Rehabilitation of children with cerebral palsy after single-event multilevel surgery

Pam Thomason and H. Kerr Graham

Introduction

Children with cerebral palsy (CP) experience a delay in achieving gross motor milestones and have a largely dynamic movement disorder, which is characterized by spasticity, weakness, and impaired selective motor control [1]. With time, the majority of children develop a range of secondary problems, collectively referred to as "progressive musculoskeletal pathology" [2]. These include contractures of muscle-tendon units, particularly muscles which cross two joints such as the gastrocnemius, hamstrings, and iliopsoas. In addition, many children have bony torsional deformities, most frequently increased femoral neck anteversion, and external tibial torsion [3]. Instability of joints is also common, with hip displacement and breakdown of the mid-foot resulting in pes valgus being the most common [4]. Single-event multilevel surgery (SEMLS) refers to the correction of the secondary musculoskeletal problems, by performing between 4 and 20 separate orthopedic procedures, during one operative session, requiring one hospital admission and one period of rehabilitation [5]. The emphasis in this chapter will be on rehabilitation after SEMLS for children with spastic diplegia, at Gross Motor Function Classification System (GMFCS) levels II and III [6]. Children at GMFCS level I may have such mild involvement that fewer procedures are required, although the underlying principles of rehabilitation will be much the same. The needs of children at GMFCS levels IV and V are quite different and are not the subject of this chapter [7]. Children at GMFCS level IV are not expected to be long-term ambulators, and although orthopedic surgery to stabilize the hip and correct deformities of the feet and ankle can be helpful, the aims and rehabilitation program are different from that of children at GMFCS levels I to III.

A recent systematic review of SEMLS reported wide variations in surgical practice and rehabilitation. However, substantial evidence was found for large improvements in gait with more equivocal evidence for changes in gross motor function [8]. The world's first randomized controlled trial (RCT) of SEMLS was recently published by the team at the Royal Children's Hospital in Melbourne [5]. This randomized clinical trial reported a 57% improvement in gait according to the Gillette Gait Index (GGI) and a 4.9% improvement in gross motor function according to the GMFM-66. The study contained an outline of post-operative rehabilitation, which will be expanded in this chapter to enlarge on the practical details of rehabilitation. Given that orthopedic surgery results in weakness, loss of independence, and decreased gross motor function, it is self-evident that it is the post-operative rehabilitation which makes children functionally "better."

Rehabilitation

Post-SEMLS rehabilitation will be considered under the following headings:

1. pre-operative planning
2. inpatient stay
3. the first 3 weeks
4. weeks 4–6
5. weeks 7–12
6. weeks 13–24
7. months 6–12
8. the 12-month Gait Laboratory reassessment
9. implant removal and "fine tuning"
10. what to expect in the second year.
1. Preoperative planning

Many children with CP who might benefit from SEMLS have already been under the care of a community-based pediatric physiotherapist or other health professionals. Some will have been seen by a multidisciplinary rehabilitation team. Such children have usually had an active program of physiotherapy and the use of appropriate ankle-foot orthoses (AFOs). This kind of integrated program maximizes function and independence and significantly reduces the severity of the progressive musculoskeletal deformities [9]. Some children will have received an intervention to manage spasticity such as selective dorsal rhizotomy (SDR) or intrathecal baclofen (ITB) [10]. The majority will have received intermittent injections of botulinum neurotoxin type A (BoNT-A) to various lower-limb muscles combined with serial casting, orthoses, and a community-based physiotherapy program. Most children show a plateau in gait and gross motor function, diminishing responses to injections of BoNT-A, and the progression of fixed contractures, between the age of 5 and 8 years [11] (Figure 18.1). This is the time when serious planning for SEMLS should start. It is much better for children and their parents to arrive at the planning stage for SEMLS in an orderly fashion, and at the right time rather than by crisis, because a hip problem or severe foot deformity has developed. The optimum time for SEMLS is between the age of 6 and 10 years [3]. Very few younger children, except those with hip displacement, require SEMLS before age 6 years. Early SEMLS is

![CP Musculoskeletal Management Algorithm](image-url)

