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Outcome of single event multi-level surgery in the treatment of spastic cerebral palsy involving lower limbs

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ABSTRACT

Background: Spastic cerebral palsy (CP) is a leading cause of childhood physical disability, characterized by muscle stiffness and movement limitations, primarily affecting the lower limbs. Single Event Multi-Level Surgery (SEMLS) is considered a gold-standard surgical intervention for managing musculoskeletal deformities associated with spastic CP. However, limited data exist on the effectiveness of SEMLS in low- and middle-income countries (LMICs) like Bangladesh. This study aimed to evaluate the outcomes of SEMLS in children with spastic cerebral palsy involving the lower limbs, focusing on improvements in gait patterns, gross motor function, range of motion (ROM) and postoperative complications.

Methods: A quasi-experimental study was conducted at the National Institute of Traumatology and Orthopedics Rehabilitation (NITOR), Dhaka, Bangladesh, from September 2021 to March 2024. A total of 36 children aged 7–16 years with spastic hemiplegic or diplegic CP underwent SEMLS. Outcomes were assessed using gait analysis, GMFCS levels, ROM measurements and complication rates.

Results: Postoperative outcomes demonstrated significant improvements in gait, with 72.22% achieving near-normal gait and 27.78% attaining normal gait. A substantial shift was observed in GMFCS levels, with 63.89% of participants improving to level I. Statistically significant improvements were also recorded in hip, knee and ankle ROM ($p<0.001$), with minimal postoperative complications observed.

Conclusions: SEMLS is an effective surgical intervention for improving mobility, joint function and overall quality of life in children with spastic cerebral palsy, particularly in resource-constrained settings.

Keywords: Bangladesh, Gross motor function classification system, Gait improvement, Postoperative complications, Range of motion, Spastic cerebral palsy, Single event multi-level surgery

INTRODUCTION

Cerebral palsy (CP) is a non-progressive neurological disorder resulting from injury or malformation of the developing brain, primarily affecting motor function, posture and coordination.[1] It is considered the most common cause of childhood physical disability worldwide, with an estimated global prevalence ranging between 2 to 3 per 1,000 live births.[2] The burden of CP is disproportionately higher in low- and middle-income countries (LMICs), where more than 98% of children with CP reside. In countries like Bangladesh, the challenges are even more pronounced due to limited access to early intervention and specialized care. Studies reveal that CP is significantly underdiagnosed and undertreated in rural Bangladesh, with many children presenting late due to lack of awareness, financial hardship and inadequate rehabilitation infrastructure.[1]

In Bangladesh, the Bangladesh cerebral palsy register (BCPR) has highlighted alarming statistics regarding the prevalence and socio-economic impact of CP, particularly in rural settings. According to Solaiman et al, perinatal asphyxia was identified as the leading cause of CP,

accounting for approximately 78.4% of cases, with spastic quadriplegia being the most prevalent subtype, affecting a majority of children from low-income backgrounds.[3] This disproportionate burden is exacerbated by limited access to rehabilitation services; nearly 49.8% of children with CP in Bangladesh have never received any formal rehabilitation.[1]

The economic, social and psychological effects of CP are profound, imposing a heavy financial burden on families and significantly reducing caregivers' quality of life.[4] This is especially true in LMICs, where healthcare resources are often scarce and rehabilitation services are underutilized due to socioeconomic constraints.[5]

Among the various subtypes of cerebral palsy, spastic CP is the most common, accounting for nearly 70-80% of all cases globally.[6] This form of CP primarily manifests as increased muscle tone, leading to stiffness and restricted movement, especially in the lower limbs.[7] Spastic diplegia and quadriplegia often result in significant functional limitations, including impaired walking ability, joint contractures and skeletal deformities.[8]

These motor impairments contribute to abnormal gait patterns, such as crouch gait, jump gait and stiff knee gait, which substantially affect mobility and independence.[9] The limitations posed by spasticity and associated musculoskeletal abnormalities severely compromise the quality of life and participation in daily activities, highlighting the need for effective interventions.[10] Current treatment modalities for managing spastic CP are broadly categorized into non-surgical and surgical interventions.

