed and should be the focus of future studies.

Systematic review registration no.: CRD42024495762 (https://www.crd.york.ac.uk/prospero/)

https://thejns.org/doi/abs/10.3171/2024.3.FOCUS2478

KEYWORDS single-level selective dorsal rhizotomy; cerebral palsy; spasticity; non-ambulant; GMFCS level IV; GMFCS level V; pediatric neurosurgery

ABBREVIATIONS CP = cerebral palsy; CPQoL = CP Quality of Life Questionnaire; GMFCS = Gross Motor Function Classification System; GMFM = Gross Motor Function Measure; ITB = intrathecal baclofen; MAS = modified Ashworth scale; NOS = Newcastle-Ottawa Scale; PROM = patient-reported outcome measure; ROM = range of motion; SDR = selective dorsal rhizotomy.

SUBMITTED February 1, 2024. ACCEPTED March 20, 2024.

INCLUDE WHEN CITING DOI: 10.3171/2024.3.FOCUS2478.

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Cerebral palsy (CP), the most common disability in childhood with an incidence of 2–3 cases per 1000 births, is a condition characterized by permanent disorders resulting from abnormal development of the fetal or infant brain. Its manifestations include slow motor development, hypertonia, and spasticity-induced pathological posture, leading to disturbances in sensation, perception, cognition, and communication. Available CP treatments vary and are based on the severity of spasticity, with no known curative approaches. Noninvasive treatments such as intensive physiotherapy and occupational therapy are commonly used. Surgical interventions such as selective dorsal rhizotomy (SDR) and intrathecal baclofen (ITB) pumps serve as primary strategies to reduce lower-extremity spasticity, thereby enhancing mobility and improving the quality of life for affected individuals.

The decision regarding surgical intervention typically depends on the Gross Motor Function Classification System (GMFCS), which categorizes gross motor skills into 5 levels, usually targeting patients with GMFCS levels I–III to maintain or enhance ambulation.

SDR was first described by Peacock in the 1980s and included a multilevel laminectomy, exposing the L2–S2 levels. Subsequently, the SDR surgical technique has evolved over time, becoming less invasive with a single-level approach, potentially making it also a valuable option for patients with high GMFCS levels. However, traditionally for these patients ITB pumps are implanted with the aim of alleviating spasticity in both the lower and upper extremities and improving dystonia. To date, evidence supporting the effectiveness and improvement in quality of life of palliative SDR for GMFCS high-level patients is lacking, although some reports do support its use for children with CP and high GMFCS levels.

The aim of this study was to present our retrospective case series and provide a systematic overview of the literature regarding indication and outcome of palliative SDR for nonambulatory patients with CP and GMFCS levels IV and V, focusing on improvement of spasticity and quality of life of the patients and their caregivers.

Methods

Case Series

We conducted a retrospective case series of 11 consecutive nonambulatory children under the age of 25 years suffering from CP GMFCS level IV or V who underwent palliative SDR between 2018 and 2024 at the University Children’s Hospital Basel, Switzerland. Age, gender, GMFCS level, and follow-up duration were assessed as baseline characteristics. The primary outcome was the reduction of spasticity after SDR, described as the mean reduction rate of the modified Ashworth scale (MAS) score. Secondary outcomes were change of the initial GMFCS level after SDR, variation of Gross Motor Function Measure-66 (GMFM-66) score, patient-reported outcome measures (PROMs), surgery-related morbidity, and mortality. Preoperative MAS scores were collected, as well as parameters potentially influencing the indication for palliative SDR. The surgical technique of SDR used at our institution has been previously presented. The GMFCS for patient inclusion is summarized in Table 1. The MAS was used for primary outcome assessment. The MAS is based on measurement of the increase in muscle tone and assigns a spasticity score from 0 to 4 on an ordinal scale in patients with lesions of the CNS. The score is assigned by moving a joint and the associated muscle through a high-velocity quick stretch. The 6 scores on the 0–4 scale are as follows: 0 = no increase in muscle tone; 1 = slight increase in muscle tone, manifested by a catch and release at the end of range of motion (ROM); 1+ = slight increase in muscle tone, manifested by a catch, followed by minimal resistance at the end of ROM; 2 = more marked increase in muscle tone through most of the ROM, but affected part(s) are easily moved; 3 = considerable increase in muscle tone, passive movement difficult; and 4 = affected part(s) rigid in flexion or extension.