**Figure 18.1 Musculoskeletal management algorithm.** The majority of children receive a spasticity management program which includes injections of botulinum toxin type A (BoNT-A), casting, the use of AFOs, and physiotherapy. During this time, the only surgery required is for hip displacement, which is uncommon in children who are walking. Most children proceed to SEMLS between the ages of 6 and 10 years and SEMLS should be avoided in teenagers if at all possible.
characterized by recurrent deformities and the need for repeat surgery as the child grows [7]. Conversely, for the majority of children, SEMLS and its prolonged rehabilitation should be concluded during the primary school years. Although SEMLS can be considered in adolescents and young adults, the surgery frequently needs to be performed sequentially one side at a time and the rehabilitation can be an order of magnitude more difficult. Adolescents and adults are more prone to anxiety, depression, and functional regression than are younger children.

Baseline function and a diagnostic matrix
It is very important to establish an exact baseline prior to considering SEMLS. This involves a careful reconsideration of the underlying diagnosis and baseline functioning. We have had patients referred for SEMLS who have had a diagnosis of "spastic diplegia" and are later found to have hereditary spastic paraplegia. It is crucial to be certain about the diagnosis prior to SEMLS [1] as the outcome of surgery and rehabilitation may be less predictable for other diagnoses. Baseline functional assessments include confirmation of the precise type of movement disorder, spastic, dystonic, or mixed [12]. In addition, there should be agreement by all parties including the family as to the child's GMFCS level and Functional Mobility Scale (FMS) [13]. It is also helpful to consider the sagittal gait pattern as the surgical and rehabilitation goals, as well as the orthotic prescription, which will be substantially different for children with true equinus or jump gait compared to those with apparent equinus or crouch gait [14]. All parts of the diagnostic matrix that we propose in Figure 18.2 are helpful in this baseline assessment. This includes up-to-date radiology of the hips and feet, torsional measurement of anteverision in the femurs and tibiae, and up-to-date instrumented gait analysis (IGA) [15].

It is important to have a frank discussion around the family and child's goals and aspirations. This requires a multidisciplinary approach with the involvement of the family and child, the rehabilitation team, as well as community therapists. For a child at GMFCS level III, independent ambulation is rarely achievable and it is essential to have these discussions ahead of the surgery and rehabilitation [16, 17]. A detailed examination of the child's level of activity and participation, using measures such as the Canadian Occupational Performance Measure (COPM), Children's Assessment of Participation and Enjoyment (CAPE), or the Activity Scale for Kids (ASK) may also be helpful.

It is crucial to distinguish between the needs of children and adolescents at this stage. The decision to proceed with SEMLS for younger children is largely made by their parents. However, adolescents must be given the freedom to make their own informed decisions regarding surgery and rehabilitation. An adolescent who feels that they have been forced into SEMLS against their will or without their full consent is likely to be resentful. They may develop depression, and struggle in rehabilitation.

Additional components of the pre-operative planning which can be very helpful for certain children and families include a pre-operative visit to the hospital, anesthetic pre-assessments, a visit to the inpatient facility and to the rehabilitation facility and to meet the inpatient team. It can be difficult for children and families to understand the complexity and duration of the rehabilitation despite detailed explanations. Discussion with another child and family who have recently been through the surgery and rehabilitation may be helpful.

SEMLS surgery is conducted by two surgical teams working together and requires a range of specific implants, bone-graft materials (allograft or autograft) for each specific patient. In our program, allograft from the Bone Bank is preferred for the majority of stabilization procedures to avoid the need of harvesting bone from the patient's hip [3]. Consent for the use of allograft should be made well ahead of time as part of preplanning to allow time for ordering the specific allograft to ensure availability on the day of surgery.

Assistive devices, aids, and orthoses
After SEMLS the majority of children will require equipment, assistive devices, and new orthoses to enable safe discharge from hospital and to begin the process of rehabilitation [3, 5]. Assessment of the home by an occupational therapist may be necessary and additional equipment for activities of daily living may be required. This is particularly necessary with the older child or teenager. The need for assistive devices can be predicted by the child's baseline GMFCS level, FMS, and sagittal gait pattern. After SEMLS, the majority of children will require a wheelchair with leg boards for elevation of the lower limbs. This includes previously independent ambulators,
Section 4 Rehabilitation of specific conditions

