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Original Article

Rehabilitation outcomes across neurological disorders: A six-year analysis using rehabilitation impact indices

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Abstract

Objectives: This study aims to evaluate the effectiveness and efficiency of first inpatient rehabilitation stay among patients with neurological disorders admitted to neurological rehabilitation ward of Hospital Rehabilitasi Cheras.

Patients and methods: This retrospective cohort study included a total of 938 patients with neurological disorders admitted for first inpatient rehabilitation stay at our center between January 2018 and December 2023. Functional outcomes were assessed using absolute functional gain (AFG), rehabilitation effectiveness (REs), and rehabilitation efficiency (REy) derived from Modified Barthel Index (MBI) scores. The REs was defined as the percentage of the highest possible functional improvement, while the REy was defined as the daily MBI improvement rate.

Results: Of the patients, 574 were male and 364 were female with a mean age of 54.8 ± 12.8 (range, 18 to 82) years. The mean length of stay (LOS) was 23.1 ± 7.5 (range, 12 to 66) days. Among the patients, 720 patients had first-ever stroke, 117 had recurrent stroke and other neurological disorders including multiple sclerosis, Guillain-Barré syndrome, spinocerebellar ataxia, muscular dystrophy, and critical illness polyneuropathy. The overall mean MBI improved from 44.7 ± 23.0 at the time of admission to 66.0 ± 25.5 at the time of discharge, with a mean AFG of 21.3 ± 15.1 points. Among first-ever stroke patients, the mean REs was 45.0 ± 27.1% and mean REy was 1.00 ± 0.67 MBI points/day. Approximately 62.5% achieved clinically effective rehabilitation (REs ≥ 35%), while 76.4% achieved clinically meaningful efficiency (REy ≥ 0.5). Functional gains were also observed across recurrent stroke and non-stroke neurological disorders. Rehabilitation outcomes remained stable throughout the novel coronavirus disease 2019 (COVID-19) pandemic.

Conclusion: Inpatient neurorehabilitation yields clinically meaningful and time-efficient recovery, particularly in patients with first-ever stroke. Functional gains can be achieved in recurrent stroke and other neurological disorders, supporting the role of inpatient neurorehabilitation in both stroke and other neurological disorders.

Keywords: Inpatient rehabilitation, neurological disorders, neurorehabilitation, rehabilitation effectiveness, rehabilitation efficiency.

The prevalence of non-communicable, progressive or chronic diseases, including neurological disorders, is predicted to rise with the increasing life span and population aging.[1] The advancement in medicine have reduced mortality in neurological diseases, but this has also led to increase in neurological complications.[1] Sequelae of neurological disorders cause disabilities and impairments that affect one's self-care, domestic activities, social participation and employment,[2] while also burden their families, caregivers and the healthcare services.[3,4] The growing prevalence

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of these conditions is associated with increased healthcare expenditure and reduced economic productivity, adding to their socioeconomic burden.[5] Therefore, the demand for rehabilitation services is expected to rise substantially.[6]

Multidisciplinary rehabilitation is an important intervention to reduce disability, restore function, and enhance quality of life.[7] Multiple studies have shown that inpatient rehabilitation for patients with various neurological diseases leads to significant functional improvements.[8-11] Recent evidence has further demonstrated that targeted activities of daily living interventions can improve functional performance among stroke inpatients.[12] Moreover, for patients with high dependency, structured inpatient rehabilitation can be cost-effective by reducing long-term care needs and associated economic burdens.[13-15]

Hospital Rehabilitasi Cheras is a government hospital in Malaysia dedicated exclusively to rehabilitation services. Within Hospital Rehabilitasi Cheras, the Neurological Rehabilitation team manages patients with various neurological disorders, including ischemic stroke, multiple sclerosis (MS), Guillain-Barré syndrome (GBS), and Parkinson's disease (PD). These patients undergo an individualized inpatient rehabilitation program designed to enhance recovery and functional independence. Despite the critical role of inpatient rehabilitation, there is a lack of research evaluating rehabilitation outcomes among neurological patients in Malaysia. Understanding both the effectiveness (clinical improvement) and efficiency (time-to-recovery) of these services is critical for patient selection, rehabilitation planning, and improving overall service quality. In the present study, we aimed to assess the effectiveness and efficiency of inpatient rehabilitation services for patients with neurological disorder at Hospital Rehabilitasi Cheras, providing evidence-based insights to enhance rehabilitation care in Malaysia.

PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at Hospital Rehabilitasi Cheras, Department of Neurological Rehabilitation between January 1st, 2018 and December, 31st, 2023. Patients with neurological disorder who were admitted for their first inpatient rehabilitation stay were screened. Patients aged over 20 years and admitted for their first inpatient rehabilitation stay were included. Exclusion criteria were as follows: *(i)* incomplete data; *(ii)* baseline Modified Barthel Index (MBI) scores ≥ 90, due to limited potential for measurable functional gains; *(iii)* premature discharge without completion of the rehabilitation program; and *(iv)* length of stay (LOS) less than 12 days. This minimum duration was selected to ensure patients received at least two full weeks of structured weekday rehabilitation, beginning on a Monday and ending on the following Friday. All relevant data were retrieved from medical records, including demographic data, clinical characteristics of neurological disorder, LOS, and MBI at the time of discharge. A total of 1,252 patients were screened for eligibility. Of these, 208 were excluded due to premature discharge before completing the rehabilitation program, 11 due to incomplete data, and 95 due to baseline MBI scores ≥ 90, which limited potential for measurable functional gains. Finally, a total of 938 patients who met the inclusion criteria and completed inpatient rehabilitation were recruited. The study protocol was approved by the Medical Research & Ethic Committee Malaysia (Date: January 08, 2024, No: 23-03539-UMM). The study was conducted in accordance with the principles of the Declaration of Helsinki.

During inpatient rehabilitation, patients underwent a structured multidisciplinary rehabilitation program led by a rehabilitation physician. Patients were reviewed regularly by the rehabilitation physician and medical officers to ensure medical stability, manage rehabilitation-related complications, and optimize participation in therapy. Individualized rehabilitation goals were established and reviewed during weekly interdisciplinary team meetings.

Most patients received physiotherapy and occupational therapy on weekdays, typically for approximately 1 h each per day, depending on individual needs and tolerance. Additional services were provided when indicated, including speech and language therapy, clinical psychology and counselling services, dietetics, medical social work, pharmacy review, audiology assessment,

orthotic prescription and review, and rehabilitation nursing. Patients were also encouraged to perform prescribed ward-based exercises and self-practice activities outside formal therapy sessions.

The MBI is used to measure a patient's performance in the activity of daily living.[11] Ten daily activities include feeding, personal toileting, bathing, dressing and undressing, getting on and off a toilet, bladder control, bowel control, transferring from wheelchair to bed and returning, walking on level surface, and ascending and descending stairs. Each activity is scored using a five-point scale, with a maximum total score of 100.[16] The MBI has shown good reliability and validity.[17,18] The LOS was calculated from the day of admission to discharge.

During inpatient rehabilitation, patient's performance was assessed using Rehabilitation Impact Indices (RII), which have been widely used in many studies.[19] Previous research has reported that RII can be effectively calculated using functional outcome measures. In our center, MBI is employed as the primary functional assessment tool; therefore, we use MBI to compute the RII, including absolute functional gain (AFG), rehabilitation effectiveness (REs), and rehabilitation efficiency (REy). The AFG is defined as the difference between admission and discharge MBI scores. The REs reflects the percentage of the highest possible functional improvement, calculated as [AFG / (Maximum possible MBI - Admission MBI)] × 100. The REs values were categorized as low (< 35%), moderate (35-49%), high (50-99%), and complete recovery (100%). These classifications were adopted from the study by Sánchez-Rodríguez et al.,[20] in which an REs value of ≥ 35% was proposed as a threshold for clinically effective rehabilitation. The REy represents the daily MBI improvement rate, obtained by dividing AFG by the LOS. The REy values were categorized as low (< 0.50), moderate (0.50-0.99), and high (≥ 1.00). In the same study, an REy value ≥ 0.50 was considered a clinically meaningful level of REy.[20]