Systematic Review

For the systematic review, two databases (PubMed and Embase) were systematically searched, and reports published in the English language from the inception of the databases until January 2024 were included. The systematic search string included a combination of the terms “selective dorsal rhizotomy,” “cerebral palsy,” and “outcome”: (“Rhizotomy”[MeSH Terms] OR “selective dorsal rhizotomy”[Title/Abstract] OR “rhizotomy”[Title/Abstract] OR “SDR”[Title/Abstract]) AND (“Muscle Spasticity”[MeSH Terms] OR “spastic”[Title/Abstract] OR “spasticity”[Title/Abstract]) AND (“Cerebral Palsy”[MeSH Terms] OR “cerebral palsy”[Title/Abstract] OR “CP”[Title/Abstract] AND “outcome”[Title/Abstract] OR “PROM”[Title/Abstract]). We included reports in which patients underwent single-level SDR (laminotomy or laminectomy at the height of the conus medullaris) under the age of 25 years. Randomized controlled trials, prospective and retrospective cohort studies, as well as descriptive case series including at least 5 patients were included in the analysis. Patients undergoing multilevel SDR, or with a GMFCS level I–III, as well as technical reports, case reports, comments, editorial letters, poster abstracts, and reviews were excluded from this systematic review. Removal of duplicates and screening of the results was performed with the help of web-based software Rayyan (https://www.rayyan.ai/).

Initially, two authors (N.A.F. and M.L.) independently screened the reports according to their titles and then their abstracts. A final list was compiled, which underwent full-text review, while the reference list of included articles was screened as well (other sources). In cases of disagreement concerning the inclusion or exclusion of an article, the senior author (J.S.) made the final decision.

We extracted the following information from eligible reports: study details (author, year of publication, design); study population (number of participants, median/mean age, mean/median follow-up time); treatment characteristics (type of surgery, the quantitative amount of dissected nerve rootlets); and outcomes measures (pre- and postoperative GMFCS level, MAS score and mean reduction after surgery, GMFM-66 score, PROMs, description of urological changes, and changes in pain). Because the
scores and parameters assessing patient/caregiver satisfaction and quality of life within the included reports were heterogeneous, we graded the results as “satisfactory,” “unclear,” and “not satisfactory” for comparison of these outcomes. The follow-up periods were heterogeneous as well, therefore we extracted data for a common follow-up period (between 8 and 14 months) as well as for the described maximum follow-up period (between 2 and 5 years). The primary outcome was defined as the reduction of spasticity after SDR, described as the mean reduction rate of MAS score. Secondary outcomes were change of spasticity after SDR, described as the mean reduction of MAS score. Secondary outcomes were change of the initial GMFCS level after SDR, improvement in GMFM-66 score, urological changes after surgery, reduction of pain, PROMs (from both the patients’ and caregivers’ perspective), as well as surgery-related morbidity and mortality. Baseline characteristics with a focus on preoperative GMFCS level and preoperative MAS score were collected to define indication parameters for palliative SDR.

**Data Analysis**

All calculations were descriptive in nature. Data are presented as mean with standard deviation. No comparative statistics were performed. The retrospective collection and processing of our patient data was approved by the local ethics committee. This systematic review was performed in accordance with the PRISMA guidelines and was registered with PROSPERO (systematic review registration no.: CRD42024495762; https://www.crd.york.ac.uk/prospero/).

**Qualitative Assessment**

Quality assessment of the studies was conducted using the Newcastle-Ottawa Scale (NOS) and was initially conducted by two authors independently (M.L. and N.A.F.) and then compared.

**Results**

**Case Series**

We included 11 consecutive children who underwent single-level SDR at our institution: 6 (54%) with GMFCS level IV and 5 (46%) with GMFCS level V. The mean patient age was 10.5 ± 5.35 (range 5–25) years, 6 (54%) of whom were female.

The extent of rhizotomy ranged between 40% and 60% and was based on intraoperative electrophysiological guidance in all patients. The follow-up duration ranged from 0.5 to 72 months. The indication in all patients was a predominance of spasticity with little or no dystonia, while patients with predominant dystonia were not considered for palliative SDR.

Nine patients (81%) were previously treated with an ITB pump, 5 of whom had a GMFCS level of IV (55%). The reason for conversion from ITB pump to SDR was mainly the end of the battery life of the ITB pump.

