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Predictors for the benefit of selective dorsal rhizotomy

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ABSTRACT

Selective dorsal rhizotomy (SDR) is a spasticity reducing treatment option for children with spastic cerebral palsy. Selection criteria for this procedure are inconclusive to date. Clinical relevance of the achieved functional improvements and side effects like the negative impact on muscle strength are discussed controversially. In this prospective cohort study one and two year results of 54 children with a mean age of 6.9 (±2.9) years at the time of SDR are analyzed with regard to gross motor function and factors affecting the functional benefit. Only ambulatory children who were able to perform a gross motor function measure test (GMFM-88) were included in this study. Additionally, the modified Ashworth scale (MAS), a manual muscle strength test (MFT), and the body mass index (BMI) were evaluated as possible outcome predictors. MAS of hip adductors and hamstrings decreased significantly ($p < 0.001$) and stayed reduced after two years, while GMFM improved significantly from 79% to 84% 12 months after SDR ($p < 0.001$) and another 2% between 12 and 24 months ($p = 0.002$). Muscle strength did improve significantly concerning knee extension ($p = 0.008$) and ankle dorsiflexion ($p = 0.006$). The improvement of function correlated moderately with age at surgery and preoperative GMFM and weakly with the standard deviation score of the BMI, the dorsiflexor and plantarflexor strength preoperatively as well as with the reduction of spasticity of the hamstrings and the preoperative spasticity of the adductors and hamstrings. Correctly indicated SDR reduces spasticity and increases motor skills sustainably in children with spastic cerebral palsy corresponding to clinically relevant changes of GMFM without compromising muscular strength. Outcome correlates to GMFM and age rather than to MAS and maximal strength testing. The data of this evaluation suggest that children who benefit the most from SDR are between 4 and 7 years old and have a preoperative GMFM between 65% and 85%.

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Bilateral spastic manifestation is the most common subtype of the non-progressive motor function altering disorder of the immature brain summarized under the umbrella term cerebral palsy (CP; Hagberg, Hagberg, Beckung, & Uvebrant, 2001; Rosenbaum et al., 2007). In CP, the filtering process via inhibitory signaling which is a regulatory mechanism of the corticospinal tract is assumed to be impaired (Eyre, 2007) resulting in an excessive afferent input routed through the sensory nerve rootlets (Johnston, 2009). The resulting spasticity is reduced permanently by selective dorsal rhizotomy (SDR). During a microscopic procedure, guided by intraoperative neuromonitoring (IONM), a significant percentage of the sensory nerve rootlets L1 to S2 is severed. It has been demonstrated that motor function can be improved by this approach (Bolster et al., 2013; Chan et al., 2008; Dudley et al., 2013; Josenby, Wagner, Jarnlo, Westbom, & Nordmark, 2012; Mittal et al., 2002; Nordmark, Jarnlo, & Hägglund, 2000; Nordmark et al., 2008; Tedroff, Löwing, Jacobson, & Åström, 2011; van Schie et al., 2011; Wright, Sheil, Drake, Wedge, & Naumann, 1998) especially in ambulatory children with bilateral spastic CP.

To date, the risk of affecting muscular strength by the permanent interruption of sensory nerve rootlets remains a matter of controverse discussion. While some authors report decreasing strength following SDR (Arens, Peacock, & Peter, 1989; Oppenheim, 1990), more recent studies rather show a postoperative increase in strength (Carraro et al., 2014; Engsberg, Ross, & Park, 1999; Engsberg, Ross, Wagner, & Park, 2002; Ross, Engsberg, Olree, & Park, 2001). Another point of concern remains the patient selection as a recent review of inclusion criteria reveals (Grunt, Fieggen, Vermeulen, Becher, & Langerak, 2014).

The aim of this study is to evaluate the impact of preoperative age, BMI, strength, spasticity and motor function on the functional outcome of SDR in ambulatory children with bilateral spastic cerebral palsy.

1. Participants and methods

1.1. Participants

Ambulatory children (GMFCS level I and II) with bilateral spastic CP who were approved for SDR were included in this study if they were able to perform a complete GMFM-88, their parents gave their informed consent, and a German health insurance covered the procedure. The children were recruited from a multiprofessional CP clinic held weekly at our social pediatric center. The evaluation was carried out interdisciplinary by a neuropediatrician, a pediatric neurosurgeon, a pediatric orthopedic surgeon, and a physiotherapist. CP was confirmed by a neuropediatrician after thorough clinical examination when either a pre-term delivery was mentioned in the child's history or when a magnetic resonance imaging (MRI) sequence showed periventricular leucomalacia. Skeletal deformities were assessed by the pediatric orthopedic surgeon while functional tests were performed by the physiotherapist to evaluate these sections of the inclusion and exclusion criteria.

1.2. Methods

As SDR is a non-reversible procedure, approved inclusion criteria, proposed by Peacock and Staudt (1991), were applied. The main prerequisites to be eligible for SDR are a predominantly spastic bilateral subtype of cerebral palsy, some form of ambulatory ability (GMFCS I to III), good cognitive function, interest in activity and locomotion, absence of musculoskeletal deformities and contractures and no history of multi-level surgery.

SDR was performed by a single pediatric neurosurgeon (EJH) via single level laminectomy exposing the conus medullaris. In modification of the procedure described by Park and Johnston (2006) the location of the access was determined by preoperative MRI and the resected lamina was repositioned using a novel technique of ligament preserving laminectomy developed by EJH (Haberl, 2012). The microscopic sectioning of about 50% of the afferent dorsal rootlets L1 through S2 was guided by IONM using the criteria of Park and Johnston (2006).

A comprehensive rehabilitation program started on the first postoperative day with emphasis on locomotive training after the first postoperative week in an in-patient setting for at least 3 weeks.

The parents of all children gave their written, informed consent (including data publication and video recording), to participate in this study, which was approved by the local ethics committee.

1.3. Study design

This study was designed as a prospective clinical cohort trial based on examinations standardized via internal audits and conducted by the same team of experienced physicians and therapists. To minimize the bias of the non-blinded evaluators the examinations were performed before consulting the chart for previous information. Data were then anonymized for further analysis and processed by colleagues who were not involved in the clinical examination at any point in time. Data collected before and 12 and 24 months after surgery are presented in this manuscript.

1.4. Outcome parameters

Standard parameters evaluating body structure and function as well as the gross motor function measure (GMFM) as a comprehensive indicator not only for function but also for activity and participation were evaluated in this cohort of CP