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Changes in gait which occur before and during the adolescent growth spurt in children treated by selective dorsal rhizotomy

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ABSTRACT

This paper presents long term follow up results from 17 children (6 girls, 11 boys, GMFCS levels II–IV), treated by means of selective dorsal rhizotomy (SDR). The particular focus is on the effect of the adolescent growth spurt on patients who had previously undergone SDR. The children were all assessed using 3D gait analysis, in combination with clinical examination at three time points–before SDR surgery (PRE), after SDR surgery when pre-adolescent (POST1) and post-adolescence (POST2). The total follow up period to POST2 was 8 years 6 months for girls and 9 years 5 months for boys. All children maintained or improved their GMFCS level. Positive changes in ranges of motion and gait were observed at POST1 and these were generally maintained over adolescence to POST2. The mean Gait Profile Score (GPS) had improved by 3.2 points (14.7–11.5) at POST1, with a non-significant deterioration of 0.3 over the adolescent growth spurt. These positive results reflect the total package of care for the children, involving careful pre-operative selection by a multidisciplinary team and post-operative management including intensive physiotherapy and maintenance in tuned ankle foot orthoses. Fifty-nine per cent of children had some additional orthopaedic surgery, mostly bony procedures. The overall benefits arising from their management need to be considered in the light of the likely deterioration experienced by this patient group. The results of this study support the use of SDR as part of a management strategy for carefully selected children with cerebral palsy with the aim of optimizing gait at skeletal maturity.

1. Introduction

Selective dorsal rhizotomy (SDR) was refined and popularized by the team of Dr Peacock, in South Africa [1], to reduce spasticity in children with cerebral palsy. The procedure has been in use for over 30 years, with a substantial body of literature from centres publishing their local outcomes. The earliest patients treated are now adults, making it possible to assess the long term impact of SDR performed in childhood.

Despite substantial clinical experience of SDR there are very few randomized controlled trials, the main three [2–4] being summarized in the meta-analysis published by McLaughlin et al. in 2002 [5]. None of these studies used instrumented 3D gait analysis, and so were not able to report gait changes in detail. The follow up times are also relatively short at between 9 and 24 months.

The Oswestry SDR programme began in 1995. All children treated in Oswestry are assessed pre-operatively by means of a full lower limb clinical examination and gait assessment. These measures are then repeated 12 months post-operatively, and the short term outcome data have been presented elsewhere [6]. A number of other centres have also reported short term outcome data, including pre- and post-operative gait analysis (e.g. 7–9). Common features are seen in data from different centres. Following SDR children typically have greater passive extension at hip and knee and more dorsiflexion at the ankle. These changes are translated into better extension and foot posture during gait, along with a higher rate of knee flexion in swing leading to greater peak knee flexion. Global measures of gait function and quality (GMFCS, GGI) also show improvements. The only consistent negative change reported is increased anterior pelvic tilt.

Long term follow up data are more sparse, and rarely include gait analysis as an outcome measure. When SDR began to be offered 3D gait facilities were not commonly available. The team in Cape Town [10,11] have published their long term outcomes (up to 20 years post-op) using a simple 2D gait analysis technique. They

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showed that key post-operative improvements, such as improved normalized step length and knee range of motion, continue to be apparent 20 years after SDR.

Other long term follow up studies use outcome measures such as GMFM, GMFCS and Ashworth scales (e.g. 12–14). Improvements seen after treatment are generally preserved, though studies lack the specific detail of gait patterns available from gait analysis. Beneficial changes seem to occur in the first 5 years after treatment, followed by a plateau period [13]. Tedroff et al. [15] reports maximum improvements at 3 years. However, whilst spasticity reduction was largely preserved, by 10 years joint range of motion and GMFM had deteriorated. Despite this GMFM values were still significantly better than pre-operative measurements.

In Oswestry, after the initial follow up visits at 1 and 2 years, we review our patients at fixed developmental milestones. In particular we are interested in observing children over the adolescent growth spurt, a period of rapid physical change commonly considered to pose a challenge to function (particularly gait) in cerebral palsy. Our long term follow up assessments are therefore performed at 10 and 16 years of age for girls and 12 and 18 years of age for boys.

This paper presents the results for a cohort of children who have now reached adulthood. Our objective when performing an SDR is to optimize gait for the whole of life, so our primary aim in this study was to investigate whether the good short term outcomes were maintained to adulthood.