These patients were classified according to clinical diagnosis and the number of cases seen in our center, with rarer conditions grouped together for reporting purposes. The first-ever stroke group refers to patients experiencing their first-ever clinically diagnosed stroke event, while the recurrent stroke group includes individuals with a documented history of one or more prior strokes. The MS group included patients with relapsing-remitting, primary progressive, or secondary progressive subtypes. The GBS group included both demyelinating and axonal variants. The spinocerebellar ataxia (SCA) group consisted of genetically or clinically diagnosed degenerative ataxias. The muscular dystrophy group referred to adult patients with genetically confirmed or clinically diagnosed dystrophinopathies. The critical illness polyneuropathy (CIP) group comprised patients recovering from prolonged intensive care unit (ICU) admissions with confirmed or suspected CIP. The other neurological diseases group comprised patients with PD, motor neuron disease (MND), and multiple system atrophy. Finally, the others category included less common but clinically significant conditions encountered in our setting, such as myasthenia gravis, Charcot-Marie-Tooth disease, adult cerebral palsy, hypoxic-ischemic encephalopathy (HIE), and functional neurological disorders.

Statistical analysis

Statistical analysis was performed using the SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Continuous data were presented in mean ± standard deviation (SD) or median (min-max), while categorical data were presented in number and frequency. Cases with incomplete data were excluded from the analysis, and no missing data imputation was performed.

RESULTS

Of a total of 938 patients, 574 were male and 364 were female with a mean age of 54.8 ± 12.8 (range, 18 to 82) years. Among these patients with neurological disorders, stroke represented the majority (720 first-ever strokes and 117 recurrent strokes), followed by smaller groups of MS (n = 19), GBS (n = 27), SCA (n = 13), muscular dystrophy (n = 7), CIP (n = 12), and other neurodegenerative diseases (n = 11). The mean LOS was 23.1 ± 7.5 (range, 12 to 66) days.

Stroke patients (first-ever and recurrent combined) were older (mean: 56.1 ± 11.7 years) and

Table 1. Patient characteristics and rehabilitation impact indices across neurological disorders

	All (n = 938)	First-ever stroke (n = 720)	Recurrent stroke (n = 117)	MS (n = 19)	GBS (n = 27)	SCA (n = 13)	Muscular dystrophy (n = 7)	Other Neurodegenerative diseases (n = 11)	CIP (n = 12)	Others (n = 12)
Age (year) (Mean ± SD)	54.8 ± 12.8	55.9 ± 12.0	57.7 ± 10.2	40.4 ± 12.5	41.6 ± 16.0	44.0 ± 11.8	44.9 ± 18.4	61.2 ± 9.1	40.22 ± 15.6	43.3 ± 16.5
Sex (n) Male Female	 574 364	 441 279	 85 32	 7 12	 15 12	 10 3	 3 4	 5 6	 2 10	 6 6
LOS (Mean ± SD)	23.1 ± 7.5	23.0 ± 6.9	21.8 ± 6.1	22.3 ± 6.6	33.7 ± 13.2	26.0 ± 5.1	19.6 ± 4.2	16.4 ± 3.7	23.6 ± 7.9	24.8 ± 18.6
MBI admission (Mean ± SD)	44.7 ± 23.0	44.8 ± 22.1	37.9 ± 24.2	64.2 ± 23.9	45.8 ± 25.8	63.3 ± 16.2	68.6 ± 16.0	41.2 ± 24.6	54.7 ± 18.5	29.4 ± 28.0
MBI discharge (Mean ± SD)	66.0 ± 25.5	67.0 ± 24.7	57.4 ± 27.3	75.5 ± 23.2	71.3 ± 28.3	80.3 ± 12.2	78.3 ± 16.8	51.7 ± 28.3	75.8 ± 16.4	45.8 ± 35.7
AFG (Mean ± SD)	21.3 ± 15.1	22.2 ± 14.7	19.5 ± 16.2	11.4 ± 8.3	25.5 ± 20.1	17.0 ± 11.9	9.71 ± 5.9	10.6 ± 9.7	21.2 ± 18.1	16.4 ± 15.4
REs (Mean ± SD)	43.3 ± 27.6	45.0 ± 27.1	35.6 ± 27.4	38.7 ± 28.7	52.1 ± 33.5	44.5 ± 24.8	35.9 ± 21.9	23.1 ± 24.0	45.3 ± 27.4	30.0 ± 29.4
REy (Mean ± SD)	0.95 ± 0.67	1.00 ± 0.67	0.90 ± 0.75	0.50 ± 0.36	0.83 ± 0.65	0.67 ± 0.48	0.54 ± 0.37	0.64 ± 0.56	0.99 ± 0.83	0.70 ± 0.66