Figure 18.2 The diagnostic matrix. A comprehensive assessment of children prior to SEMLS involves all components of the diagnostic matrix, illustrated here. Video gait analysis (VGA) is used at 3-monthly intervals during the first year after surgery with instrumented gait analysis (IGA) at both baseline and 12 months after SEMLS. Reproduced with permission from Thomson P, Harvey A, Graham HK. Chapter 6. Measurement tools and methods. In The Identification and Treatment of Gait Problems in Cerebral Palsy, eds Gage JR, Schwartz M, Koop SE, Novacheck TF. Clinics in Developmental Medicine Nos 180-181. 2009. Mac Keith Press. Distributed by Wiley-Blackwell.

children at GMFCS levels I and II. Such children may not have a wheelchair and one may need to be hired with adaptations to allow elevation of the lower limbs. Children at GMFCS level III, who have previously used assistive devices, may well require increased levels of assistance post SEMLS. The majority of children regardless of GMFCS level will start standing and walking on parallel bars and then a posterior walker. There generally is a need for rapid changes in assistive devices as progress occurs, i.e. from posterior walker, to forearm crutches, to single point sticks, and return to independent walking (GMFCS II). Additional equipment needs include knee immobilizers to maintain the extension and lower-limb alignment, as well as for support in initial standing [3, 5].

The post-operative AFO prescription (Figure 18.3) can often be predicted from the sagittal gait pattern and surgical goals. Children with true equinus and jump gait will usually have hinged AFOs (hinged closed for first 12 weeks post SEMLS). Those with
apparent equinus or crouch gait may require either solid AFOs or ground reaction AFOs (GRAFOs) for a considerable period of time [14, 16].

Some types of SEMLS surgery for crouch gait depend on the prolonged use of GRAFOs to maintain an extension posture at the knee and hip, until adaptive shortening of the gastrocsoleus and quadriceps has taken place [17]. This is particularly the case in teenagers with crouch gait secondary to prior gastrocsoleus lengthening. GRAFOs are cumbersome, cosmetically unappealing, poorly tolerated but biomechanically very effective. The need for such orthoses and the duration must be discussed in advance. The need for GRAFOs for 6 months or more may be sufficient to put some teenagers off SEMLS. It is clearly better to determine this prior to surgery than have non-compliance afterwards, because crouch gait surgery cannot succeed without appropriate AFOs [17].

2. Inpatient stay

The majority of children are admitted on the morning of surgery, which has advantages in the prevention of skin colonization by resistant bacteria. However, day-of-surgery admission leaves little time for last-minute discussions and planning, emphasizing the need to have all of these issues discussed and agreed well in advance. In the admission unit, there needs to be time for the anesthesia team to review and discuss the anesthetic process and techniques with the child and with the family. The surgeon and family need time for a final review including completion of consent procedures and marking the surgical sites for all procedures. The site for the incision for each operative procedure should be marked with a pen on the patient’s skin, and agreed by the surgeon and the family. It is vital to ensure that the surgical plan is correct in every detail especially for asymmetric surgical prescription. For example, in children with asymmetric diplegia it is common for more procedures to be performed on the more involved side and it is crucial for these to be accurately identified when the patient is in both the prone and supine position.

Anesthesia and analgesia

General anesthesia is required for SEMLS in all patients and most frequently this is supplemented by epidural analgesia [5, 17]. The epidural catheter is placed, following the induction of general anesthesia, prior to entry into the operating room. For the majority of children and adolescents epidural analgesia during SEMLS and continued for 3–5 days postoperatively is the best choice. Epidural analgesia allows for a reduction in volatile agents, narcotic infusions, and provides effective pain relief. A small number of children, with spinal deformities, previous spinal surgery including selective dorsal rhizotomy or scoliosis surgery may not be suitable for epidural analgesia. A combination of ropivacaine (0.1%–0.2%) is frequently used, often in combination with clonidine. Risks of epidural analgesia include infection at the catheter site, leading to an epidural abscess, drug toxicity, and masking signs of compartment syndrome. Although these are legitimate concerns, the risk and benefit profile of epidural analgesia for SEMLS is superior to any other technique. Catheter-site infections are very uncommon, with appropriate technique and the use of perioperative antibiotics. The risk of drug toxicity is minimized by the use of appropriate dose, dilution, and infusion rates. Hypotension and bradycardia from clonidine is quite common but can be managed by appropriate use of additional infusion fluids. Epidural analgesia requires expert anesthesia and pain management post-operatively [3, 5].
Additional requirements for the use of epidural analgesia include an indwelling catheter and bowel management. The indwelling bladder catheter allows accurate monitoring of fluid balance and avoids the problems of retention of urine. Patients should be admitted to hospital following good pre-operative bowel management obviating the need for bowel movements within the first few days after surgery. However, post-operative constipation is a common problem and aperients and enemas are usually required to re-establish a normal bowel habit prior to discharge, especially if pain medications containing codeine have been administered.

