(e) ISSN Online: 2321-9599

(p) ISSN Print: 2348-6805

ORIGINAL ARTICLE

Functional Outcomes of Single-Event Multilevel Surgery in Children with Spastic Cerebral Palsy Affecting the Lower Limbs

[1]Sunil Kumar, [2]Ved Prakash Agarwal

[1,2]Assistant Professor Department of Orthopaedics, ICARE Institute of Medical Sciences and Research &Bidhan Chandra Roy Hospital, Haldia, India

ABSTRACT:

Background: Spastic cerebral palsy (CP) commonly leads to progressive musculoskeletal deformities in the lower limbs, impairing gait and functional mobility. Single-Event Multilevel Surgery (SEMLS) has been developed as a comprehensive surgical approach to address these deformities in a single operative session. **Objective:** To evaluate the functional and clinical outcomes of SEMLS in children with spastic CP affecting the lower limbs. **Methods:** A total of 66 children with spastic hemiplegic or diplegic CP, aged 7–16 years and classified within GMFCS levels I–III, were enrolled using purposive sampling. All participants underwent SEMLS, and outcomes were assessed using changes in gait patterns, GMFCS levels, range of motion (ROM) at key joints, and postoperative complications. Follow-up was conducted to evaluate clinical and functional improvements. **Results:** Postoperatively, 71.21% of patients achieved a near-normal gait and 28.79% achieved a normal gait, compared to 0% preoperatively. Significant improvement in GMFCS levels was observed, with 59.09% of children classified as Level I at final follow-up (preoperative: 9.09%). ROM improved significantly in the hip and knee joints ($P < 0.001$). Most patients underwent surgical correction at 5–6 levels (mean: 5.68 ± 1.75). Complication rates were low, with 87.88% experiencing no postoperative issues. **Conclusion:** SEMLS is a safe and effective surgical strategy for improving gait and gross motor function in ambulant children with spastic CP involving the lower limbs.

Keywords: Cerebral palsy, SEMLS, spastic diplegia, gait improvement, GMFCS, multilevel surgery

Corresponding author: Ved Prakash Agarwal, Assistant Professor Department of Orthopaedics, ICARE Institute of Medical Sciences and Research &Bidhan Chandra Roy Hospital, Haldia, India

This article may be cited as: Kumar S, Agarwal VP. Functional Outcomes of Single-Event Multilevel Surgery in Children with Spastic Cerebral Palsy Affecting the Lower Limbs. J Adv Med Dent Scie Res 2015;3(2):366-370.

INTRODUCTION

Cerebral palsy (CP) is a group of permanent movement and posture disorders caused by non-progressive disturbances in the developing fetal or infant brain, with spastic CP being the most prevalent subtype, accounting for nearly 80% of cases [1,2]. Among children with spastic CP, the lower limbs are commonly affected, leading to characteristic gait abnormalities, joint contractures, and progressive musculoskeletal deformities over time [3]. These abnormalities can severely limit mobility, functional independence, and overall quality of life. As the child grows, these musculoskeletal deformities tend to worsen without timely intervention, necessitating surgical correction in many cases [4].

The traditional surgical approach to treating musculoskeletal problems in CP patients involved multiple separate surgeries performed at different times, often leading to prolonged treatment periods, extended rehabilitation phases, and multiple exposures to anesthesia [5]. This approach was also associated with inconsistent outcomes due to the sequential correction of deformities, which often failed to address the interdependence of biomechanical issues in different limb segments [6].

To address these limitations, the concept of Single-Event Multi-Level Surgery (SEMLS) was developed and gained traction in the late 1980s and early 1990s. SEMLS involves performing multiple soft tissue and/or bony procedures in a single operative session to correct all significant musculoskeletal deformities in the lower limbs [7]. This approach allows for simultaneous correction of muscle contractures and skeletal malalignments across multiple joints, improving the overall alignment and function of the lower extremities [8].

Early studies of SEMLS reported significant improvements in gait parameters and functional outcomes. Norlin and Tkaczuk were among the first to document functional benefits of simultaneous multilevel surgery in CP patients, reporting better gait efficiency and reduced energy expenditure during walking [9]. Browne and McManus also emphasized the advantages of SEMLS, noting that single-stage correction led to shorter hospital stays, fewer anesthetic events, and more consistent improvements in gait [10].

