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Burden and System-wise Distribution of Multisystem Post-Stroke Complications in an Ambispective Cohort

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Abstract
Background: Post-stroke complications are common and contribute to delayed recovery and long-term disability. However, the cumulative burden of multisystem complications and their relationship with functional outcomes remain insufficiently characterized. Objective: To evaluate the prevalence, system-wise distribution, and functional impact of multisystem post-stroke complications in an ambispective cohort. Methods: An ambispective observational study was conducted in a tertiary care center, integrating six years of retrospective data with six months of prospective follow-up. A total of 350 stroke patients were included. Complications (n = 1,676) were classified across twelve organ systems. Functional outcomes were assessed using changes in the Barthel Index (BI). Multivariable regression, correlation, and subgroup analyses were performed. Results: CNS-related complications were most frequent (40.0%), followed by pain-related (14.9%) and gastrointestinal (11.6%) complications. Mean BI scores improved significantly (67.5 to 73.5; $p < 0.001$), with 82.9% of patients showing functional improvement. Multivariable analysis did not identify independent predictors of recovery, and no correlation was observed between complication burden and BI change. Subgroup analyses showed consistent improvement across patient categories. Conclusion: Multisystem complications are highly prevalent after stroke but were not independently associated with functional recovery. Recovery appears to be influenced by multifactorial determinants, highlighting the importance of sustained multidisciplinary management.

Keywords: Stroke complications; Barthel Index; Multisystem morbidity; Functional recovery; Neurorehabilitation.

1. Introduction

Stroke remains one of the leading causes of long-term disability and mortality worldwide, with a substantial socioeconomic and healthcare burden [1] [2] [3]. Although advances in acute stroke management have improved survival rates, many survivors experience a wide spectrum of post-stroke complications that significantly influence rehabilitation trajectories, quality of life, and long-term functional independence [4] [5]. These complications extend beyond primary neurological deficits and involve multiple organ systems, including cardiovascular, respiratory, gastrointestinal, urinary, musculoskeletal, emotional, and general systemic domains [6] [7].

Post-stroke complications arise from complex pathophysiological mechanisms such as neuroinflammation, autonomic dysregulation, immobility, metabolic alterations, and stroke-induced immunosuppression [8] [9] [10]. Central nervous system (CNS)–related sequelae such as motor deficits, seizures, cognitive dysfunction, sleep disturbances, and post-stroke fatigue are commonly reported and

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contribute substantially to disability. Additionally, secondary systemic complications, including infections, constipation, urinary disturbances, pain syndromes, and emotional disorders, further complicate recovery and may delay rehabilitation progress. Importantly, several of these complications persist beyond the acute phase, highlighting the dynamic and evolving nature of post-stroke morbidity [11] [12].

While previous studies have evaluated specific complications or focused on individual systems, comprehensive system-wise assessment of multisystem post-stroke complications within a single cohort remains limited, particularly in resource-constrained tertiary care settings [13] [14]. Moreover, the association between multisystem complication burden and functional recovery outcomes has not been adequately explored in ambispective cohort designs combining long-term retrospective data with prospective follow-up [15] [16].

A better understanding of the frequency, distribution, temporal patterns, and functional implications of multisystem post-stroke complications is essential to optimize rehabilitation strategies and improve long-term outcomes [17]. Therefore, the present study aimed to evaluate the prevalence and system-wise distribution of post-stroke complications, compare patterns across ischemic and hemorrhagic stroke subtypes, analyze temporal trends, and assess their association with functional recovery using the Barthel Index in an ambispective observational cohort [18].

To our knowledge, this is one of the few ambispective cohort studies integrating multisystem complication burden with functional recovery outcomes in a real-world clinical setting.

2. Materials and Methods

2.1 Study Design and Setting

This ambispective observational cohort study was conducted in the Department of Neurology at Ramesh Hospitals, Guntur, Andhra Pradesh, India. The study comprised two phases: a retrospective phase spanning six years and a prospective follow-up phase conducted over six months. The retrospective component included patients admitted between January 2018 and December 2023, while prospective data were collected from January 2024 to June 2024.

The study protocol was approved by the Institutional Ethics Committee of Ramesh Hospitals (Registration Number: ECR/81/INST/AP/2013/RR/2019; DHR Registration Number: ECR/NEW/INST/2020/1485). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from prospectively enrolled patients or their legally authorized representatives. This study is reported in accordance with the STROBE guidelines for observational studies.

