Introduction
This article examines the evidence to date regarding the neurosurgical technique Selective Dorsal Rhizotomy (SDR) as a treatment option in the management of spasticity and its impact for paediatric physiotherapists. SDR is a surgical procedure dividing the posterior nerve rootlets from spinal cord segments L1 and L2. An incision is made along the lower back and a laminectomy of one or more vertebrae is made to expose and test small nerve rootlets consisting of spinal sensory nerves, 3-5 rootlets are normally identified. Rootlets with an abnormal electromyography response are selectively cut, the motor nerve rootlets remain untouched and leg movement is preserved (NICE guidelines 2006).

Spasticity is a positive sign of an upper motor neurone syndrome and the focus of many treatment interventions, it is also a clinical feature in over 75% of cases of children with Cerebral Palsy (CP) and is considered to be the major cause of discomfort affecting gait and function in children with CP (McLaughlin et al 2002). Although SDR is the focus of this paper due to the recent increase in publicity surrounding it, paediatric physiotherapists should be cognisant with the other ways to manage spasticity. Pountney (2007) identifies physical treatment techniques, e.g. neuro-developmental therapy or conductive education; medication intervention, e.g. baclofen and botulinum toxin; and also other surgical/neurosurgical management approaches to spasticity.

Background
Dorsal rhizotomy was first documented by Sherrington (1898); he noted that extensor rigidity was eliminated in some de-cerebrate cats by sectioning posterior rootlets. Fifteen years later Foerster (1913) used this technique in patients with congenital spastic paraplegia to reduce their tone, but did not recommend it for improving function due to the negative side affects noted by sensory loss. Fasano et al (1978) later modified the technique to be more ‘selective’ in its approach by identifying and sectioning aberrant posterior rootlets that reduced sensory loss. By electrically stimulating rootlets they were able to identify the ones showing abnormal tonic contraction in the muscles innervated by the stimulated root as well as in distant muscles. Fasano et al (1980) claimed that by selective interruption of the abnormal circuits, spasticity could be reduced and sensation preserved by sectioning only the aberrant rootlets. Within North America in the 1980’s the procedure was further modified by changing the surgical site from the conus medullaris to the cauda equina, preserving the sacral nerve roots innervating the bowel and bladder (Peacock et al 1991, Giuliani 1991).

Neurophysiological evidence supported the view that spasticity was due to the decreased inhibition from multiple upper motor neuron and interneuron inputs and could increase excitability of alpha motor neurons (Young 1994). Sensory afferents from muscles have a mainly excitatory effect on alpha motor neurons and the developers of SDR (McLaughlin et al 1998) surmised that excitatory sensory input to the anterior horn could be reduced without impairing the sensory function. Electrophysiological measurement criteria were introduced by Fasano and modified by Peacock (Staudt et al 1995) to optimise the ‘selectivity’ of the rhizotomy. Opinion on the technique has alternated between enthusiasm (Park and Owen 1992) to varying levels of scepticism (McLaughlin et al 1998).

Literature Review
A review of the literature pertaining to SDR was conducted between April and July 2011. The search terms used were: SDR, neuro-surgery, cerebral palsy and diplegia. The following databases were accessed: Medline, CINHAL, EBOS, Pub Med and the Cochrane Collaboration data bases. 30 publications were retrieved and of these 10 were deemed suitable.

The majority of the evidence to date originates from North America and Europe which includes three randomised control trials (RCTs) (Steinbock et al
1997, McLaughlin et al 1998, Wright et al 1998) and a meta-analysis (McLaughlin et al 2002). A brief overview of these studies follows to contextualise the impact of SDR for paediatric physiotherapists.

Steinbock et al (1997) compared selective posterior rhizotomy plus physiotherapy with physiotherapy alone in children with spastic diplegic CP. A total of 15 patients were included within this RCT, with one child in each group dropping out after randomisation. Although numbers are small it reflects the relatively few numbers of children undergoing this procedure. Patients were randomly assigned to one of two treatment modalities:
1. SDR followed by 9 months of intensive outpatient physiotherapy;
2. 9 months of intensive outpatient physiotherapy (3 x week for 3 months, 2 x week for 6 months – passive ROM, strengthening exercises to hip abductors and extensors, knee extensors and ankle dorsiflexors, plus practice of normal patterns of movement based on neurodevelopmental theories).