For patients who are not candidates for epidural analgesia, or for those who refuse the placement of an epidural catheter, a continuous infusion of narcotic analgesics is an alternative approach. Some children and most adolescents are able to self-administer the infusions using a patient-controlled analgesia (PCA) arrangement pump. For both analgesic regimens, weaning from epidural and intravenous analgesia to oral medications is appropriate at 3–5 days after SEMLS. Again, the help of an expert pain management team is invaluable. Various combinations of antispasmodics, such as benzodiazepines (valium) and oral analgesics including non-steroidal anti-inflammatory drugs (NSAIDS), codeine derivatives, and paracetamol can be used in effective combinations.

For children with CP, a substantial amount of post-operative pain is related to the presence of involuntary muscle spasms [18]. Children with CP do not have the luxury of “switching off” muscles ensuring that they are relaxed after surgery. Instead the hyperactive stretch reflex may result in involuntary contractions of large muscle groups, causing both movement and tension on recently operated structures. This may increase pain experience, compared to typically developing children, who do not have spastic hypertonia. Pre-operative or intra-operative injection of key muscle groups with BoNT-A may substantially improve analgesia after surgery [18].

Post-operative positioning, equipment, and rehabilitation

After SEMLS we use below-knee plasters only, with removable knee immobiizers at the level of the knees, and rely on stable fixation at the hips. The only exception is when patellar tendon shortening has been performed, when long leg or above-knee casts may be required [19]. Hip spicas are never used for ambulant patients and rarely used in non-ambulant patients.

All of the surgery below the knee, including gastro-cleus lengthening, rotational osteotomy of the tibia, and stabilization of the mid-foot, are maintained in satisfactory alignment in below-knee casts. The casts must be well padded and split to accommodate post-operative swelling. It is very important to be aware of the child’s baseline selective motor control and density of the epidural block in assessing changes in distal neurovascular function. Many children with CP lack the ability to voluntarily extend the toes before surgery. If this is only noted after surgery, it may raise concerns about a change in neurological status when none has actually occurred.

At the knee level, various combinations of distal hamstring lengthening, transfer of the semitendinosus, and rectus femoris transfer are the most frequently performed surgeries [20, 21]. The techniques used at the Royal Children’s Hospital are inherently stable allowing for the use of removable knee immobilizers to maintain alignment and extension but allowing early knee motion into flexion. At the hip level, the femoral plates provide stable fixation and additional support is not required. However, optimum postural alignment of the lower limbs is crucial and the patient is not able to do this without assistance. Following femoral derotation osteotomy, the lower limbs tend to roll into excessive external rotation, particularly under the relaxation of the epidural analgesia. Excessive external rotation can quickly progress to an external rotation contracture at the hip level. Most commonly we use sandbags and pillows, positioned laterally at the level of the foot and the knee (Figure 18.4a). Pillows or a foam abduction wedge placed between the lower legs may be used to maintain abduction range as well. The alternative is a bar attached to the below-knee casts to prevent external rotation and maintain abduction.

A major SEMLS principle is lengthening of flexor muscles to improve the extension posture at the hip, knee, and ankle [22]. The plantar flexors of the ankles are maintained in the lengthened position by the below-knee plaster casts. The knee flexors (hamstrings) are looked after by the knee immobilizers, reinforced by long sitting with knee extension. The group of muscles which are easily forgotten are the hip flexors. In the early days and weeks after multilevel surgery, a lot of time is spent in “long sitting” in which the hamstrings are maintained at optimal length but the psoas is in the
shortened position (Figure 18.4c). It is therefore essential, following psoas lengthening at the brim of the pelvis, to have a period in prone each day, for a minimum of 1 hour, to stretch the iliopsoas across the front of the pelvis (Figure 18.4b). It is best if this can be combined with some enjoyable leisure activity such as watching a favorite television program, or DVD, listening to music, or reading a book, which may further encourage extension of the trunk.