SD: Standard deviation; MS, multiple sclerosis; GBS, Guillain-Barré syndrome; SCA, spinocerebellar ataxia; CIP, critical illness polyneuropathy; LOS, length of stay; MBI, Modified Barthel Index; AFG, absolute functional gain; REs, rehabilitation effectiveness; REy, rehabilitation efficiency. Other neurodegenerative diseases: Parkinson's disease, motor neuron disease, and multiple system atrophy; others: myasthenia gravis, Charcot-Marie-Tooth disease, adult cerebral palsy, hypoxic-ischemic encephalopathy, and functional neurological disorders.

more often male than non-stroke patients, while patients with diagnoses such as MS, GBS, SCA, and CIP had mean ages ranging from to 45 years. According to diagnosis, LOS was similar for stroke (23.0 days) and CIP (23.6 days), slightly shorter for recurrent stroke (21.8 days), and longer for GBS (33.7 days) (Table 1). Admission functional status (MBI) averaged 44.7 points overall; stroke patients averaged 44.8, recurrent stroke 37.9, whereas MS, SCA, muscular dystrophy patients had higher baseline function (63 to 69 points), indicating milder disability at the time of admission. Functional improvement was observed across all diagnostic groups. The mean discharge MBI was 66.0 ± 25.5, yielding a mean absolute gain of 21.3 ± 15.1 points.

Among the stroke patients, the mean REs was 45.0 ± 27.1% for first-ever strokes and 35.6 ± 27.4% for recurrent strokes. Based on the predefined thresholds, about 62.5% of first-ever stroke patients and 46% of recurrent stroke patients achieved clinically effective rehabilitation (RE ≥ 35%), with 10 first-ever stroke patients achieved complete recovery. The overall mean REy was 1.00 ± 0.67 for first-ever strokes and 0.90 ± 0.75 for recurrent strokes. A total of 76.4% of first-ever stroke patients achieved a clinically meaningful REy ≥ 0.5, with 44.3% had high efficiency (REy > 1.0) (Table 2).

For other neurological conditions, only absolute REs and REy values are reported, as these threshold classifications have not been validated in those populations. To illustrate, patients with GBS had among the highest functional improvements (AFG = 25.5 ± 20.1, REs = 52.1 ± 33.5), while patients with muscular dystrophy and CIP showed relatively lower functional gains and efficiency.

Annual trends from 2018 to 2023 showed consistency in patient demographics, LOS, AFG, REs, and REy (Table 3). Descriptive annual trends did not demonstrate an apparent deterioration in rehabilitation outcomes during 2020-2021 compared to other years.

DISCUSSION

In the present study, we assessed the effectiveness and efficiency of inpatient

Table 2. Rehabilitation effectiveness and efficiency in first-ever and recurrent stroke

	All strokes		First-ever stroke		Recurrent stroke	
	n	%	n	%	n	%
Rehabilitation effectiveness						
0 (No recovery)	53	6.3	38	5.3	15	12.8
1-34% (Low to moderate recovery)	280	33.5	232	32.2	48	41.0
35-99% (High recovery)	493	58.9	440	61.1	53	45.3
100% (Complete recovery)	11	1.3	10	1.4	1	0.9
Total	837		720		117	
Rehabilitation efficiency						
< 0.49 (Low efficiency)	211	25.2	170	23.6	41	35.0
0.5-1.0 (Moderate efficiency)	260	31.1	231	32.1	29	24.8
> 1.0 (High efficiency)	366	43.7	319	44.3	47	40.2
Total	837		720		117	

Rehabilitation Effectiveness ≥ 35% considered clinically effective; Rehabilitation Efficiency ≥0.50 considered clinically meaningful difference.

