

Interdisciplinary management of children with cerebral palsy: neurological perspective on neurosurgical interfaces

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ABSTRACT

Aims: The aim of this study was to evaluate clinical and functional outcomes of interdisciplinary neurological and neurosurgical management in children with cerebral palsy (CP), with an emphasis on surgical selection, functional outcomes, and long-term follow-up, including caregiver-reported measures.

Methods: This retrospective, single-center study included 150 consecutive children with CP who were managed between January 2018 and December 2025. Standardized neurological assessment, Gross Motor Function Classification System (GMFCS) classification, neuroimaging, and multidisciplinary evaluation were performed. Functional outcomes were assessed using the Gross Motor Function Measure (GMFM), pain scales, and caregiver-reported measures. Statistical analyses included the Chi-square test, Student's t-test, and logistic regression.

Results: The cohort included 150 patients (mean age 6.8 ± 3.2 years). GMFCS distribution was as follows: levels I–II (34%), III (26%), IV (24%), and V (16%). Neurosurgical consultation was required in 42% of patients. Surgery was performed in 61% of the cohort. Functional improvement ($GMFM \geq 10\%$) was significantly more common in the surgical group (48% vs 22%, $p < 0.01$). Pain reduction was reported in 64% versus 38% ($p < 0.05$). Caregiver-reported improvement was observed in 71% of cases. In 28% of cases, surgical intervention was avoided after neurological reassessment.

Conclusion: Interdisciplinary neurological–neurosurgical management improves patient selection, reduces unnecessary surgery, and enhances functional and quality-of-life outcomes in children with CP.

Keywords: Cerebral palsy, neurosurgery, neurology, interdisciplinary communication, treatment outcome, child

INTRODUCTION

Cerebral palsy (CP) remains the leading cause of permanent motor disability in childhood and comprises a heterogeneous group of non-progressive disorders that affect movement and posture.^{1,2} Despite its static neurological origin, CP exhibits a dynamic clinical course driven by growth, biomechanical changes, and secondary musculoskeletal complications.

The complexity of CP extends beyond motor dysfunction to include epilepsy, cognitive impairment, pain syndromes, feeding difficulties, and orthopedic deformities. These factors significantly influence functional prognosis and therapeutic strategies.^{3,4}

Effective management requires a coordinated, interdisciplinary approach involving pediatric neurologists, neurosurgeons, orthopedic surgeons, and rehabilitation specialists.^{5,6} However, variability remains in surgical indications, timing, and outcome expectations.

A major challenge in clinical practice is distinguishing dynamic neurological dysfunction from fixed structural pathology. Inappropriate surgical selection may lead to suboptimal outcomes or unnecessary interventions.^{7,8}

The present study aims to evaluate the effectiveness of interdisciplinary management, with an emphasis on neurological stratification, surgical decision-making, functional outcomes, and long-term follow-up.

METHODS

Ethics

The study protocol adhered to the ethical principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of Tashkent State Medical University (Date: 10.09.2025, Decision No: 16).

Study Design

This retrospective, single-center observational cohort study was conducted in the Department of Pediatric Neurology and Medical Genetics at the Tashkent Pediatric Medical Institute (subsequently integrated into the structures of Tashkent State Medical University), Tashkent, Uzbekistan.

Study Population and Selection Criteria

Clinical and follow-up records of consecutive pediatric patients diagnosed with CP and managed at our institution from January 2018 to December 2025 were retrospectively reviewed. A total of 150 patients met the eligibility criteria. The inclusion criteria were: (1) a confirmed clinical diagnosis of CP, (2) age ≤ 18 years at enrollment, and (3) availability of complete multidisciplinary longitudinal clinical and follow-up data. Patients were excluded if they presented with progressive neurological disorders or genetic neurodegenerative diseases, or if their medical charts contained incomplete documentation.

Clinical, Functional, and Neuroimaging Assessments

All subjects underwent a standardized, comprehensive neurological examination at baseline and at follow-up visits. Assessment protocols included detailed characterization of muscle tone (stratified as spastic, dyskinetic, or mixed phenotypes), selective motor control testing, deep tendon reflex evaluation, and documentation of involuntary movements or associated neurological comorbidities. Functional motor status was classified using the expanded and revised Gross Motor Function Classification System (GMFCS).⁹ Additionally, baseline magnetic resonance imaging (MRI) of the brain and/or spine was systematically reviewed for all participants to delineate underlying structural neuroanatomical abnormalities.