2.2 Study Population

Adult patients aged ≥18 years with a confirmed diagnosis of ischemic or hemorrhagic stroke based on clinical assessment and neuroimaging were eligible for inclusion. Patients of either sex with complete medical records and follow-up data were included.

Exclusion criteria comprised: Age <18 years; Pregnancy or lactation; Pre-existing psychosis, epilepsy, major depressive disorder, dementia, movement disorders, central nervous system infections, or other unrelated neurological disorders. These exclusions were applied to minimize confounding in the evaluation of post-stroke complications.

2.3 Sample Size and Unit of Analysis

A convenience sampling approach was adopted based on case availability during the study period. A total of 350 eligible patients were included for functional outcome analysis.

Complication-level analysis included 1,676 documented post-stroke complications, as individual patients could experience multiple complications. Functional outcomes were analyzed at the patient level (n = 350), whereas complication frequency and distribution analyses were conducted at the complication level (n = 1,676).

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2.4 Identification and Classification of Post-Stroke Complications

Post-stroke complications were identified through systematic review of inpatient records, outpatient follow-up documentation, neurological examinations, laboratory findings, and neuroimaging reports. Prospective data were collected using a standardized data abstraction form to ensure uniformity.

Documented complications were classified into twelve predefined organ-system categories: Central nervous system; Cardiovascular; Respiratory; Gastrointestinal; Urinary; Pain-related; Musculoskeletal; Dermatological; Ophthalmological; Otological; Emotional; General systemic. This system-wise classification enabled structured descriptive and comparative analysis.

2.5 Data Collection and Variables

Demographic variables included age and gender. Age was stratified into predefined categories (<40, 40–50, 50–60, 60–70, >70 years). Stroke subtype was classified as ischemic or hemorrhagic based on neuroimaging.

The timing of complication onset was categorized as: Early: <90 days from stroke onset and Late: ≥90 days from stroke onset. Detailed age-wise, gender-wise, and temporal onset analyses are provided in the supplementary material. Detailed descriptive analyses including age-wise, gender-wise, and temporal distribution of complications are provided in Supplementary Tables S1–S3.

2.6 Outcomes and Functional Assessment

The primary outcome was functional improvement, defined as an increase of ≥5 points in the Barthel Index (BI) score from baseline to follow-up.

Secondary outcomes included: system-wise prevalence of post-stroke complications, comparison of complication patterns between ischemic and hemorrhagic stroke subtypes, and temporal distribution of complications (<90 vs ≥90 days from stroke onset).

Functional status was assessed using the Barthel Index (BI), a validated measure of activities of daily living [19] [20]. Baseline BI scores were recorded at initial assessment, and follow-up BI scores were documented after completion of structured post-stroke management. Changes in BI scores were analyzed both as continuous variables and as categorical improvement levels.

2.7 Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Pre- and post-management Barthel Index (BI) scores were compared using a paired t-test. To evaluate associations between post-stroke complications and functional recovery, additional inferential analyses were performed. Functional improvement was defined as a ≥5-point increase in BI score from baseline to follow-up.

A multivariable binary logistic regression analysis was conducted to identify independent predictors of functional improvement. Independent variables included age, gender, stroke subtype, presence of central nervous system (CNS) complications, and total number of complications per patient. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated.

Correlation analysis was performed to assess the relationship between total complication burden and change in BI score using Pearson's correlation coefficient. Subgroup analyses were conducted to compare functional outcomes across demographic and clinical variables, including age groups, gender, stroke subtype, and presence of CNS complications.

All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant. Subgroup

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comparisons of mean BI change were performed using independent t-tests or one-way ANOVA, as appropriate.

3. Results

3.1 Study Population Characteristics

A total of 350 patients were included in the functional outcome analysis. Across these patients, 1,676 post-stroke complications were documented, as multiple complications were recorded per patient.

The highest proportion of complications was observed among patients aged 60–70 years (32.6%), followed by those aged >70 years (24.5%) (Fig. 1). Male patients accounted for 62.7% (Fig. 2) of total recorded complications, whereas females accounted for 37.3% (Table 1).