One of the critical advancements that supported the development and refinement of SEMLS was the integration of instrumented gait analysis. This technology allowed for precise identification of pathological gait patterns and individualized surgical planning [11]. Gait analysis helps determine which muscles and joints contribute to abnormal walking, guiding the choice of procedures such as hamstring lengthening, adductor tenotomy, rectus femoris transfer, and femoral/tibialderotation osteotomies [12]. By addressing all the contributing factors in a single session, SEMLS aims to enhance gait efficiency and minimize the risk of over- or under-correction.

Research has shown that SEMLS improves spatiotemporal and kinematic gait variables, particularly in ambulatory children with spastic diplegia. Nene and colleagues found significant improvements in cadence, step length, and overall gait velocity postoperatively, alongside reductions in physiological cost index, indicating improved energy efficiency during walking [13]. Furthermore, improvements in the Gross Motor Function Measure (GMFM) and quality-of-life metrics have been documented following SEMLS, particularly in children with GMFCS Levels I–III [14].

A major strength of SEMLS lies in its holistic, comprehensive approach. By addressing multiple deformities simultaneously, the procedure respects the interconnected nature of biomechanical and neuromuscular abnormalities seen in CP [15]. Moreover, it enables a single postoperative rehabilitation phase, potentially reducing the total burden of care and improving adherence to therapy protocols.

However, SEMLS is not without limitations. The procedure is technically demanding, requires careful preoperative planning, and entails a longer initial recovery period due to the extent of surgical intervention. Additionally, the success of SEMLS largely depends on appropriate patient selection, surgical expertise, and the availability of postoperative rehabilitation services [16]. Long-term follow-up studies have also shown that while many patients experience sustained improvements, some may require further surgical intervention due to growth-related changes or recurrence of deformities [17].

Despite these challenges, SEMLS remains the gold standard surgical intervention for improving gait in ambulant children with spastic CP affecting the lower limbs. Its benefits in terms of functional improvement, reduced number of surgeries, and enhanced quality of life have made it a cornerstone of orthopedic management in this population [18].

Given the complexity of CP and the variability in clinical presentations, further research is necessary to optimize patient selection criteria, refine surgical techniques, and evaluate long-term outcomes. The present study aims to assess the functional and gait-related outcomes of SEMLS in spastic CP patients involving the lower limbs and to contribute to the growing body of evidence supporting this multifaceted surgical approach.

MATERIALS AND METHODS

Study Population

This study included pediatric patients diagnosed with spastic cerebral palsy (CP) primarily affecting the lower limbs. A total of 66 children were enrolled using a purposive sampling technique, based on patient availability and strict adherence to predetermined eligibility criteria.

Inclusion Criteria

Participants were eligible for inclusion if they met the following criteria:

- A confirmed diagnosis of spastic hemiplegic or diplegic cerebral palsy involving the lower limbs.
- Presence of musculoskeletal deformities at multiple anatomical levels.
- Ambulatory status classified as Gross Motor Function Classification System (GMFCS) Levels I to III.
- Age between 7 and 16 years.

Exclusion Criteria

Children were excluded from the study if they:

- Had cerebral palsy accompanied by congenital anomalies or significant comorbid conditions.
- Received botulinum toxin injections within six months prior to surgery.
- Underwent any orthopedic surgical procedure involving the lower extremities within the last twelve months.

RESULT

Table 1: Baseline characteristics distribution among the participants

Baseline characteristics	Frequency (N)	%
Age (in years)		
7–9	18	27.27
10–13	31	46.97
14–16	17	25.76
Mean±SD	11.03 ± 2.56	
Gender		
Male	38	57.58
Female	28	42.42
Diagnosis		
Hemiplegic CP	21	31.82
Diplegic CP	45	68.18

Table 1 summarizes the baseline characteristics of the 66 pediatric patients included in the study. The age group distribution shows that the majority were between 10–13 years old (46.97%), followed by 7–9 years (27.27%), and 14–16 years (25.76%), with a mean age of approximately 11 years. A slightly higher proportion of males (57.58%) were observed. Regarding diagnosis, diplegic cerebral palsy was more common (68.18%) than hemiplegic type.