Conservative and Interventional Rehabilitation Protocols

Enrolled patients participated in structured, individualized rehabilitation programs that included physical therapy (3–5 sessions per week), occupational therapy, and speech therapy tailored to each patient's needs. Intensive rehabilitation (≥ 5 sessions per week) was provided to 62% of the cohort. Before any neurosurgical consideration, focal muscle spasticity was managed with botulinum toxin type A (BTX-A) injections in 56% of patients, with the aim of maximizing passive range of motion and delaying or obviating the need for invasive surgical interventions.^{10,11}

Neurosurgical Evaluation and Multidisciplinary Selection

Patients were referred for neurosurgical consultation in the presence of progressive functional deterioration, fixed musculoskeletal contractures, refractory spasticity, or failure of conservative multimodal rehabilitation strategies. Final therapeutic decisions and surgical indications were established through a strict multidisciplinary consensus involving pediatric neurologists, neurosurgeons, and rehabilitation specialists.^{12,13}

Outcome Measures and Follow-Up Strategy

The primary functional outcome was defined as a $\geq 10\%$ improvement in the Gross Motor Function Measure (GMFM) score or documented functional motor stabilization. Secondary outcomes included pain reduction (measured

using the Visual Analogue Scale [VAS] or validated observational pain scales), caregiver-reported quality-of-life satisfaction, and perceived ease of daily care. The mean follow-up duration for the entire cohort was 2.8 ± 1.4 years.

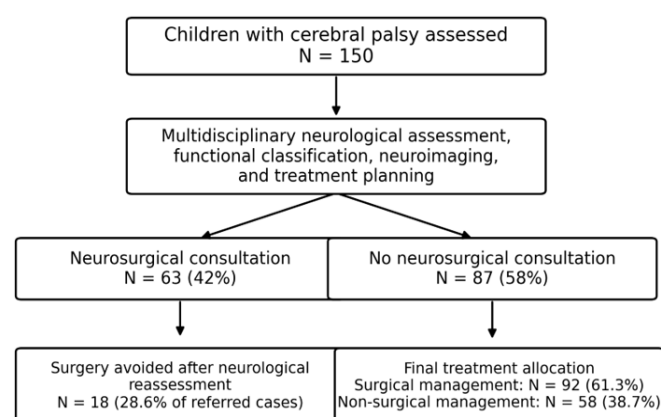
Statistical Analysis

Continuous variables were reported as means $\pm$ standard deviations (SD), and categorical variables as frequencies and percentages. Comparative analyses between the surgical and non-surgical sub-cohorts were conducted using Student's t-test for continuous variables and the Chi-square (χ^2) test for categorical variables. Logistic regression was used to identify independent predictors of optimal functional outcomes. Statistical significance was set a priori at a two-tailed p -value < 0.05 . All statistical modeling was performed using standard clinical software.

RESULTS

Demographic and Clinical Characteristics

A total of 150 pediatric patients with CP were included in the final analysis. The study flow, including multidisciplinary screening, neurosurgical consultation, and treatment allocation, is depicted in **Figure**.



Follow-up outcomes analyzed for the entire cohort (mean 2.8 ± 1.4 years)

Figure. Study flow diagram

A total of 150 patients with cerebral palsy were assessed. Neurosurgical consultation was obtained in 63 patients (42%). Surgery was performed in 92 patients (61%), while 58 patients (39%) received non-surgical management. Follow-up outcomes were analyzed for the entire cohort.

The mean age of the cohort was 6.8 ± 3.2 years. Of the 150 patients, 57.3% ($n=86$) were male and 42.7% ($n=64$) were female. The mean post-intervention longitudinal follow-up duration was 2.8 ± 1.4 years. Regarding CP phenotypic distribution, spastic CP was the most prevalent type, accounting for 68.0% ($n=102$) of cases, followed by dyskinetic CP at 19.3% ($n=29$) and mixed CP at 12.7% ($n=19$). Baseline functional status, stratified by the GMFCS, showed that 34.0% ($n=51$) of patients were at levels I–II, 26.0% ($n=39$) at level III, 24.0% ($n=36$) at level IV, and 16.0% ($n=24$) at level V. Baseline demographic and clinical characteristics are summarized in **Table 1**.