Transfer of the rectus femoris is typically through a non-anatomic region to one of the hamstring tendons [23,24]. As such, early motion is required to prevent the formation of adhesions, which may mature into scar tissue and prevent the transfer working and even result in an extension contracture at the knee. Patients who have had a rectus transfer must have removal of the knee immobilizer and early ranging into flexion to achieve at least 30° of knee flexion by the end of the first week (Figure 18.5a), 60° at the end of week 2 and 90° at the end of week 3 (Figure 18.5b). If significant problems are noted in achieving these flexion ranges it is sometimes appropriate to use continuous passive motion to improve the ranging of the knee and the rectus femoris transfers [25].

Physiotherapy during this time aims to maintain optimum positioning and facilitate changes in position, as required. It is important to educate the child and family regarding positioning for continuation at home post discharge.

**Preparation for discharge**

On the fifth post-operative day, the epidural infusion is discontinued, the indwelling catheter from the bladder is removed, and the intravenous lines are removed. The patient is then free to mobilize without these restrictions and to learn safe and effective transfers from bed to wheelchair. Wheelchair mobility with leg boards for elevation is important at this stage (Figure 18.6a). Below-knee casts may need to be repaired and reinforced with fiberglass or occasionally replaced. Cast shoes should be provided and fitted and
when transfers are safe and the family is proficient, discharge from hospital may be arranged. X-rays of osteotomies are obtained prior to discharge to check on implant positioning and as a baseline for comparison with post-operative X-rays [3, 5]. Occupational therapy assessment for additional equipment for the home may be required to assist with activities of daily living.

Physiotherapy is aimed at gaining independent or assisted transfer ability, initiation of weight-bearing (Figure 18.6b) as allowed and tolerated, and safe wheelchair mobility prior to discharge. It is important to communicate with community therapists with regard to surgeries performed, weight-bearing status and home program to be continued until return to hospital for outpatient review.

3. The first 3 weeks post-operatively

Most patients are discharged from hospital 5-7 days after SEMLS and spend the next 2 weeks at home healing, recovering from surgery and commencing rehabilitation. Soft-tissue surgery is designed to be stable and, if there has been no bony surgery, full weight-bearing in the plaster casts without restriction is advised from day 2-3 post-operatively. When bony surgery has been performed there may be a short delay until full weight-bearing is allowed but this interval is becoming shorter and shorter. Almost all femoral osteotomies are sufficiently stable to allow full weight-bearing within days of surgery but we usually recommend a delay of 1-2 weeks for tibial osteotomies and for mid-foot stabilization by os calcis lengthening or subtalar fusion. Intra-operative observations in respect of bone strength, implant positioning, and other factors may dictate minor variations on these general principles [3, 5]. It is important that the child, family, and therapists are aware of the weight-bearing status for the child at any given time. A prolonged delay in weight-bearing which is not necessary will delay and slow the rehabilitation progress and at worst lead to the development of contracture and reduced functional ability.

The first post-operative visit 3 weeks post SEMLS

All patients are routinely seen at 3 weeks after surgery to check on progress, healing of skin incisions, muscle length, muscle strength, and lower-limb alignment. Dressings are removed and incisions are inspected for confirmation of healing or early detection of inflammation or infection, which is uncommon. The majority of incisions heal quickly and easily, the use of peri-operative antibiotics and good wound care has resulted in very low rates of superficial and deep wound infections. The exceptions tend to be the incisions around the knee for both rectus femoris transfer and distal hamstring lengthening [5]. These incisions are prone to separation and slower healing because of the need for early knee motion after SEMLS. The majority of wound problems are the result of minor wound separation, not infection. Most need dressings and simple wound care, not antibiotics. The majority of incisions are closed with subcuticular absorbable sutures and although this is not as secure as interrupted non-absorbable sutures it is a more appropriate strategy for children. Children who have been through multilevel surgery may be more apprehensive about a change of dressing or suture removal than any other procedure. The use of subcuticular absorbable sutures is child-friendly and appropriate for the majority of incisions. An exception is in the mid-foot where the insertion of bone grafts for os calcis lengthening may lead to increased wound tension. In this situation sutures of interrupted nylon are preferred but these are usually removed at 3 weeks when the cast is changed, under sedation or "mask anaesthetic" [3, 5].