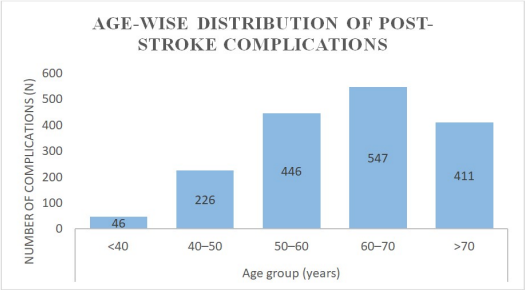

Fig. 1: Age-wise distribution of recorded post-stroke complications (n = 1,676).

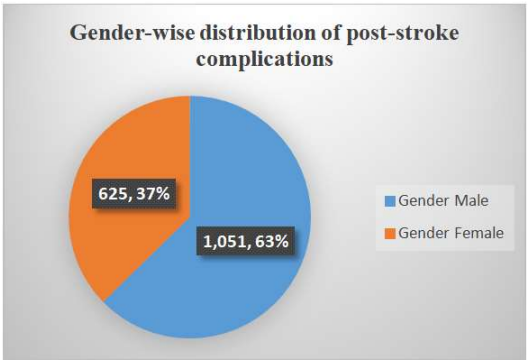

Fig. 2: Gender-wise distribution of recorded post-stroke complications (n = 1,676).

3.2 Overall System-Wise Distribution of Post-Stroke Complications

Central nervous system (CNS)–related complications constituted the largest proportion of total recorded events (n = 671; 40.0%) (Table 2) [21] [22]. Pain-related complications accounted for 249 (14.9%), followed by gastrointestinal complications (n = 194; 11.6%).

Urinary (6.8%), general systemic (6.7%), respiratory (5.3%), musculoskeletal (4.2%), cardiovascular (2.8%), ophthalmological (2.7%), dermatological (2.3%), emotional (2.1%), and otological (0.5%) complications comprised the remaining distribution (Fig. 3).

3.3 Most Prevalent Individual Complications

Fatigue (28%) was the most prevalent individual complication overall (Table 3). Among CNS manifestations, quadriparesis (26.6%), giddiness (25.1%), headache (23.1%), and numbness (22.8%)

Table 1: Demographic Distribution of Post-Stroke Complications (Complication-Level, n = 1,676).

Demographic variable	Category	Number of complications (n)	Proportion (%)
Age group (years)	<40	46	2.74
	40–50	226	13.49
	50–60	446	26.61
	60–70	547	32.64
	>70	411	24.52
Gender	Male	1,051	62.70
	Female	625	37.30

Note: Percentages calculated using the total number of post-stroke complications as the denominator.

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Table 2: System-Wise Distribution of Post-Stroke Complications (n = 1,676)

Medical category	Number of complications recorded	% of Total Complications
CNS	671	40.0
General	113	6.7
Dermatological	39	2.3
Cardiovascular	47	2.8
Ophthalmological	46	2.7
Otological	9	0.5
Emotional	36	2.1
Respiratory	88	5.3
Gastrointestinal	194	11.6
Urinary	114	6.8
Pain-related	249	14.9
Musculoskeletal	70	4.2

Table 3: Most Common Individual Post-Stroke Complications

Complication	Prevalence (%)
Fatigue	28.0
Quadriparesis	26.6
Giddiness	25.1
Headache	23.1
Numbness	22.8
Limb pain	20.3
Insomnia	18.6
Reeling sensation	18.0
Constipation	15.7
Edema	13.7

were most frequent.

Within gastrointestinal complications, constipation (15.7%) and loss of appetite (10.3%) predominated. Limb pain (20.3%) was the most frequent pain-related complication.

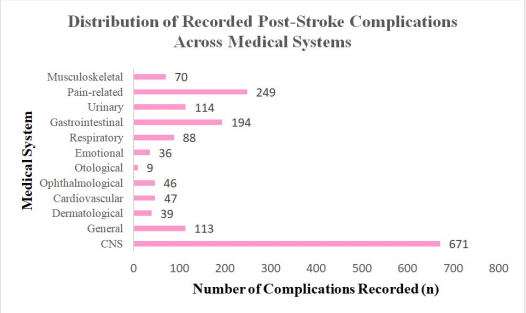

Fig. 3: System-wise distribution of recorded post-stroke complications across predefined medical categories (n = 1,676).