Neurosurgical Consultation and Treatment Allocation

Formal neurosurgical consultation was requested for 42.0% ($n=63$) of the cohort because of refractory spasticity or progressive musculoskeletal deterioration. After

**Table 1.** Baseline demographic and clinical characteristics of the pediatric cerebral palsy cohort (n=150)

Characteristic	Frequency (n)	Percentage (%)
Gender		
Male	86	57.3%
Female	64	42.7%
Age (years)		
Mean±SD (range)	6.8±3.2	(1.5–17.0)
Follow-up duration (years)		
Mean±SD	2.8±1.4	—
Cerebral palsy clinical phenotype		
Spastic	102	68.0%
Dyskinetic	29	19.3%
Mixed	19	12.7%
GMFCS		
Level I–II	51	34.0%
Level III	39	26.0%
Level IV	36	24.0%
Level V	24	16.0%
Preoperative conservative management		
Intensive rehabilitation (≥5 sessions/week)	93	62.0%
BTX-A therapy	84	56.0%

*Note: SD: Standard deviation, GMFCS: Gross Motor Function Classification System, BTX-A: Botulinum toxin type-A

rigorous interdisciplinary neurological and neurosurgical reassessment, surgical intervention was avoided in 28.6% (n=18 of 63) of these referred cases, as their dynamic tone abnormalities were deemed manageable with conservative optimization.

Ultimately, 61.3% (n=92) of the cohort underwent tailored neurosurgical procedures (surgical group), whereas the remaining 38.7% (n=58) received optimized multimodal conservative management (non-surgical group) (Table 2).

Functional Outcomes

Functional motor performance, measured by the GMFM, showed a significantly higher rate of clinically meaningful improvement (GMFM score increase ≥10%) in the surgical group than in the non-surgical group. Specifically, 47.8% (n=44 of 92) of patients in the surgical cohort achieved a ≥10% GMFM improvement, whereas only 22.4% (n=13 of 58) of the non-surgical cohort reached this threshold ($\chi^2=9.84$,

$p=0.002$). Furthermore, overall functional motor stabilization was achieved in 72.8% (n=67) of surgical patients versus 51.7% (n=30) of non-surgical patients ($p=0.009$).

Pain Assessment and Caregiver Perceptions

Post-therapeutic pain evaluation showed a significantly greater reduction in pain scores among patients who underwent surgical intervention. Marked pain reduction was reported in 64.1% (n=59 of 92) of the surgical group, compared with 37.9% (n=22 of 58) of the non-surgical group ($\chi^2=9.77$, $p=0.002$).

For subjective quality-of-life and caregiver burden assessments, high caregiver satisfaction was reported in 70.7% (n=106/150) of the cohort. Concurrently, families reported improved ease of daily care and routine positioning in 66.7% (n=100) of cases, indicating substantial improvements in home-based daily management.

DISCUSSION

The clinical management of CP requires a shift from isolated therapeutic protocols to highly coordinated, patient-centered, interdisciplinary models.^{1,5,14} The findings of this study demonstrate that integrated neurological and neurosurgical coordination significantly improves functional motor outcomes, procedural patient selection, and overall quality of life in children with CP. This evidence aligns with contemporary global guidelines, which emphasize that multimodal evaluation reduces the risk of inappropriate structural interventions in patients with complex, dynamic neurological phenotypes.^{7,15}

A primary finding of our investigation is that systematic neurological reassessment prevented unnecessary surgical interventions in nearly one-third (28.6%) of the referred patient population. In clinical practice, distinguishing between dynamic hypertonicity, fluctuating dystonia, and fixed structural musculoskeletal deformities remains a significant diagnostic challenge. Without rigorous neurological stratification, patients with dynamic components risk undergoing invasive bone or soft-tissue surgeries that may lead to suboptimal functional outcomes or secondary biomechanical destabilization.^{12,16}