Non-surgical strategies aim to improve muscle function and reduce spasticity through physical therapy, orthotic devices and pharmacological interventions.[11] Pharmacological treatments, such as oral baclofen, diazepam and botulinum toxin injections, have shown considerable efficacy in reducing localized spasticity and improving motor function.[12,13]

However, while these treatments can offer temporary relief, they often fail to address the underlying musculoskeletal deformities that contribute to long-term functional impairment. Surgical intervention, particularly Single Event Multi-Level Surgery (SEMLS), has emerged as the gold-standard surgical approach for correcting musculoskeletal deformities associated with spastic CP.[14]

SEMLS involves performing multiple orthopedic procedures such as soft tissue releases, tendon lengthening and bony corrections during a single operative session to address various deformities simultaneously.[15] The primary objectives of SEMLS are to correct musculoskeletal deformities, improve gait mechanics and minimize the frequency of surgical interventions and postoperative rehabilitation periods.[16] Studies have shown that SEMLS can lead to significant improvements in gait parameters, joint alignment and functional mobility, particularly in children with spastic diplegia and quadriplegia.[17] A systematic review by Lamberts et al, further supports SEMLS as an effective intervention, demonstrating marked improvements in ankle dorsiflexion, knee extension and hip rotation.[18] Despite the growing global acceptance of SEMLS, there is a critical lack of data regarding its outcomes in LMICs such as Bangladesh.

Factors such as limited access to specialized surgical care, variability in postoperative rehabilitation services and socioeconomic disparities can significantly influence treatment outcomes.[1] In rural Bangladesh, economic hardship often limits access to consistent postoperative care, which is essential for achieving optimal functional outcomes following SEMLS.

Moreover, studies have highlighted that poverty and lack of parental education further exacerbate challenges in accessing rehabilitation services, delaying critical interventions for children with CP.[19] Given this context, the present study aims to assess the outcomes of single event multi-level surgery (SEMLS) in improving functional mobility, reducing spasticity and enhancing the quality of life among children with spastic cerebral palsy involving the lower limbs in Bangladesh.

By addressing this critical gap in the literature, the study seeks to inform clinical practice, guide policy formulation and contribute to the development of sustainable rehabilitation frameworks in LMICs. Ultimately, this research could provide valuable insights into optimizing surgical outcomes and improving the quality of life for children with spastic CP in resource-limited settings.

METHODS

Study place

This quasi-experimental study was conducted at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), located in Sher-e-Bangla Nagar, Dhaka, Bangladesh.

Study duration

The study was conducted over a period from September 2021 to March 2024.

The study population consisted of children diagnosed with spastic cerebral palsy (CP) involving the lower limbs. A total of 36 participants were selected using a purposive sampling method, based on patient availability and strict adherence to the inclusion and exclusion criteria.

Inclusion criteria

The inclusion criteria for participant selection were children diagnosed with spastic hemi- or diplegic cerebral palsy affecting the lower limbs, patients presenting with musculoskeletal abnormalities at multiple levels, those

who were ambulatory and classified within Gross Motor Function Classification System (GMFCS) levels I to III and children aged 7 to 16 years.

Exclusion criteria

The exclusion criteria included children with CP accompanied by other anomalies or comorbid conditions, patients who had received botulinum toxin injections within six months prior to surgery and those who had undergone any form of orthopedic lower limb surgery within the preceding twelve months.

Ethical approval

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of NITOR, Dhaka, Bangladesh. The study was conducted in compliance with the ethical principles outlined in the Helsinki Declaration of 1964 and its subsequent amendments regarding medical research involving human subjects.

All participants and their legal guardians were thoroughly informed about the study design, its objectives, the voluntary nature of participation and their right to withdraw from the study at any point without repercussions. Detailed information was provided regarding the surgical procedures, expected outcomes, potential benefits, disadvantages and possible complications. Only individuals who provided informed written consent were enrolled in the study.

RESULTS

The baseline characteristics of the 36 participants enrolled in the study are presented in Table 1. The mean age of the participants was 10.53 years with a standard deviation of±2.569. A majority of the participants (47.22%) were aged between 10 and 13 years, followed by 38.89% in the 7 to 9 years age group and 13.89% were between 14 and 16 years. In terms of gender distribution, there was a higher representation of males, with 21 participants (58.33%), compared to 15 females (41.67%). Regarding the type of cerebral palsy diagnosis, most participants were diagnosed with diplegic CP, accounting for 66.67% (n=24), while the remaining 33.33% (n=12) were diagnosed with hemiplegic CP.

The distribution of participants according to their gait patterns before surgery and at the final follow-up is presented in Table 2. Preoperatively, the majority of participants exhibited abnormal gait patterns, with 20 participants (55.56%) demonstrating a jump gait, followed by 12 participants (33.33%) with a hemiplegic gait and 4 participants (11.11%) showing a crouch gait. Notably, none of the participants exhibited a normal or near-normal gait before surgery.