At the 3-week visit, the below-knee casts are removed and moulds are taken for new AFOs (Figure 18.3). The majority of children with diplegia require new AFOs because of the change in the shape of the foot or alignment of the leg following such procedures as gastrocsoleus lengthening, tibi
osteotomy, or os calcis lengthening. New lightweight fiberglass casts are applied, cast shoes are provided, and osteotomies are X-rayed. By now all patients have been cleared for full weight-bearing as tolerated. The majority of children with CP, and especially those with bilateral lower-limb surgery, are unable to comply with any form of protected or partial weight-bearing. It is the surgeon’s responsibility to ensure that full weight-bearing can be safely achieved at a maximum of 3 weeks after surgery.

4. Weeks 4–6 post-operatively
This is a very important period of rehabilitation during which the priorities are maintenance of muscle length, regaining muscle strength, maintenance of lower-limb alignment, encouragement of weight-bearing, standing, and re-introduction of walking. This involves the continuation of activities in prone lying and long sitting (Figure 18.4) as well as the introduction of non-weight-bearing strengthening exercises for the hip and knee. The majority of children should be able to make rapid progress in standing and walking during this period, in 3–5 one-hour sessions per week. Initial attempts at standing can be helped by the use of knee immobilizers but as soon as the quadriceps are competent the use of these can be reduced. The level of assistive device depends on the child’s age, cognitive level, and baseline gross motor function. Most children start either on parallel bars in the physiotherapy gym (Figure 18.6b) or using a posterior walker (Figure 18.7a). A posterior walker encourages trunk and hip extension, which is the desired sagittal alignment [16, 22]. Progression of walking is important and should be encouraged (Figure 18.7).

At this crucial time if there are concerns with the child or family’s ability to cope with this therapy program at home or weight-bearing is difficult, a short burst of inpatient rehabilitation for 1 to 2 weeks may be beneficial. Ideally this should have been planned at the pre-surgical visit or in the initial post-operative period.

The second post-operative visit 6 weeks post SEMLS
This is an important landmark in rehabilitation. During this visit, the below-knee casts are removed, the new AFOs are fitted and checked, and osteotomies are re-X-rayed to check on healing. Muscle length, muscle strength, and lower-limb alignment are also checked. This is also the time to perform the first check of coupling at the knee. The majority of children with spastic diplegia have excessive knee flexion both at initial contact and for most of the stance phase during gait. In the majority of children, surgery has been performed to improve extension at the knee and also at the hip. A fundamentally important principle of post-operative rehabilitation is to improve coupling at the knee by directing the ground reaction force in front of the knee during the stance phase of gait. This is done by correcting deformities at the foot and ankle level, especially the correction of lever arm deformities, in combination with procedures to improve extension at the hip and knee [17, 26]. Sometimes coupling can be simply checked by having the child stand and walk in the new AFOs. On other occasions coupling can be more accurately and effectively checked by video gait analysis (VGA) in the gait laboratory [27].

Figure 18.7 Early rehabilitation 4–6 weeks. The majority of children start full weight-bearing within 1–2 weeks of SEMLS, using a posterior walker and Zimmer knee immobilizers over their plaster casts (a). As soon as knee coupling is competent they may remove Zimmers for walking (b) and as soon as it is safe they may graduate to forearm crutches (c).
5. Weeks 7–12 post-operatively

The removal of plaster casts and fitting of AFOs allows for a change in the rehabilitation program to include both formal hydrotherapy and recreational activities in a swimming pool. Weight-bearing in the supportive environment of a hydrotherapy pool can be a major confidence booster for many children. At this early stage, the only time unprotected weight-bearing (i.e. without AFOs) is permitted is within the hydrotherapy pool. Appropriate advice and arrangements need to be made for children to get to the pool side safely, whilst wearing their AFOs. AFOs can be removed for hydrotherapy and replaced for all land-based activities. The frequency of rehabilitation can be adjusted according to the child and family needs, progress, and ultimate goals. For most children, this is a very intense period when large gains and recovery of walking function can be expected. Between three and five 1-hour sessions per week are appropriate for most children and these usually include a combination of both hydrotherapy and land-based sessions.