2. Methods

Seventeen patients were recruited from the Oswestry database of children treated by means of an SDR. This cohort was drawn from 27 consecutive cases treated between November 1996 and January 2007. Of the 10 children excluded, 9 had yet to reach the age for their final assessment and one could not be assessed pre-operatively with the 6 camera 3D system we had at the time owing to her extensive walking aids. No children were lost to follow up and all completed all three assessment time points. The group included six girls with an average age of 7 years 8 months (SD 1 year 1 month) and 11 boys with average age of 8 years 9 months (SD 11 year 11 months) at the time of their SDRs. Six children were GMFCS level II, nine were level III and two were level IV.

All of the patients met our selection criteria (Table 1) and had spastic cerebral palsy; two had quadriplegia and the remaining 15 had diplegia. All the families gave informed consent for their children's data to be used for research and subsequent publication. Each child underwent an extensive pre-operative assessment including consultations with a paediatric neurologist, orthopaedic surgeon and physiotherapist, X-rays of the spine and hips and MRIs of the brain and spinal cord, full clinical examination and 3D gait analysis.

All children were treated with an open procedure. Laminotomies were performed and rootlets at the levels L1–S1 were selected for transection. The percentage of rootlets cut at each level was determined by severity of spasticity and informed by intra-operative neurophysiological monitoring. On the basis of the 13 patients for whom information is available, the mean number of rootlets cut was 33.7% (sd 7.4, range 23.1–50.3). All children underwent a lengthy period of in-patient rehabilitation (6–12 weeks) and were managed post-operatively in tuned rigid AFOs. They were discharged with a home exercise programme.

After SDR children were followed up regularly and orthopaedic surgery was carried out as required. No fixed protocol was used to determine when to intervene, however feet which became uncomfortable were stabilized, persistent transverse plane deformities were corrected and significant contractures resulting from residual spasticity or weakness were addressed.

In this paper gait assessment and clinical examination results are given for three specific time points: pre-SDR surgery (PRE); post-SDR surgery pre-adolescence (POST1); and post-SDR surgery post-adolescence (POST2). The target ages for POST1 and POST2 were 12 and 18 years respectively for males and 10 and 16 years respectively for females.

At each assessment a full clinical examination, comprising range of movements and MRC joint powers, was performed. 3D gait analyses were conducted using a Vicon motion analysis system and standard marker set (Plug-in-Gait with knee alignment devices). System specifications did vary over the study period, with between 6 and 12 cameras used and either Kistler or AMTI forceplates. Data were processed using Vicon Clinical Manager or Plug-in-Gait. At each hardware/software upgrade tests were made to confirm that there was no impact on the results of analyses. At each assessment multiple trials were collected, walking barefoot, with or without walking aids. For each patient a minimum of five trials was inspected for consistency and then an average was created from which key values were extracted and Gait Profile Scores (GPS) were calculated. Statistical analysis was performed using SPSS.

Clinical examination and gait data were compared across the three time points: PRE, POST1 and POST2. Random missing data were accounted for using multiple imputation methods [16]. Within subject analysis of variance was determined using Friedman and Wilcoxon signed ranks tests at a significance level of $p = 0.05$ (2-tailed).

3. Results

Pre-operative assessments were performed at an average of 7 months pre-operatively for both boys and girls. The girls' post-operative assessments took place at 10 years 5 months (SD 0 years 6 months) and 16 years 2 months (SD 0 years 6 months). The equivalent time points for the boys were 12 years 5 months (SD 1 year 2 months) and 18 years 4 months (SD 0 years 6 months).

The additional surgical treatments (including Botulinum toxin injections) received by each child after their SDR but before the final assessment (POST2) are listed in Table 2. Conservative care such as physiotherapy or orthotic management is not recorded.

Table 1
Criteria used to select patients for selective dorsal rhizotomy (adapted from Cole et al. [6]).

From history	From examination	From investigation
1. Age range 5–10 years	1. Diagnosis spastic diplegia, quadriplegia, severe hemiplegia, HSP	1. No hip dysplasia
2. Absence of chronic conditions, e.g. BPD, refractory epilepsy, severe visual impairment, scoliosis	2. Spasticity moderate to severe	2. No basal ganglia change on MRI
3. Cognitive ability–IQ 70 or above	3. Mean lower limb power >3 on MRC scale	Weight not disproportionately greater than height
4. Well motivated, emotionally robust child	4. Movement control at least moderate	
5. No previous multilevel surgery	5. Balance at least moderate	
Good family/social support	6. Absence of severe fixed joint deformity	
	No involuntary movements or dystonia	

BPD, broncho-pulmonary dysplasia; HSP, hereditary spastic paraparesis.