The mean preoperative MAS score was 3.09 ± 0.5 (range 2–4) points, whereas the mean postoperative MAS score was 2 ± 0.8 (range 1–3) points, resulting in a mean reduction of MAS score of 1.09 ± 0.66 (range 0–2) points. In patients with GMFCS level IV, a mean reduction of 1.05 ± 0.72 points was found, whereas for level V patients the mean reduction was 0.86 ± 0.62 points. The positive effect of SDR on reduction of spasticity remained stable over the entire follow-up period, except in 1 patient who experienced significant improvement of spasticity after surgery with slow deterioration after 3 months. This patient underwent repeat SDR surgery with inclusion of the L1 and L2 levels, which were initially preserved due to a distal predominance of the spasticity, with sustained improvement of the spasticity thereafter.

The GMFCS level changed after surgery in 2 patients (18%), from level IV to level III. PROMs were obtained for 7 patients and caregivers, showing an improvement in general satisfaction after surgery throughout the cohort. Quality of life significantly improved after surgery in 57% of the patients. Surgical morbidity or death did not occur in our cohort. One female patient (9.1%) died 2 years after surgery due to respiratory insufficiency as part of the underlying CP.

**Systematic Review**

In addition to the case series, our systematic review identified 318 reports, of which 106 were removed as duplicates. After screening the titles and abstracts, 28 articles underwent full-text evaluation. Four articles were ultimately included in our systematic review (Fig. 1), involving a total cohort of 274 patients with GMFCS levels IV and V (including our presented case series). We excluded the previous report by our group on the outcome of SDR to avoid duplicating the same patients. Three reports included were prospective observational cohort studies, while 2 (including our present case series) were retrospective. Of the 165 patients with provided gender distribution, 83 (50%) were female (Table 2).

**Baseline Characteristics, Surgical Technique, and Follow-Up**

The mean age at surgery ranged from 7.24 to 12.1 years with an overall range from 3 to 25 years (Table 2). All included reports used a single-level approach and intraoperative electrophysiological guidance. The extent of rhizotomy varied from 40%–60% to 60%–70% of the identified dorsal roots. No detailed information was provided on the percentage of nerve root disconnection in 2 reports. The common follow-up duration ranged from 14 to 24 months across the studies, and the maximum follow-up was 5 years. The indication for palliative SDR was GMFCS level IV or V with spasticity predominance and little or no dystonia in all reports. Spastic CP with GMFCS level IV was diagnosed in 161 patients.
patients (58.8%) and the remaining 113 patients (41.2%) presented with GMFCS level V (Table 2). Thirty-five patients (12.8%) were previously treated with an ITB pump, 8 (2.9%) of whom were GMFCS level IV. The reason for conversion from ITB to SDR was mainly end of the ITB battery life.

Reduction in Spasticity

The preoperative MAS score as well as the reduction in MAS score could be extracted from all studies. The postoperative MAS score was documented in 4 of 5 cohorts, including our case series, and therefore included 264 patients (96.4%). The mean preoperative MAS score ranged from 2.42 to 3.6 points. The mean postoperative MAS score ranged from 0.3 to 2 points (our cohort). The mean reduction in MAS score ranged from 1.09 points to 3.2 points. SDR surgery resulted in a reduced MAS score in all included studies. The positive effect of SDR on reduction of spasticity remained stable during the described follow-up periods.

D’Aquino et al. and Ingale et al. also analyzed the impact of SDR on the spasticity of the upper extremities, quantified by the MAS. A positive effect could be seen, with a range of reduction from 1.7 to 2.8 points. For both the lower and upper extremities, a subgroup analysis of GMFCS levels IV and V by D’Aquino et al. proved a more effective treatment for GMFCS level V patients without statistical significance between the subgroups. Results are summarized in Table 2.

Change in Mobility Scores, Morbidity, and Mortality

The GMFM-66 score was used by 2 studies, including 199 patients (72.6%), to describe the effectiveness of SDR for their cohorts. Both studies showed improved results at last follow-up with greater benefit in higher GMFCS levels.

FIG. 1. Flowchart of study inclusion according to the PRISMA guidelines for systematic reviews and meta-analyses. *Databases screened: PubMed and Embase. **Reports excluded through abstract and title screening. Data added to the PRISMA template (from Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71) under the terms of the Creative Commons Attribution (CC BY 4.0) License (https://creativecommons.org/licenses/by/4.0/).
The effect of SDR on bladder function was described by 2 studies including 64 patients (23.4%). All patients had neurogenic bladder dysfunction preoperatively with incontinence; continence and bladder capacity improved in 50 patients (78%), while no patient’s condition deteriorated. Surgical morbidity was described in 3 studies including 64 patients (23.4%). All patients or caregivers indicated a satisfactory outcome and related deaths occurred. The vast majority (92%) of the patients or caregivers indicated a satisfactory outcome and improved quality of life after palliative SDR. No surgery-related deaths occurred.