rehabilitation services for patients with neurological disorder at our center. Our study results showed that first inpatient rehabilitation stay for patients with neurological disorders in the neurological rehabilitation ward of our center, particularly for patients with first-ever stroke, resulted in meaningful functional improvements. An average AFG of 22.2 points on the MBI, an REs of 45.0%, and an REy of 1.00 MBI point per day reflected outcomes that were usually comparable to those reported in selected international cohorts.[21-28] These findings provide valuable local benchmark data on inpatient neurological rehabilitation and demonstrate the contribution of structured interdisciplinary rehabilitation in improving functional outcomes, particularly among patients with first-ever stroke.

When benchmarked against studies using the MBI or Barthel Index (BI), our first-ever stroke patients showed functional improvements that were consistent with regional and international benchmarks. A multi-center study in Thailand reported a gain of 4.5 points on the 20-point BI, approximately 22.5 on the MBI scale.[21] Ramathibodi Hospital reported a higher mean gain of 32.8 points,[22] while Taiwan's Post-Acute Care (PAC) program showed a 31-point gain.[23] In contrast, Singapore's subacute stroke ward reported a median gain of 17 MBI points.[24] Our mean gain of 22.2 ± 14.7 points, achieved within a mean LOS of 23.1 ± 7.5 days, indicating a clinically meaningful recovery within a shorter rehabilitation stay. Although the absolute gain was not the highest, our REy of 1.00 MBI points/day compares favorably with other reports in the region, suggesting efficient recovery within the inpatient setting.

The level of efficiency among first-ever stroke patients becomes more meaningful when interpreted alongside REs. Our mean REs of 45.0 ± 27.1% exceeded the recalculated REs of approximately 37.2% in the 2009 Thai multi-center study,[21] and remained within the effective recovery zone despite a shorter LOS. The Ramathibodi cohort reported a higher REs of approximately 72%, although this was based on a small subgroup with longer LOS.[22] The Singapore's integrated subacute stroke ward similarly reported an REs of 35.3%, with a median LOS of 44 days.[24] These comparisons suggest that our center is able to achieve clinically effective outcomes within a relatively shorter rehabilitation period.

The REy observed among first-ever stroke patients is further supported when compared within a global context. The Thai studies reported REy values around 1.2 MBI/day.[21,22] In Saudi Arabia, Functional Independence Measure (FIM) based daily gains ranged from 0.52 to 0.72,[25] while Canadian centers reported REy averages around 0.35.[26] In the United States, Wang et al.[27]

Table 3. Patient characteristics and rehabilitation impact indices, 2018-2023

Year	All (n = 940)		2018 (n = 157)		2019 (n = 176)		2020 (n = 159)		2021 (n = 111)		2022 (n = 163)		2023 (n = 174)	
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
Age (year)		54.8 ± 12.8		55.2 ± 13.7		55.2 ± 12.6		54.8 ± 13.5		54.1 ± 12.6		55.6 ± 12.3		53.6 ± 12.0
Sex														
Male	574		105		109		96		67		100		97	
Female	366		52		67		63		44		63		77	
LOS		23.1 ± 7.5		22.1 ± 8.7		22.2 ± 6.2		23.6 ± 7.8		22.7 ± 7.4		22.4 ± 7.7		24.0 ± 7.2
MBI admission		44.7 ± 23.0		41.6 ± 22.8		42.1 ± 22.6		43.7 ± 24.6		45.9 ± 22.6		48.9 ± 22.4		46.5 ± 22.3
MBI discharge		66.0 ± 25.5		62.6 ± 26.6		64.1 ± 26.7		67.6 ± 27.9		64.3 ± 26.2		68.0 ± 23.3		68.7 ± 21.8
AFG		21.3 ± 15.1		21.0 ± 15.1		22.0 ± 16.0		23.9 ± 15.9		18.6 ± 14.4		19.1 ± 14.1		22.3 ± 14.3
REs		43.3 ± 27.6		41.2 ± 27.1		42.7 ± 28.9		49.8 ± 29.1		38.2 ± 27.8		41.3 ± 26.5		44.8 ± 25.4
REy		0.95 ± 0.67		0.96 ± 0.70		1.00 ± 0.74		1.06 ± 0.70		0.84 ± 0.68		0.88 ± 0.62		0.95 ± 0.58