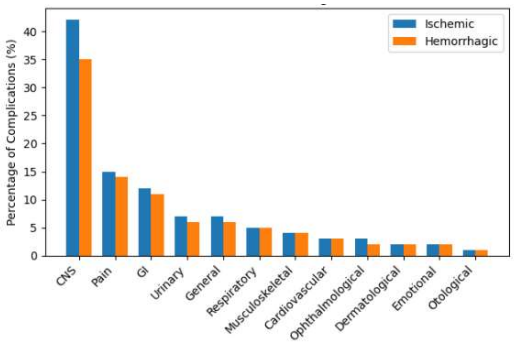

Fig. 4: Comparison of system-wise complication distribution between ischemic and hemorrhagic stroke.

3.4 Comparison Between Ischemic and Hemorrhagic Stroke

A statistically significant difference in complication distribution between ischemic and hemorrhagic stroke was observed (Fig. 4) only for CNS-related complications ($p = 0.032$) (Table 4). No significant differences were identified across other medical categories (all $p > 0.05$), indicating broadly similar systemic complication patterns across stroke subtypes.

3.5 Temporal Distribution of Complications

Figure 5 illustrates the system-wise distribution of post-stroke complications occurring within 90 days and beyond 90 days following stroke onset. CNS-related

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Table 4: Comparison of System-Wise Distribution of Post-Stroke Complications Between Ischemic and Hemorrhagic Stroke

System	Ischemic Complications	Ischemic (n, %)	Hemorrhagic Complications	Hemorrhagic (n, %)	p-value
CNS	611	36.46%	60	3.58%	0.032*
General	105	6.26%	8	0.48%	0.185
Dermatological	32	1.91%	7	0.42%	0.057
Cardiovascular	41	2.45%	6	0.36%	0.154
Ophthalmological	45	2.69%	1	0.06%	0.061
Otological	8	0.48%	1	0.06%	0.553
Emotional	34	2.03%	2	0.12%	0.617
Respiratory	84	5.01%	4	0.24%	0.479
Gastrointestinal	175	10.44%	19	1.13%	0.091
Urinary	100	5.97%	14	0.84%	0.480
Pain related	222	13.25%	27	1.61%	0.720
Musculoskeletal	59	3.52%	11	0.66%	0.952
Total	1516	90.45%	160	9.55%	
*Statistically significant ($p < 0.05$)					

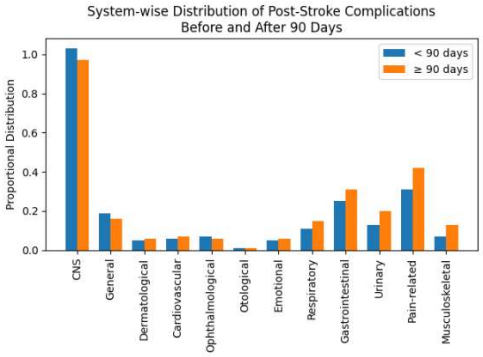

Fig. 5: System-wise distribution of post-stroke complications occurring within 90 days and beyond 90 days from stroke onset.

complications were observed across both early and late phases. Pain-related, gastrointestinal, and urinary complications demonstrated relatively greater persistence beyond 90 days, indicating continued morbidity during the chronic recovery period.

3.6 Functional Outcomes

Clinically meaningful functional improvement (≥5-point increase in Barthel Index score) was observed in 82.9% of patients (Table 5). Mean BI scores increased significantly from 67.45 at baseline to 73.54 at follow-up (paired t-test, $p < 0.0001$), indicating improved functional independence following structured post-stroke management (Fig. 6).

Table 5: Distribution of Functional Improvement Based on BI Score Change (n = 350)

BI Change Category	n	%
Deterioration (<0)	10	2.9
No/Mild Improvement (0–5)	50	14.3
Moderate Improvement (6–15)	283	80.9
Marked Improvement (>15)	7	2.0

3.7 Predictors of Functional Recovery

Multivariable logistic regression analysis was performed to identify independent predictors of functional improvement (≥5-point increase in Barthel Index score).