Steinbock et al (1997) found a statistically significant and clinically important difference in improvement in motor function in favour of the SDR group.

In the second RCT McLaughlin et al (1998) looked at the efficacy and safety in an investigator-masked RCT. This was a larger study where 43 children with spastic diplegia were randomly assigned to receive SDR plus physiotherapy or physiotherapy alone. A total of 38 children completed follow up through 24 months with 21 children in the treatment group and 17 in the control group. McLaughlin et al (1998) concluded that SDR is safe and reduces spasticity in children with spastic diplegia. Unlike Steinbock et al (1997) the results of the McLaughlin et al study (1998) reported an equal improvement in the independent mobility at 24 months in the treatment and control group. They went a step further and stated that SDR may not be an ‘efficacious’ treatment for children with mild spastic diplegia.

The final RCT (Wright et al 1998) evaluated the efficacy of SDR for the reduction of spasticity in cerebral palsy. This study included 24 children who were randomly assigned to one of 2 groups:
1. SDR with physiotherapy and occupational therapy as an in-patient for 6 weeks;
2. equivalent physiotherapy and occupational therapy (each child received a 45 minute physiotherapy session and a 45 minute occupational therapy session twice a week, reduced to 2 sessions a week - 2 hours in total - for the remainder of the study period).

One year post SDR, changes with gross motor function were measured - findings concluded that SDR combined with physiotherapy and occupational therapy produced a greater functional motor improvement after 1 year than just therapy alone.

A meta-analysis of the results showed only a small functional improvement in the client (McLaughlin et al 1998, Cole et al 2007). Studies have been plagued by bias, lack of controls, variable surgical techniques and subjective outcome measures (Arens et al 1989, Abot et al 1993, Cohen et al 1991). The absence of solid evidence to support efficacy and the lack of information regarding safety aspects and long term implications has resulted in some controversy over this technique and some doctors have had concerns regarding the invasive and irreversible nature of the procedure (NINDS 2009). There is controversy regarding how selective SDR is and the fact that there might only be a small improvement in function for such an extensive operation (NINDS 2009).

McLaughlin’s meta-analysis (2002) highlighted a small, but statistically significant, advantage of SDR and physiotherapy over physiotherapy alone. The study also identified a direct causal relationship between the percentage of dorsal root tissue cut and the level of gain in function, however there is marked variability between studies on percentage of rootlets cut. McLaughlin (2002) also noted that although the improvements in gross motor function were disappointing the results did not take into account the longer term outcomes of the surgery; positive and negative.

Although there are limitations in the research evidence to date it is possible to conclude that SDR reduces spasticity in children with CP. There is no conclusive evidence that SDR leads to long term functional benefit. This needs to be contextualised with the risks of any surgical intervention and also in the cost benefit analysis for all children in the decision making process prior to further investment. There has been an acknowledgment in many centres of the need for selection criteria, as variations have been noted in patient selection, patient numbers, intra operative techniques, post operative therapeutic intervention and outcome measures for this operation (Cole et al 2007). Further research
would be beneficial to enable an evidence base to be established.

**Current Practice**

SDR is only practiced in a few centres in the UK, one of which is Oswestry. The Oswestry experience (Cole et al 2007) is the first UK cohort studied consisting of 19 patients. Their findings supported previous studies whereby SDR reduced lower limb spasticity and also demonstrated a small functional benefit on children with CP when adhering to strict selection criteria (Table 1). Cole et al (2007) further purported that SDR is an excellent procedure for overcoming crouch gait and tightness at the hamstrings if strict selection criteria are maintained. The outcome measure to support this was gait analysis.