Subjective Satisfaction After Surgery, PROMs, and Quality of Life

Scoring parameters for evaluation of caregiver and patient satisfaction and quality of life after SDR surgery (CP Quality of Life Questionnaire [CPQoL], Pediatric Evaluation of Disability Inventory self-care and mobility components, and Health-Related Quality of Life Questionnaire) were available from 3 reports, including our cohort, for 125 patients (45%). The vast majority of caregivers or patients (n = 116, 92%) were satisfied and described an improved quality of life after palliative SDR. No significant improvement in all aspects was described by 6% (n = 7), and 2% (n = 3) were unsatisfied after palliative SDR.

Qualitative Assessment

The qualitative assessment for the 4 cohort studies showed a mean NOS score of 6.75 ± 1.5.

Discussion

Following our presented case series and systematic review, 274 patients who underwent single-level SDR due to CP GMFCS level IV or V were included in our analysis. Based on our data, a decrease in MAS score and thus reduced spasticity was observed in all included studies. Based on some reports, palliative SDR even showed a beneficial outcome for spasticity of the upper extremities. Furthermore, reduction of the MAS score also remained at last follow-up. The GMFM-66 scale score increased from 2.2 to 5 points after SDR surgery, resulting in improved mobility of the affected patients. Bladder function improved cumulatively in 78% of the patients, resulting in better bladder capacity and less incontinence. Surgically related morbidity remained low, while no surgery related deaths occurred. The vast majority (92%) of the patients or caregivers indicated a satisfactory outcome and improved quality of life after palliative SDR.

Palliative Single-Level SDR: A Valid Treatment Option for Patients With CP and GMFCS Level IV and V?

Overall, the literature on palliative SDR is sparse, but promising data have emerged over the last decade. The traditional indication for single-level SDR consists of maintenance or improvement of ambulation, therefore functional SDR was previously mainly reserved for patients with GMFCS levels I–III. Due to the high psychological and physiological strain for both patients and caregivers, some studies evaluated single-level SDR even for GMFCS level IV and V patients with promising results, finally providing a valuable alternative to ITB pump implantation with the aim of reducing spasticity and therefore reducing pain and facilitating daily care of the patients.

When SDR was first developed and applied in 1987 by Peacock, it gained much popularity for spasticity treatment and remained the standard surgical technique for more than 30 years, exposing spinal roots via multilevel access from the conus medullaris down to S2, with slight modifications over time. Considering the higher peri-and postoperative risks of multilevel SDR such as spinal deformity, CSF leaks, and severe infections, this procedure was initially reserved for GMFCS level I–III patients with the aim of maintaining or improving ambulation.
The single-level interlaminar approach or single-level laminotomy/laminoplasty approaches are less invasive and used more frequently nowadays, causing fewer postoperative spinal deformities or instabilities and fewer CSF fistulas.25,28,29 Due to this innovation in surgical technique, leading to low morbidity, and the possibility of exact electrophysiological quantification of hypersensitive dorsal roots during surgery, SDR is becoming a valid surgical alternative to ITB pump implantation and an important part of the multimodal treatment of patients with all CP severity grades. It is important to recognize that rhizotomy criteria fully rely on the intraoperative electromyographic interpretation, therefore neuro-electrophysiological monitoring has a crucial role once SDR is performed via a single-level approach.30

Outcome of Palliative SDR

To assess the effectiveness, spasticity, mobility, and quality of life of functional and palliative SDR, multiple scores are available. This inhomogeneity, also represented in our included studies, makes the comparison of the outcome measures difficult, and consequently hampers the objectification of the benefits of palliative SDR. Nonetheless, the MAS score was available for all studies and showed SDR to be a good and valid option for nonambulatory patients.24,26,31,32 This finding is consistent with previous reports focusing on ambulatory patients (GMFCS levels I–III) undergoing SDR and underlines its effectiveness even in high-level patients.2,12,24,28,33–35

Another important and evolving tool for quantifying the outcome of a treatment is the implementation of PROMs and scores addressing the quality of life not only of the patients, but also of the caregivers. Gillespie et al. implemented the CPQoL score in their analysis, which mainly focuses on the well-being and perception of the patient.23 Our group recently published an analysis implementing PROMs as an evaluation tool of subjective outcome assessment by the patients or the caregivers after SDR.25 The implementation of PROMs has gained increasing interest and is applied in all fields of patient care.36,37 Our previously published series presented favorable results regarding improvement in quality of life of the patient as well as of the caregivers, further emphasizing the positive effects of palliative SDR.25 Comparable results could be found in our systematic literature review analysis.21–24 However, the lack of homogeneity in applied scores hampers comparability, which is why large prospective cohort studies with homogenous score assessment, both for functional and quality of life–related outcomes, are needed to effectively delineate the impact of palliative SDR on patients and their caregivers.