Increasing age was not significantly associated with functional recovery (OR = 0.98, 95% CI: 0.95–1.01, $p = 0.157$). Male

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Table 6: Logistic Regression Analysis of Predictors of Functional Improvement			
Variable	OR	95% CI	p-value
Age	0.98	0.95 – 1.01	0.157
Gender (Male)	1.78	0.99 – 3.21	0.051
Stroke Type	0.25	0.05 – 1.10	0.068
CNS Complications	0.95	0.47 – 1.92	0.890
Total Complications	1.00	0.96 – 1.04	0.918

Table 7: Correlation Between Complication Burden and Functional Recovery		
Variable 1	Variable 2	p-value
Total complications	BI change	>0.05

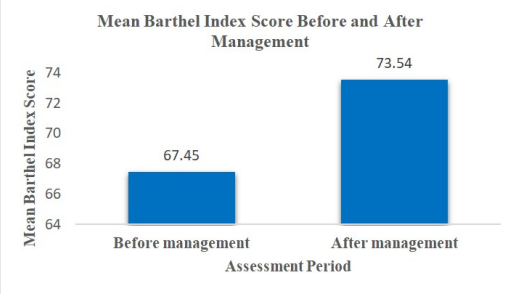

Fig. 6: Mean Barthel Index (BI) scores before and after structured post-stroke management (n = 350).

gender showed a trend toward improved functional outcomes, although this did not reach statistical significance (OR = 1.78, 95% CI: 0.99–3.21, p = 0.051).

Stroke subtype demonstrated a borderline association with functional recovery, with ischemic stroke patients showing lower odds of improvement compared to hemorrhagic stroke (OR = 0.25, 95% CI: 0.05–1.10, p = 0.068).

The presence of CNS-related complications was not significantly associated with functional improvement (OR = 0.95, 95% CI: 0.47–1.92, p = 0.890). Similarly, total complication burden was not significantly associated with functional recovery (OR = 1.00, 95% CI: 0.96–1.04, p = 0.918). The model demonstrated acceptable fit based on the Hosmer–Lemeshow test (p > 0.05) (Table 6).

3.8 Correlation Analysis

No statistically significant correlation was observed between total complication burden and change in Barthel Index score (p > 0.05) (Table 7).

3.9 Subgroup Analysis of Functional Outcomes

Subgroup analyses were performed to evaluate differences in functional recovery across clinical and demographic variables. No statistically significant differences were observed in subgroup comparisons using independent t-test/ANOVA (all p > 0.05).

Patients with CNS-related complications demonstrated similar functional improvement compared to those without CNS complications, with no statistically significant difference in BI change (p > 0.05). Patients with hemorrhagic stroke showed a trend toward greater functional improvement compared to ischemic stroke, although this difference did not reach statistical significance (p ≈ 0.06). Male patients demonstrated slightly higher functional improvement compared to females; however, this difference was not statistically significant (p ≈ 0.05).

Increasing age showed a trend toward reduced functional improvement, although this was not statistically significant.

4. Discussion

This ambispective cohort study provides a comprehensive evaluation of multisystem post-stroke complications and their association with functional recovery in a tertiary care setting. The findings demonstrate

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that post-stroke morbidity is predominantly neurological but extends across multiple organ systems, with significant implications for long-term rehabilitation outcomes.

4.1 Multisystem Burden of Post-Stroke Complications

Central nervous system (CNS)–related complications constituted the largest proportion of recorded events, accounting for 40% of total complications. This predominance is consistent with the fundamental pathophysiology of stroke, where primary cerebral injury results in secondary motor, sensory, cognitive, and autonomic disturbances. Previous cohort studies have similarly reported high rates of neurological sequelae following stroke, particularly motor deficits and cognitive impairment. However, many prior investigations have focused on isolated complications rather than adopting a structured multisystem framework [23].

Pain-related and gastrointestinal complications represented the second and third most frequent categories, respectively [24]. Persistent pain syndromes following stroke may result from central sensitization, altered cortical processing, spasticity, and musculoskeletal deconditioning. Gastrointestinal complications such as constipation likely reflect autonomic dysfunction, reduced mobility, medication effects, and altered dietary intake. The persistence of these complications beyond the early post-stroke period highlights the chronic and evolving nature of post-stroke morbidity [25].

Fatigue emerged as the most prevalent individual complication in this cohort. Post-stroke fatigue is increasingly recognized as an independent and disabling condition associated with neuroinflammatory pathways, disrupted neurotransmitter balance, and psychological stress. Its high prevalence underscores the need for systematic screening and targeted management strategies within rehabilitation programs.