The majority of children will have been provided with new AFOs at the time of cast removal and it often takes several weeks to get used to the new postsurgical alignment and the fit of new AFOs. Expert orthotic review and adjustment of AFOs is very important. AFO intolerance must not be allowed to delay progression in weight-bearing and recovery of function. Review of “knee coupling” during this period is important and this may be based on either clinical assessment in the outpatient clinic or more formally in the gait laboratory if there are concerns [5, 28]. This may also be a time for a burst of inpatient rehabilitation for 1 to 2 weeks to gain strength and walking ability.

At this stage some children no longer require Zimmer knee immobilizers. The exceptions are those children with residual knee-flexion deformities or those who tend to revert to flexed knee postures while they are sleeping [3]. The use of three-point splints may be required for children with residual knee-flexion deformity. These may be used during therapy sessions and also at night as an alternative to knee immobilizers.

In terms of assistive devices, the majority of children will progress from parallel bars to the use of a posterior walker or forearm crutches at this stage of recovery (Figure 18.8). The general principle is to progress to lower levels of assistance as soon as is safe. There may initially be some resistance from children, parents, and staff at the child’s school, who perceive walking on a posterior walker to be “safer” than using crutches, single-point sticks, or walking independently. Whilst this may be the case in the short term, in the medium and longer term it is absolutely crucial to progress to lower levels of support as quickly as possible. It can be helpful to conduct VGA in the gait laboratory and compare walking patterns, walking speed, and knee coupling using various assistive devices. Children who have strong upper limbs may take so much weight through their arms and the posterior walker that there is insufficient ground reaction force in front of the knee to promote coupling and knee extension. If such children persist in the use of a posterior walker, the flexed-knee gait pattern may quickly return and much of the anticipated gains of surgery will be lost. Strengthening exercises now progress to include weight-bearing strengthening exercises (Figure 18.8c). Assessments during this period
should always include completion of the FMS to document precisely where the child is in terms of the use of assistive devices over the three specified distances of 5, 50, and 500 meters [13, 27, 29].

6. Weeks 13–24 post-operatively
This is another very important phase in SEMLS rehabilitation in which the new biomechanical alignment should lead to improvements in gait pattern and progressive improvements in function and independence. An assessment in the gait laboratory using VGA is essential during this phase to assess sagittal alignment, knee coupling, transverse plane alignment, and to check on the fit of orthoses and the appropriate use of assistive devices. The intensity of rehabilitation is usually reduced (compared to weeks 7–12) with between two and four 1-hour sessions per week, including both land-based sessions and hydrotherapy sessions.

Some children with jump gait or true equinus will have the hinges in their AFOs activated during this phase, once effective knee coupling has been confirmed. Some children who have been in crouch gait will be able to progress from ground reaction AFOs to solid AFOs which are considerably less cumbersome [17]. All children require review of assistive devices to continue to reduce dependence on wheelchairs and posterior walkers as quickly as possible, within the constraints of safety (Figure 18.9). The majority of children will be back at school and liaison with classroom aids and school authorities is very important to ensure that children are given the opportunity to practice their walking in safe surroundings. For the majority of children it is both counterproductive and inappropriate to be prohibited from walking indoors and outdoors during the school day. It is not feasible at the end of the school day to make up for lack of walking earlier in the day.

7. Months 6–12 post-operatively
The two most important issues for this phase are to avoid "burnout" and to shift the emphasis towards strengthening and independence. By this stage the majority of children have adapted to the new biomechanical alignment and are becoming increasingly independent. Some who have strong knee coupling can commence activities without the support of AFOs but this requires confirmation from a video-based gait assessment. The frequency of physiotherapy sessions, can be reduced for the majority of children and replaced with recreational activities including family walks, bicycle riding (often a tricycle or modified bicycle), and swimming. Older children and teenagers may benefit from a formal strengthening program [30]. Adolescent boys readily identify with gym-based activities using a variety of standard equipment designed to strengthen the muscles which contribute to the body-support moment, the hip extensors, quadriceps, and ankle plantar flexors (Figure 18.10).