Table 1 Criteria used to select patients for SDR – Oswestry (Cole et al 2007)

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<thead>
<tr>
<th>History</th>
<th>Examination</th>
<th>Investigations</th>
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<tbody>
<tr>
<td>Age range 5-10</td>
<td>Diagnosis of diplegia, severe hemiplegia, HSP</td>
<td>No hip dysplasia</td>
</tr>
<tr>
<td>Absence of chronic conditions e.g. BPD, refractory epilepsy, severe visual impairment, scoliosis</td>
<td>Spasticity moderate to severe</td>
<td>No basal ganglia change on MRI</td>
</tr>
<tr>
<td>Cognitive ability IQ 70 or above</td>
<td>Mean lower limb power&gt;3 on MRC scale</td>
<td>Weight not disproportionally greater than height</td>
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<tr>
<td>Well motivated, emotionally robust</td>
<td>Movement control at least moderate</td>
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<tr>
<td>No previous multi-level surgery</td>
<td>Balance at least moderate</td>
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<tr>
<td>Good family/social support</td>
<td>Absence of severe fixed joint deformity</td>
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<td></td>
<td>No involuntary movements or dystonia</td>
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*(BPD – broncho pulmonary dysplasia; HSP – hereditary spastic paraparesis)*

There is a growing body of interest in SDR as a treatment option and doctors from hospitals such as Liverpool and Bristol have begun to develop links with doctors in USA who have significantly more experience. A study day held in Great Ormond Street Hospital in 2011 was facilitated by Dr Park and his St Louis Hospital team. Dr Park and his team state that of all the surgical techniques currently performed on patients with CP, SDR has undergone more thorough scientific scrutiny than any other neurosurgical technique (video footage 2011 website www.stlouischildrens.org). Accumulated evidence and experience indicate that SDR is an excellent option for patients with spastic CP (St Louis 2010). Dr Park and his team in USA have performed the SDR procedure on over 2000 children between the ages of 2 and 18 years with 66% under the age of 5 years, 44% of whom were born at less than 29 weeks (St Louis Hospital Brochure p.16 2010). Dr Park and his team recommend early surgery between 2-5 years to avoid potential problems with deformities of the legs. 79% of the patients had spastic diplegia with 83% walking with either a walker, crutches or independently – all improved their walking ability post operatively (St Louis SDR Brochure 2010).

Table 2 Criteria used to select patients for SDR - St Louis, USA

*Factors to be considered in italics*

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<thead>
<tr>
<th>History</th>
<th>Examination</th>
<th>Investigations</th>
</tr>
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<tbody>
<tr>
<td>At least 2 yrs of age</td>
<td>Diagnosis of spastic diplegia, quadriplegia or spastic hemiplegia</td>
<td>No severe damage to basal ganglia on MRI</td>
</tr>
<tr>
<td>Motivation and ability to co-operate in therapy</td>
<td>Some form of mobility – e.g. crawling, walking with/without assistance</td>
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<td>Commitment to rehabilitation and follow up</td>
<td>History of premature birth – if born full term must have signs of spastic diplegia</td>
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<tr>
<td>Wait at least 1 yr post orthopaedic surgery</td>
<td>Patient exhibits potential for improvement in functional skills after SDR</td>
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<td>Good muscle strength in legs and trunk</td>
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<td>Evidence of adequate motor control</td>
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Frenchay hospital in Bristol has just become the first hospital in the UK to carry out a pioneering neurosurgical procedure offering a new version of SDR which concentrates on the lower part of the spinal cord, increasing its effectiveness and reducing risk (North Bristol NHS Trust May 2011). A programme following the procedure was broadcast on BBC Inside Out West on the 20th June 2011 linking with another child having the operation at St Louis, USA.
Discussion

There are still considerable variations in the way that SDR is conducted and how patients are selected, most notably the disparity in ages between St Louis (>2 years) and Oswestry (5-10 years). It could be argued that 2 years of age is too young to have such a major intervention when the clinical picture of spasticity and movement is changing so much and the full picture will not have evolved with regard to functional mobility or conservative management. It does mean that it precedes the development of deformities and contractures that may have started and all the postural issues that ensue. The presentation of spasticity in children with CP makes it very challenging to have defined criteria which does explain the variances. There are enough similarities that it would facilitate discussions with parents who are considering the technique.