At the final follow-up, there was a significant improvement in gait patterns across all participants. All cases of hemiplegic, jump and crouch gaits were fully corrected, with none of these patterns observed postoperatively. Among the participants, 10 individuals (27.78%) achieved a normal gait, while the remaining 26 participants (72.22%) exhibited a near-normal gait.

Table 1: Baseline characteristics distribution among the participants (n=36).

Baseline characteristics	Frequency (N)	%
Age (in years)		
7-9	14	38.89
10-13	17	47.22
14-16	5	13.89
Mean±SD	10.53±2.569	
Gender		
Male	21	58.33
Female	15	41.67
Diagnosis		
Hemiplegic CP	12	33.33
Diplegic CP	24	66.67

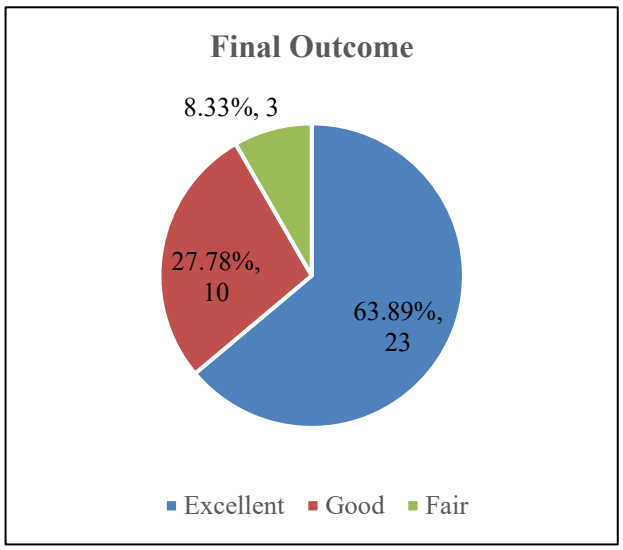

Figure 1: Distribution of cases by final outcome (n=36).

The changes in gross motor function among participants, as classified by the Gross Motor Function Classification System (GMFCS), are summarized in Table 3. Prior to the intervention, the majority of participants were classified at higher levels of motor impairment, with 21 participants (58.33%) categorized as GMFCS level II, indicating moderate motor function limitations.

Additionally, 12 participants (33.33%) were at level III, reflecting more severe motor impairment, while only 3 participants (8.33%) demonstrated minimal motor limitations, falling within GMFCS level I. At the final follow-up, significant improvements were observed in gross motor function. The number of participants classified as GMFCS level I increased markedly to 23

(63.89%), suggesting a substantial gain in functional mobility and independence. The proportion of participants in level II decreased to 8 (22.22%) and those in level III dropped to 5 (13.89%).

Table 2: Distribution of cases by gait pattern preoperatively and at final follow up (n=36).

Gait pattern	Preoperatively		At final follow up	
	Frequency (N)	%	Frequency (N)	%
Hemiplegic	12	33.33	0	0.00
Jump	20	55.56	0	0.00
Crouch	4	11.11	0	0.00
Normal	0	0.00	10	27.78
Near normal	0	0.00	26	72.22

Table 3: Distribution of cases by improvement of gross motor function (n=36).

GMFCS	Preoperatively		At final follow up	
	Frequency (N)	%	Frequency (N)	%
I	3	8.33	23	63.89
II	21	58.33	8	22.22
III	12	33.33	5	13.89

Table 4: Distribution of cases by ROM of hip, knee and ankle (n=36).

ROM location	Preoperatively	At final follow up	P value
ROM of Hip			
Fixed flexion deformity	20.83±11.116	2.78±4.992	<0.001[a]
Further flexion	115.56±13.978	123.89±10.427	<0. 001[b]
Abduction	23.61±3.893	37.08±4.982	<0. 001[b]
ROM of Knee			
Popliteal angle	52.39±6.720	5.14±7.698	<0.001[a]
Flexion	114.17±11.307	122.78±8.819	<0.001[b]
ROM of Ankle			
Dorsiflexion	12.08±7.307	8.06±4.822	<0.001[a]
Planter flexion	33.06±5.767	35.28±5.969	0.420[b]

p value calculated by a—Wilcoxon signed-ranks test, b—paired sample t-test, ROM, range of motion

Table 5: Distribution of study patients by number of levels of surgical release (n=36).

Number of levels of surgical release	Frequency (N)	%
2-4	10	27.78
5-6	18	50.00
7-8	8	22.22
Mean±SD	5.39±1.64	

Table 6: Distribution of cases by complication (n=36).