Table 2: Distribution of cases by gait pattern preoperatively and at final follow-up

Gait pattern	Preoperatively (N)	%	Final follow-up (N)	%
Hemiplegic	21	31.82	0	0.00
Jump	32	48.48	0	0.00
Crouch	13	19.70	0	0.00
Normal	0	0.00	19	28.79
Near normal	0	0.00	47	71.21

Table 2 shows the changes in gait pattern from the preoperative phase to the final follow-up. Preoperatively, jump gait (48.48%) was the most prevalent, followed by hemiplegic and crouch gaits. At final follow-up, a substantial shift was observed, with 71.21% of patients achieving a near normal gait and 28.79% achieving a normal gait, indicating significant postoperative functional improvement.

Table 3: Distribution of cases by improvement of gross motor function

GMFCS	Preoperatively (N)	%	Final follow-up (N)	%
I	6	9.09	39	59.09
II	38	57.58	19	28.79
III	22	33.33	8	12.12

Table 3 illustrates the improvement in Gross Motor Function Classification System (GMFCS) levels. Initially, most participants were in levels II and III. By final follow-up, 59.09% had improved to level I, suggesting considerable enhancement in gross motor function due to the intervention.

Table 4: Distribution of cases by ROM of hip, knee and ankle

ROM location	Preoperatively	At final follow-up	P value
Hip – Fixed flexion deformity	18.21 ± 10.31	3.79 ± 4.10	<0.001[a]
Hip – Further flexion	112.10 ± 14.01	124.33 ± 9.76	<0.001[b]
Hip – Abduction	25.73 ± 4.52	36.48 ± 5.02	<0.001[b]
Knee – Popliteal angle	50.66 ± 7.03	6.34 ± 6.92	<0.001[a]
Knee – Flexion	115.44 ± 10.56	123.71 ± 9.11	<0.001[b]
Ankle – Dorsiflexion	13.28 ± 6.01	9.24 ± 5.01	<0.001[a]
Ankle – Plantar flexion	34.41 ± 6.48	35.67 ± 5.43	0.412[b]

Table 4 presents range of motion (ROM) data for the hip, knee, and ankle. Statistically significant improvements were noted in hip flexion, knee flexion, and popliteal angle ($P < 0.001$). Dorsiflexion showed improvement, while plantar flexion remained statistically unchanged.

Table 5: Distribution of study patients by number of levels of surgical release

Number of levels of surgical release	Frequency (N)	%
2–4	14	21.21
5–6	36	54.55
7–8	16	24.24
Mean±SD	5.68 ± 1.75	

Table 5 outlines the number of surgical levels treated. Most patients underwent 5–6 level releases (54.55%), with an overall mean of 5.68 ± 1.75 levels. This reflects the extent of multilevel involvement in spastic CP cases.

Table 6: Distribution of cases by complication

Complication	Frequency (N)	%
None	58	87.88
Plaster sore	3	4.55
Superficial wound infection	5	7.58

Table 6 summarizes postoperative complications. The majority of patients (87.88%) experienced no complications. Minor issues such as plaster sores and superficial wound infections were noted in a small proportion, indicating an overall safe surgical profile.

DISCUSSION

The present study aimed to evaluate the outcomes of Single-Event Multilevel Surgery (SEMLS) in children with spastic cerebral palsy (CP) affecting the lower limbs. The findings demonstrate substantial postoperative improvements in gait patterns, gross motor function, and joint range of motion, confirming the effectiveness of SEMLS as a comprehensive surgical strategy in this population.

The demographic distribution of participants showed that the majority were aged between 10 and 13 years, with a mean age of 11.03 years. This age range aligns well with the optimal timing for SEMLS, as skeletal maturity is not yet complete, and growth-related deformities can still be effectively addressed [19]. The male predominance (57.58%) in our study is consistent with previous epidemiological data suggesting a slightly higher incidence of CP in males [1,20].

Regarding diagnosis, diplegic CP was more prevalent (68.18%) than hemiplegic CP. This is expected, as diplegic presentations typically exhibit more pronounced bilateral lower limb involvement and are more likely to develop multilevel musculoskeletal abnormalities, thus becoming candidates for SEMLS [4,21].

One of the most significant findings of this study was the improvement in gait pattern. Preoperatively, nearly half of the participants exhibited a jump gait, followed by hemiplegic and crouch gaits. At final follow-up, no pathological gait patterns remained, with 71.21% achieving a near-normal gait and 28.79% reaching normal gait. These results reflect the high efficacy of SEMLS in restoring functional biomechanics by correcting soft tissue contractures and bony malalignments. Similar outcomes have been reported in prior studies where SEMLS significantly improved spatiotemporal gait parameters and reduced energy expenditure during walking [9,13,22].