In any discussion with parents the potential complications of this procedure need to be highlighted as SDR is a long and complicated neurosurgical operation. Some reported and potential risks must be considered - paralysis of the legs and bladder, impotence and sensory loss are the most serious, but wound infections, and leakage of the spinal fluid through the wounds are also potential issues. Sensitivity of the skin on the feet and legs is quite common post SDR but usually resolves within 6 months. Urinary tract infections and pneumonia are also a possibility, as is hip subluxation. Vertebral prominence has been noted and the most frequent occurrence has been weight gain (St Louis 2010, Cole et al 2007). Dr Park’s team note that they have had no long term complications in any of their patients who have undergone SDR with data going back to 1987.

With the advent of more centres looking into SDR both abroad and in the UK, more studies and research should be forthcoming. A large study looking at patients with spastic diplegia from childhood into adulthood is required to see the long term outcome on gait, pain reduction, function, participation and quality of life as well as the rate of acquired musculoskeletal deformities (McLaughlin et al 2002, NINDS 2009). This is an area that is developing and evolving and members of the health profession need to be aware of current practice and the criteria for selection to enable parents to make an informed choice on whether to proceed. This year alone over 40 families from the UK have gone to USA for SDR treatment at their own expense, but more hospitals in the UK are showing an interest at using this technique and parental pressure to have the procedure available on the NHS is strengthening in force as can be seen on their website (www.support4sdr.org).

SDR is currently the only surgical procedure that can provide permanent reduction of spasticity in CP; it is not suitable for all types of CP but studies with children with diplegia are showing small but positive outcomes as long as set criteria are adhered to and all parties involved are committed. Given the lack of conclusive evidence of the impact on gross motor function it could also be argued that the commitment of these parents to the treatment if applied to physiotherapy alone could produce similar results. St Louis is now treating children with hemiplegia after several procedures showed significant improvement. It follows a similar technique but only the nerve roots on the affected side are severed.

Conclusion

SDR is one of a range of treatment options available to control spasticity; it is non reversible and needs to be approached with all the facts and a clear view of all the potential issues that may arise. The procedure is now being performed in the UK but many parents may still want to go to USA as they feel that with over 2000 operations behind them they are the main centre of excellence for this procedure. This could have financial implications and also potential conflicts of interest regarding protocols and follow up which are given post surgery in the USA. Not all children are suitable for this technique and careful assessment and discussion is required to avoid false hope and non effective surgery.

Another major issue that has been raised on the iCSP has been the amount of post operative physiotherapy recommended. Most NHS services do not have the capacity to offer the recommended sessions when considering the needs of all children with paediatric physiotherapy requirements. Therefore parents must be committed to carrying out the programme themselves or potentially employing private physiotherapists to provide the level of input they feel is necessary. This may be more difficult in remote and rural areas and will need close working relationships with NHS paediatric physiotherapists. Having spoken to a colleague who has just returned from USA observing Dr Park and his surgical technique she states that there is no hard evidence in favour of therapy 4-5 times per week as opposed to twice weekly. The different structures in healthcare may...
go some way to explain the historical presence of this input and this is likely to be reviewed.

In the longer term, if SDR becomes more mainstream and the expectation is for intensive rehabilitation post surgery then workforce planning will need to take this into consideration. In the short term where there is no conclusive evidence of long term or significant functional improvement then it would be very difficult for the NHS to justify the intensive rehabilitation at the expense of other children. It will be up to local resources and negotiation to decide upon appropriate level of input.

Ongoing research is essential and centres are continually developing and refining their techniques and criteria. Research is required into the long term implications of SDR, beyond 5 and 10 year studies and the success rate depending on the severity of the spasticity – how effective is it with milder cases, is it worth doing for the more severe, non mobile children focusing on the reduction of spasms and the beneficial aspects of positioning and toileting. Many more questions are out there and it will be interesting to monitor the evidence coming forward over the next few years.

References:
Foerster O (1913) On the indications and results of the excision of posterior spinal nerve roots in met. Surgery, Gynecology and Obstetrics 16:463-474
North Bristol NHS Trust publicity statement – UK’s first pioneering operation at Frenchay offers hope to children with cerebral palsy. 24th May 2011


St Louis Hospital Center for Cerebral palsy spasticity Aug 2010 - SDR Brochure www.stlouischildrens.org


www.support4sdr.org – parent led website in support of SDR in the UK


Young RR (1994) Spasticity: a review. Neurology 44 (suppl.) 12-20