Complication	Frequency (N)	%
None	33	91.67
Plaster sore	1	2.78
Superficial wound infection	2	5.56

Statistically significant improvements were observed in multiple ROM parameters across all three joints. For the hip joint, there was a significant reduction in fixed flexion deformity, with the mean angle decreasing from 20.83°±11.116 preoperatively to 2.78°±4.992 at the final follow-up ($p<0.001$). Additionally, there was a notable increase in the further flexion capacity, which improved from 115.56°±13.978 to 123.89°±10.427 ($p<0.001$).

Hip abduction also showed a significant improvement, increasing from 23.61°±3.893 preoperatively to 37.08°±4.982 postoperatively ($p<0.001$), indicating better

lateral movement and flexibility. In the knee joint, the popliteal angle showed substantial improvement, with values decreasing from 52.39°±6.720 preoperatively to 5.14°±7.698 at the final follow-up ($p<0.001$), reflecting a significant reduction in knee contractures.

Furthermore, knee flexion improved from 114.17°±11.307 to 122.78°±8.819 ($p<0.001$), suggesting better bending capability post-surgery. For the ankle joint, a significant reduction in dorsiflexion limitation was noted, with an improvement from 12.08°±7.307 preoperatively to 8.06°±4.822 at follow-up ($p<0.001$). However, the change in plantar flexion was not statistically significant, showing a slight increase from 33.06°±5.767 to 35.28°±5.969 ($p=0.420$).

The mean number of surgical release levels was 5.39±1.64. The majority of participants, 18 out of 36 (50.00%), underwent surgical releases at 5 to 6 levels.

Additionally, 10 participants (27.78%) had surgical releases at 2 to 4 levels, while 8 participants (22.22%) required more extensive intervention, with releases performed at 7 to 8 levels.

The distribution of postoperative complications among the study participants is shown in Table 6. The vast majority of participants, 33 out of 36 (91.67%), experienced no complications following surgery, indicating a high level of procedural safety. Minor complications were observed in a small proportion of cases 1 participant (2.78%) developed a plaster sore, while 2 participants (5.56%) experienced a superficial wound infection.

The majority of patients, 23 out of 36 (63.89%), achieved an excellent outcome, indicating significant functional improvements and successful surgical results.

Additionally, 10 participants (27.78%) experienced a good outcome, reflecting notable but less pronounced improvements. A smaller proportion of participants, 3 out of 36 (8.33%), demonstrated a fair outcome, suggesting modest improvements with some residual functional limitations.

DISCUSSION

This study aimed to evaluate the outcomes of Single Event Multi-Level Surgery (SEMLS) in children with spastic cerebral palsy (CP) involving the lower limbs, focusing on improvements in gait patterns, gross motor function, range of motion (ROM) and postoperative complications. The findings of this study revealed significant improvements across multiple clinical parameters, aligning with and, in some cases, surpassing results from previous studies conducted in various international settings.

The baseline characteristics of the participants in this study showed a mean age of 10.53±2.569 years, with a predominance of male participants (58.33%) and a higher incidence of diplegic CP (66.67%) compared to hemiplegic CP (33.33%). These findings are consistent with previous research, which reported similar demographic distributions.

For example, Suzuki et al, observed a higher prevalence of spastic diplegia among children with CP in Japan, while a study by Viswanath et al, in India also reported a predominance of diplegic CP cases, reinforcing the global trend of higher diplegic CP incidence in children.[20,21] Moreover, similar male predominance has been observed across various studies, highlighting a potential gender-based vulnerability to CP.[22] One of the most significant outcomes in this study was the notable improvement in gait patterns following SEMLS. Preoperatively, abnormal gait patterns such as jump gait (55.56%), hemiplegic gait (33.33%) and crouch gait (11.11%) were prevalent. At the final follow-up, there were no remaining cases of these gait abnormalities, with 72.22% of participants achieving a near-normal gait and 27.78% attaining a normal gait.