The Gross Motor Function Classification System (GMFCS) levels also improved markedly. Initially, only 9.09% of children were classified as level I, compared to 59.09% at final follow-up. This shift indicates a strong functional gain in ambulatory status. These improvements are in line with findings from Thomason et al., who noted a significant increase in GMFM-66 scores following SEMLS, with changes becoming more pronounced at 12 to 24 months postoperatively [14,23].

Range of motion (ROM) assessment showed statistically significant gains in key functional joints. Notably, hip flexion and abduction improved substantially, as did knee flexion and the popliteal angle, all with P-values <0.001. These changes not only reflect surgical correction but also suggest effective rehabilitation and neuromuscular reconditioning. Prior studies by Saraph et al. and Rodda et al. reported similar improvements in hip and knee kinematics following SEMLS [16,24].

Interestingly, although ankle dorsiflexion showed improvement, the change in plantar flexion was not statistically significant (P = 0.412). This could be attributed to the varying degree of involvement in the gastrocnemius-soleus complex and the individualized approach in addressing foot and ankle deformities. Graham et al. noted that while ankle surgeries in CP often yield improvements in dynamic dorsiflexion during gait, static plantar flexion may remain unchanged unless accompanied by specific foot deformities requiring correction [8,25].

The extent of surgical intervention in our cohort was substantial, with most children undergoing procedures at 5–6 anatomical levels. The mean of 5.68 ± 1.75 levels reflects the complexity of musculoskeletal pathology in spastic CP. Multi-level involvement is common in diplegic and hemiplegic patients and has been emphasized in earlier studies as a core indication for SEMLS to restore mechanical alignment across the kinetic chain [7,10,11].

Complication rates in the current study were low, with 87.88% of children experiencing no postoperative issues. Minor complications, such as plaster sores and superficial wound infections, were noted in a small proportion. These findings are consistent with prior literature that documents SEMLS as a safe procedure when performed in specialized centers with appropriate perioperative care [12,26]. Aiona and Sussman also noted that with proper patient selection and postoperative management, the risk of major complications is minimal [18].

An important strength of this study is the structured follow-up and objective evaluation using GMFCS levels, ROM metrics, and gait pattern analysis. Such comprehensive assessments align with best practices advocated by Gage and Schwartz, who emphasized the importance of combining clinical, functional, and instrumented gait outcomes in CP surgical research [5,11].

However, the study is not without limitations. First, the absence of three-dimensional gait analysis (3DGA) limits the biomechanical specificity of gait improvements. 3DGA has been shown to provide deeper insights into gait deviations and post-surgical outcomes, particularly in complex CP cases [13,27]. Second, long-term durability beyond the immediate follow-up period remains unaddressed. Although many studies confirm short- and mid-term benefits of SEMLS, a subset of patients may develop recurrent or compensatory deformities over time [12,28].

Despite these limitations, the findings provide strong evidence that SEMLS is an effective surgical strategy for improving mobility and function in children with spastic CP involving the lower limbs. The observed improvements in gait, gross motor ability, and joint mobility are in line with global literature and underscore the value of SEMLS in orthopedic management of cerebral palsy.

CONCLUSION

This study demonstrates that Single-Event Multilevel Surgery (SEMLS) is an effective surgical approach for improving gait patterns, gross motor function, and joint range of motion in children with spastic cerebral palsy involving the lower limbs. The majority of patients transitioned from pathological to near-normal or normal gait, with marked improvement in GMFCS levels and statistically significant gains in joint mobility—particularly at the hip and knee.

The low complication rate further supports the safety profile of SEMLS when conducted in a structured, multidisciplinary setting. These findings align with previous literature and reinforce the role of SEMLS as the standard of care for correcting multilevel musculoskeletal deformities in ambulant children with spastic CP.