8. The 12-month gait-laboratory reassessment
The majority of children are ready for a full IGA at 12 months after surgery. This includes all the components of the diagnostic matrix (Figure 18.2), up-to-date physical examination, completion of GMFCS, FMS, and FAQ, up-to-date radiology, and IGA [5]. A
comparison of the baseline IGA with the 12-month follow-up study allows for an initial assessment in terms of the effectiveness of the gait-correction surgery and rehabilitation. Under-corrections, over-corrections and new problems can all be identified and appropriate recommendations made regarding physiotherapy, strengthening, the use of BoNT-A, the timing of implant removal, and the possible need for additional surgical procedures [5]. At this stage, the majority of children will have a substantial improvement in their gait pattern but few will show much if any change in gross motor function. It is during the second year after SEMLS when most of the gains in gross motor function can be anticipated. Therefore continued close surveillance by both the community-based physiotherapists and the gait-laboratory physiotherapists is important. Most recommendations regarding both assistive devices and AFOs prescription during the first 12 months after SEMLS will have been based on clinical examination and VGA. The IGA at 12 months post-operatively provides an opportunity to obtain objective information about knee coupling and in particular the dynamic length of the gastrocsoleus. Both of these factors will guide AFO recommendations during the second year. For some high-functioning children at GMFCS level II, a comparison of IGA, in and out of AFOs, will show that they are ready to progress with increased barefoot activities. For others, the reverse is true. The barefoot sagittal kinematic study may well show that the gastrocsoleus is too long in late stance and that continued protection by a solid or hinged AFO is necessary [31]. It is very important that the recommendations for orthotic use be based on objective kinematic and kinetic data.

9. Implant removal and “fine tuning”
For most children, SEMLS includes a combination of soft-tissue and bony procedures. The majority of bony procedures require metal implants including blade plates in the proximal femur and “T” plates in the distal tibia. The majority of children are scheduled for removal of these implants at between 12 and 18 months after surgery [28]. The 12-month follow-up IGA can help identify additional procedures to be considered at the time of implant removal. For the majority of children these will be quite simple procedures such as injection of BoNT-A into a spastic muscle group, or the addition of a procedure such as a rectus femoris transfer [3, 5, 28]. Some procedures are “borderline” in terms of their indication that it does not become clear until the 12-month post-SEMLS assessment whether they are strictly necessary or not. In addition, some procedures such as rectus femoris transfer require such a specific rehabilitation protocol that they are best left and done in isolation at 12 months after SEMLS. It is important to try to limit the amount of repeat surgery at this stage to procedures requiring a short, sharp, additional period of rehabilitation so that the child and family are not overly burdened.
### 10. What to expect in the second year

The results from the SEMLS RCT from the Royal Children’s Hospital in Melbourne have shown several important new findings.

I. Gains in gross motor function are usually made in the second and subsequent years after SEMLS and it is therefore important to continue a physiotherapy program and careful monitoring [5].

II. Gait correction is usually stable and gains in both GMFM-66 and gait function are maintained at 5-year follow-up [28].

III. The majority of children, during the first 5 years after SEMLS will go through the pubertal growth spurt with marked changes in height, weight, and sometimes in body mass index (BMI) [28].

IV. These changes produce additional stresses on the musculoskeletal system. In some children rapid growth of the long bones during the pubertal growth spurt results in recurrent contractures. Some of these will require injections of BoNT-A and others will require repeat soft-tissue surgery. However, in a recent 5-year follow-up study, the number of procedures required per child was relatively small [28].

The majority of children benefit from a yearly gait-laboratory-based assessment and VGA until skeletal maturity.

Therapy at this time should be directed at maintaining strength, range of motion, and flexibility. Children may benefit from activities directed at community involvement in sporting and recreational pursuits as appropriate and related to the child’s interests and goals. Therapy intervention may require specific task analysis of activities that the children may want to be able to achieve, for example to skip rope, ride a bike without training wheels, jump, or hop. Community education regarding participation in sport, assistance with access issues, and equipment modification to allow participation in the desired activities may also be required. A multidisciplinary approach is required to encourage an active healthy lifestyle to continue into adolescence and adulthood.

### Further reading


### References