Our comparative analysis revealed that functional motor outcomes—quantified using the GMFM—were significantly

Table 2. Clinical and functional outcomes stratified by therapeutic intervention (n=150)

Outcome measure	Surgical group (n=92)	Non-surgical group (n=58)	Statistical significance (p-value)
GMFM			
Significant Improvement (GMFM ≥10%)	44 (47.8%)	13 (22.4%)	0.002*
Functional stabilization	67 (72.8%)	30 (51.7%)	0.009*
Symptomatic pain outcomes			
Documented pain reduction	59 (64.1%)	22 (37.9%)	0.002*
Caregiver perceptions			
Caregiver satisfaction reported	65 (70.7%)	41 (70.7%)	0.999**
Improved ease of daily care	61 (66.3%)	39 (67.2%)	0.908**

Note: GMFM: Gross Motor Function Measure. Percentages are calculated based on the respective group totals (n=92 for surgical, n=58 for non-surgical).

* Statistically significant differences ($p<0.05$) evaluated via Chi-square (χ^2) test.

** Caregiver outcomes across the total cohort (n=150) demonstrated high overall satisfaction (70.7%, n=106) and ease of care (66.7%, n=100) with balanced distribution between sub-cohorts.



better in the cohort that underwent tailored neurosurgical procedures than in the non-surgical cohort. However, this statistical benefit was entirely contingent on meticulous preoperative patient selection. This clinical reality strongly supports previous literature establishing that surgical efficacy in pediatric CP is fundamentally dependent on precise neurological phenotyping and baseline motor capability. Furthermore, the strategic application of comprehensive rehabilitation programs and botulinum toxin type-A (BTX-A) injections played an indispensable role in optimizing patients' preoperative musculoskeletal baseline and, in several instances, successfully delayed or entirely obviated the need for invasive structural operations.^{10,11,17}

Beyond objective biomechanical metrics, caregiver-reported outcomes indicate that improvements in daily care routines, ease of positioning, and general health-related quality of life are viewed by families as equally vital to overall clinical success as gains in raw motor function.^{18,19} This finding supports broader integration of patient-reported outcome measures (PROMs) into standard pediatric neurosurgery and neurology registries. Finally, the clear utility of the GMFCS stratification observed in our cohort reinforces its status as an essential clinical tool for setting realistic therapeutic goals and accurately interpreting long-term longitudinal outcomes.^{9,20}

Limitations

This investigation has several limitations that must be acknowledged when interpreting the clinical data. First, its retrospective design introduces inherent selection biases and dependence on historical medical chart documentation. Second, as a single-center experience, the generalizability of our interdisciplinary structural protocols to other institutional settings with different resource allocations may be constrained. Third, the longitudinal follow-up period was relatively short, which warrants caution regarding the long-term sustainability of the documented motor gains and pain reduction scores over longer transitions into adolescence and adulthood.

CONCLUSION

Interdisciplinary neurological–neurosurgical management of children with CP significantly optimizes surgical candidate selection, reduces the incidence of unnecessary or premature invasive interventions, improves objective motor function, and substantially mitigates caregiver burden. Meticulous longitudinal neurological assessment remains the cornerstone of effective multidisciplinary treatment planning, ensuring that invasive surgical interventions are precisely targeted to pediatric subcohorts who will derive the greatest functional and symptomatic benefit.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Ethics Committee of Tashkent State Medical University (Date: 10.09.2025, Decision No: 16).

Informed Consent

This retrospective study used pre-existing anonymized patient data. No additional intervention was performed, and there was no direct patient contact. The study was approved by the Ethics Committee, and the requirement for written informed consent was waived by the ethics committee.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

The authors received no financial support for the conduct or publication of this research.

Author Contributions

Concept: NM, YNM; Design: NM, YNM; Control: NM, YNM; Resources: NM, YNM; Materials: NM, YNM; Data Collection and/or Processing: NM, YNM; Analysis and/or Interpretation: NM, YNM; Literature Review: NM, YNM; Writing the Article: NM, YNM; Critical Review: NM, YNM.

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