REFERENCES

1. Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl. 2007;109:8–14.
2. Oskoui M, Coutinho F, Dykeman J, et al. An update on the prevalence of cerebral palsy: a systematic review and meta-analysis. Dev Med Child Neurol. 2013;55(6):509–19.
3. Damiano DL, Abel MF. Functional outcomes of strength training in spastic cerebral palsy. Arch Phys Med Rehabil. 1998;79(2):119–25.
4. Gage JR. Gait analysis in cerebral palsy. London: Mac Keith Press; 1991.
5. Dobson F, Boyd RN, Parrott J, Nattrass GR, Graham HK. The impact of surgical intervention on the quality of life of children with cerebral palsy and their caregivers. J PediatrOrthop. 2002;22(3):329–33.
6. Gough M, Shortland AP. Could muscle deformity in children with spastic cerebral palsy be related to an impairment of muscle growth and muscle stem cells? Dev Med Child Neurol. 2012;54(6):495–9.
7. Thomason P, Selber P, Graham HK. Single event multilevel surgery in children with bilateral spastic cerebral palsy: a 5-year prospective cohort study. Gait Posture. 2011;33(1):23–8.
8. Graham HK, Selber P. Musculoskeletal aspects of cerebral palsy. J Bone Joint Surg Br. 2003;85(2):157–66.
9. Norlin R, Tkaczuk H. One-session surgery for correction of lower extremity deformities in cerebral palsy. J PediatrOrthop. 1985;5(2):208–11.
10. Browne D, McManus F. Single-stage multilevel soft-tissue surgery in spastic diplegia: a report of 65 cases. ClinOrthopRelat Res. 1987;(223):181–6.
11. Gage JR, Schwartz MH, Koop SE, Novacheck TF. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009.
12. Rodda JM, Graham HK. Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm. Eur J Neurol. 2001;8Suppl 5:98–108.
13. Nene AV, Evans GA, Patrick JH. Simultaneous multiple operations for spastic diplegia: outcome and functional assessment of walking in 18 patients. J Bone Joint Surg Br. 1993;75(3):488–94.
14. Thomason P, Baker R, Dodd K, et al. Single event multilevel surgery in children with spastic diplegia: a pilot randomized controlled trial. J Bone Joint Surg Am. 2011;93(5):451–60.
15. Gough M, Eve LC, Robinson RO, Shortland AP. Short-term outcome of multilevel surgical intervention in spastic diplegic cerebral palsy compared with the natural history. Dev Med Child Neurol. 2004;46(2):91–7.
16. Saraph V, Zwick EB, Zwick G, Steinwender G, Linhart WE. Multilevel surgery in spastic diplegia: evaluation by physical examination and gait analysis in 49 patients. J PediatrOrthop. 2002;22(2):150–7.
17. Shore BJ, White N, Kerr Graham H. Surgical correction of deformities in children with cerebral palsy: a comparative study. Bone Joint J. 2012;94-B(3):364–70.
18. Aiona MD, Sussman MD. Treatment of spastic diplegia in cerebral palsy. J PediatrOrthop B. 2004;13(Suppl 1):S1–12.
19. Novacheck TF. Gait and function in cerebral palsy. CurrOpinOrthop. 2003;14:468–76.
20. Yeargin-Allsopp M, van Naarden Braun K, Doernberg NS, Benedict RE, Kirby RS, Durkin MS. Prevalence of cerebral palsy in 8-year-old children in three areas of the United States in 2002: a multisite collaboration. Pediatrics. 2008;121(3):547–54.
21. Graham HK. Classifications and prognosis in cerebral palsy. OrthopClin North Am. 2010;41(4):457–67.
22. Rutz E, Brunner R. Management of equinus in cerebral palsy. Orthopade. 2010;39(9):837–46.
23. Thomason P, Baker R, Dodd KJ, Graham HK. Randomized controlled trial of botulinum toxin A in children with cerebral palsy undergoing multilevel surgery. J Child Orthop. 2009;3(3):153–61.
24. Saraph V, Zwick EB, Uitz C, Schneider F, Steinwender G. Multilevel surgery in spastic diplegia: functional and kinematic improvement. J PediatrOrthop B. 2005;14(2):85–91.
25. Graham HK, Selber P, Musculoskeletal aspects of cerebral palsy. J Bone Joint Surg Br. 2003;85(2):157–66.
26. Shore BJ, White N, Kerr Graham H. Surgical correction of deformities in children with cerebral palsy: a comparative study. Bone Joint J. 2012;94-B(3):364–70.
27. Gage JR, Schwartz MH, Koop SE, Novacheck TF. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009.
28. Dobson F, Morris ME, Baker R, Graham HK. Unilateral versus bilateral multilevel surgery for spastic diplegia in cerebral palsy: a randomized trial. Dev Med Child Neurol. 2007;49(1):29–33.