Although multivariable regression analysis did not identify statistically significant independent predictors of functional recovery, correlation and subgroup analyses provide important clinical insights.

The absence of a significant association between total complication burden and functional improvement suggests that recovery may depend more on the nature and severity of complications rather than their cumulative number. Furthermore, the relatively consistent functional improvement observed across demographic and clinical subgroups indicates that structured multidisciplinary rehabilitation may mitigate the adverse impact of multisystem complications.

These findings emphasize the multifactorial nature of post-stroke recovery, which is likely influenced by factors beyond clinical variables assessed in this study, including rehabilitation intensity, caregiver support, and patient adherence.

4.2 Stroke Subtype Differences

CNS-related complications were significantly more frequent among patients with ischemic stroke compared to hemorrhagic stroke. This observation may reflect higher survival rates among ischemic stroke patients, resulting in prolonged exposure to chronic neurological sequelae. Alternatively, differences in lesion distribution, cortical involvement, and vascular mechanisms may contribute to subtype-specific patterns of neurological morbidity. The absence of significant differences in non-neurological systems suggests that systemic complications are likely driven by shared mechanisms such as immobility, inflammation, and autonomic dysregulation rather than stroke subtype alone.

4.3 Temporal Evolution of Complications

A substantial proportion of complications occurred within the first 90 days after stroke onset, corresponding to the acute and subacute recovery phases. Early complications may reflect acute neurological injury, immobilization, and systemic stress responses. However, pain-related, gastrointestinal, and urinary complications frequently persisted beyond 90 days, indicating sustained vulnerability during the chronic

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phase of recovery. These findings support the need for long-term follow-up and structured outpatient rehabilitation rather than limiting monitoring to the acute hospitalization period [26].

4.4 Functional Recovery Despite Multisystem Morbidity

Despite the high burden of complications, significant functional improvement was observed following structured management, with over 80% of patients demonstrating meaningful gains in Barthel Index scores. This finding reinforces the effectiveness of multidisciplinary rehabilitation even in the presence of multisystem complications. Importantly, the observed improvement highlights that complication burden does not preclude functional recovery when appropriate medical and rehabilitative interventions are implemented.

5. Strengths and Limitations

This study has several strengths. First, the ambispective design allowed integration of long-term retrospective data with prospective follow-up, enhancing temporal depth. Second, the large number of documented complications enabled comprehensive system-wise analysis within a single cohort. Third, functional outcomes were evaluated using a validated instrument (Barthel Index), permitting objective assessment of recovery.

However, certain limitations should be acknowledged. The study was conducted at a single tertiary care center, which may limit generalizability. The observational design precludes causal inference between complication burden and functional outcomes. Additionally, some complications were identified through record-based documentation, introducing the possibility of reporting bias. Future multicenter prospective studies incorporating standardized diagnostic criteria and multivariate modeling would further clarify predictors of long-term functional recovery.

6. Clinical Implications

The findings emphasize the importance of adopting a multisystem perspective in post-stroke care. Early identification and proactive management of neurological and systemic complications may reduce long-term disability and enhance rehabilitation outcomes. Structured follow-up protocols extending beyond the acute phase are particularly important for managing persistent pain, gastrointestinal disturbances, and urinary dysfunction.

7. Conclusion

This ambispective cohort study demonstrates that post-stroke complications are frequent, multisystemic, and predominantly neurological in nature, with substantial implications for functional recovery. Central nervous system–related complications constitute the largest burden, while pain-related, gastrointestinal, and urinary complications frequently persist beyond the early recovery phase. Despite the high complication burden, structured multidisciplinary management was associated with significant improvement in functional independence. Functional recovery appeared to be relatively consistent across patient subgroups, suggesting that effective multidisciplinary management may overcome the impact of multisystem complication burden.

These findings underscore the importance of early identification, continuous monitoring, and long-term, system-oriented rehabilitation strategies in stroke survivors. Adoption of a comprehensive multisystem approach may enhance recovery trajectories and reduce long-term disability in post-stroke populations.

Abbreviations

ADL – Activities of Daily Living
BI – Barthel Index
CI – Confidence Interval
CNS – Central Nervous System
GI – Gastrointestinal
OR – Odds Ratio
SD – Standard Deviation

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Conflict of Interest

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

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