Evidence on long-term outcomes after SDR suggests that the benefits of SDR are durable into early adulthood, that fewer orthopedic procedures or botulinum toxin injections are necessary, and that GMFCS level, as well as GMFM-66 scores, can be at least preserved in GMFCS level IV patients or even improved in both GMFCS level IV and V over time without a significant decline in functionality.24,34,36–40 Furthermore, for moderate to severe spasticity grades in patients with CP, data suggest that SDR is more effective both in reducing the degree of spasticity and in improving function compared to ITB pump treatment.40 Finally, SDR appears to be more cost-effective than ITB, not only due to the high cost of the implant itself, but also due to the durability of the battery, which needs to be replaced every 5–7 years.

Age and Palliative SDR

The predictive effect of age on the outcome of palliative SDR has been debated within the literature.13,24,33,42,43 Regarding age, studies of gross motor development have shown that children with spastic CP present with a plateau of spasticity during childhood that gradually declines through adolescence and adulthood.38 Furthermore, treatment efficacy appears to be age-dependent, with children under 10 years being more suitable for surgery in ambulatory (GMFCS level I–III) patients. Accordingly, our group previously analyzed the outcome measures with respect to age at surgery, revealing better results for early SDR surgery, defined as age at surgery under 11 years.25 In contrast, Gillespie et al. reported a more significant increase in quality of life measured by PROMs and CPQoL score in the 10- to 18-year age group.24 This contradiction can be explained by the distinct greater cohort size and more standardized outcome measures used by Gillespie et al., whereas our group focused more on the implementation and evaluation of PROMs in a smaller cohort. Therefore, large multicenter studies with standardized outcome measurements are still needed.

In view of its prophylactic potential, it seems purposeful that SDR should be performed at an early stage in patients with CP suffering from severe spasticity, whereas it is known that the intervention is particularly effective when the indication for surgery and the surgery itself is conducted within a coordinated, comprehensive, and specialized team as part of a spasticity program.44

Limitations of the Study

Several limitations inherent to a retrospective cohort series and a systematic review are present in this study. First, we only searched two databases (PubMed and Embase) and only searched the English literature, which carries a risk of omitting important data published elsewhere. Second, palliative single-level SDR is a rare topic, and the included studies are very heterogeneous, especially in their outcome measures, which carries a risk of bias. Third, no randomized trials are available on the topic, and this systematic review only contains prospective or retrospective analyses subject to all possible limitations of such studies and reports. Fourth, the included studies were limited to the single-level surgical approach, which induces a certain bias due to the special technique. Fifth, even though we assessed for publication bias, we cannot exclude a general publication bias due to unpublished negative studies, which are not included. Sixth, due to the limited follow-up intervals presented in our included reports, a statement on the long-term effects of SDR for GMFCS level IV and V patients cannot be sufficiently made. Lastly, the cohort studies of Gillespie et al. from 2021 and 2024 were conducted at the same institution, which could lead to a certain overlap in their patient data, although the more recent report is based on a multicenter analysis.
Conclusions

SDR, typically indicated for ambulatory patients, also represents a valid surgical option with a palliative approach in patients with CP and higher GMFCS levels. In fact, available data support the improvement in daily care and comfort, based on follow-up studies using the MAS, GMFM-66, and PROMs. Moreover, the more recently developed single-level surgical technique is associated with a low rate of surgical morbidity, making it a suitable approach for GMFCS high-level patients with CP despite the higher intrinsic risk profile of these patients.

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**Disclosures**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

**Author Contributions**

Conception and design: Licci, Frank, Soleman. Acquisition of data: Licci, Frank, Rasadurai, Juenemann, Guzman. Analysis and interpretation of data: Licci, Frank. Critically revising the article: Licci, Frank, Greuter, Fernandes Arroteia, Juenemann, Guzman, Soleman. Reviewed submitted version of manuscript: Licci, Frank, Greuter, Rasadurai, Fernandes Arroteia, Juenemann, Soleman. Approved the final version of the manuscript on behalf of all authors: Licci. Statistical analysis: Licci, Frank. Administrative/technical/material support: Frank. Study supervision: Guzman, Soleman.

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