This finding corroborates the results from Rutz et al, who demonstrated significant improvements in the Gait Profile Score (GPS) among children with spastic diplegia after SEMLS.[15] Similarly, Thomason et al, reported sustained improvements in gait quality for up to five years postoperatively.[17] Amen et al, also highlighted significant functional and mobility improvements in children with crouch gait following SEMLS, further validating the positive impact of the procedure on lower-limb function.[23]

Improvements in gross motor function were also evident in the current study, as measured by the gross motor function classification system (GMFCS). Before surgery, the majority of participants were classified at GMFCS level II (58.33%) and level III (33.33%), indicating moderate to severe motor impairment. However, postoperatively, 63.89% of participants improved to level I, indicating mild impairment, while those at levels II and III decreased to 22.22% and 13.89%, respectively. This outcome is consistent with findings from Thomason et al, who also observed sustained improvements in GMFCS levels over a five-year period.[17] Hadinoto et al, further supported these results by demonstrating significant mobility improvements across different walking distances using the functional mobility scale (FMS).[24]

The outcomes of the present study suggest that SEMLS is highly effective in enhancing gross motor function, consistent with international findings. In terms of range of motion (ROM), this study observed significant postoperative improvements across the hip, knee and ankle joints. For the hip joint, fixed flexion deformity reduced significantly from 20.83°±11.116 to 2.78°±4.992 ($p<0.001$), while further flexion and abduction also showed statistically significant improvements. Similar findings were reported by Cloodt et al, who noted consistent improvements in hip ROM after surgical interventions.[25]

Knee joint improvements were also remarkable, with the popliteal angle reducing from 52.39°±6.720 to 5.14°±7.698 ($p<0.001$), in line with results from Skoutelis et al, who found significant improvements in knee extension and flexion post-surgery.[26] For the ankle joint, dorsiflexion improved significantly ($p<0.001$), though plantar flexion changes were not statistically significant ($p=0.420$), consistent with findings from Andryanto et al, who also reported more pronounced improvements in dorsiflexion than plantar flexion following SEMLS.[27] The analysis of the number of surgical releases indicated that most participants required interventions at 5-6 levels (50%), with a mean of 5.39±1.64 levels addressed during surgery.

These findings align with those of Buddhdev et al, who noted that a higher number of surgical interventions, typically involving 3-5 procedures per patient, led to substantial improvements in gait and posture.[14] The comparable number of releases in our study suggests that similar surgical extents are effective in managing lower-limb deformities in spastic CP. Postoperative complications were minimal in this study, with 91.67% of participants experiencing no complications. Minor complications included plaster sores (2.78%) and superficial wound infections (5.56%), all of which were managed without long-term consequences. These results are consistent with findings from Schranz et al, who reported low complication rates in unilateral SEMLS procedures.[28]

Similarly, Baldwin et al, found that while complications such as wound infections and fixation failures can occur, they remain relatively uncommon.[29] The final outcome assessment revealed that 63.89% of participants achieved an excellent outcome, 27.78% had a good outcome and 8.33% exhibited a fair outcome. These results are comparable to those of Svehlik et al, who reported significant improvements in the gait deviation index (GDI) over a 10-years follow-up.[30] Similarly, Andryanto et al, found that 25% of patients achieved excellent outcomes and 49% had good outcomes following SEMLS, supporting the high efficacy of this surgical intervention.[27] Overall, the findings of this study are in agreement with existing literature on the positive impact of SEMLS in children with spastic cerebral palsy.

The significant improvements in gait, motor function and ROM observed in this study align with those reported internationally, highlighting SEMLS as an effective surgical intervention for managing musculoskeletal deformities in children with CP. Additionally, the low complication rates observed support the safety and efficacy of the procedure, particularly in resource-limited settings such as Bangladesh. These results underscore the importance of integrating SEMLS into standard clinical practice for managing spastic cerebral palsy and addressing the need for further research focused on long-term outcomes in low- and middle-income countries (LMICs).

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

CONCLUSION

This study highlights the significant benefits of Single Event Multi-Level Surgery (SEMLS) in improving functional outcomes for children with spastic cerebral palsy involving the lower limbs. The findings demonstrated substantial improvements in gait patterns, gross motor function and joint range of motion (ROM), with most participants achieving normal or near-normal gait by the final follow-up. Notably, a considerable number of patients showed marked improvements in their gross motor function classification system (GMFCS) levels, indicating enhanced mobility and independence.

The procedure also proved to be safe, with minimal postoperative complications observed. These outcomes are consistent with international findings, reinforcing the global relevance and effectiveness of SEMLS. Given the resource-limited setting of Bangladesh, these results underscore the importance of incorporating SEMLS into standard treatment protocols for spastic CP. This research contributes valuable data from a low- and middle-income country (LMIC) context, offering insights into optimizing surgical and rehabilitative strategies for improving the quality of life in children with spastic cerebral palsy. Future research should focus on long-term follow-up studies and developing cost-effective rehabilitation programs tailored to the needs of LMICs.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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