SD: Standard deviation; LOS, length of stay; MBI, Modified Barthel Index; AFG, absolute functional gain; REs, rehabilitation effectiveness; REy, rehabilitation efficiency.

observed a high efficiency of 1.4 FIM points/day among early-admitted stroke patients. Meanwhile, Alkan et al.[28] in Türkiye reported a FIM-based efficiency of 0.55 points/day with a substantially longer LOS of approximately 70 days. Although caution is warranted when comparing across measurement tools, an REy of 1.00 MBI/day places our outcomes among the higher reported value, particularly in the context of shorter LOS and real-world patient complexity.

Most studies used for comparison were conducted in countries with healthcare systems and rehabilitation resources that differ from Malaysia. Although Malaysia is an upper-middle-income country and several of the comparator countries are high-income countries, the rehabilitation outcomes observed in our cohort were usually comparable to those reported internationally. This suggests that a structured multidisciplinary rehabilitation program can achieve meaningful functional recovery even in different healthcare settings.

The trade-off concept of balancing effectiveness and efficiency was well explored by Koh et al.[29] and Damiani et al.[30] Koh et al.[29] proposed that for optimal stroke REs and REy, the admission BI score should be 30-62, and LOS between 37 and 41 days. Meanwhile, Damiani et al.[30] reported that a median rank ratio of REs to REy equal to 1 occurred in patients with BI scores between 32 and 42 and LOS of 33 days, identifying this as a balanced recovery zone across diagnoses. A mean admission MBI of 44.8 and LOS of 23 days place our patients at the edge of this optimal window. However, resulting outcomes remained aligned with international expectations for efficient and effective recovery.

A Japanese study reported a statistically significant improvement in BI effectiveness among patients receiving seven-day rehabilitation compared to those receiving weekday-only rehabilitation.[31] Although the absolute difference in BI effectiveness between the groups was small (0.60 *vs.* 0.57), multivariate analysis confirmed the benefit of higher frequency therapy.[31] In contrast, rehabilitation in our center is conducted on weekdays only. However, several mechanisms may help sustain the efficiency and effectiveness.

These include structured ward-based exercises prescribed by therapists, active encouragement of self-practice during free time, and weekend engagement activities such as group exercises, health education, leisure activities, and use of a dedicated enriched environment corner equipped with simple tools for self-directed activity. This multidisciplinary and activity-enriched approach may help to bridge the gap in therapy frequency and contribute to the outcomes observed.

Although this study focused on first-ever stroke patients, our center also treats a substantial number of patients with recurrent strokes. Recurrent stroke survivors often present with more complex neurological and functional impairments, lower baseline independence, and reduced rehabilitation potential compared to first-ever stroke patients.[32,33] A large prospective cohort from Singapore showed that recurrent stroke patients had significantly lower admission and discharge FIM scores, smaller FIM gains, and lower REs than those with first-ever strokes, although their improvements remained meaningful and clinically significant.[32] Our data reflected a similar pattern, with recurrent stroke patients showing lower admission and discharge MBI scores, smaller functional gains, and reduced REs and REy compared to those with first-ever strokes. These patients often required more time to recover and may require additional support from both the rehabilitation team and their caregivers.

Beyond strokes, our center also provides intensive rehabilitation for patients with non-stroke neurological disorders, a case mixes not commonly seen in large numbers at most facilities. Guillain-Barré syndrome patients showed particularly good functional recovery, with a mean MBI gain of 25.5 points, REs of 52.1%, and REy of 0.83. These findings are consistent with international data, including U.S. cohorts reporting FIM gains of approximately 43 points and over 80% home discharge rates in GBS patients following inpatient rehabilitation.[34] Likewise, patients with CIP showed meaningful improvement, despite limited large-scale data, consistent with clinical expectations for functional recovery following prolonged ICU stay.[35]

Functional gains were also seen in patients with chronic or degenerative neurological conditions, including MS, SCA, and muscular dystrophies. Although the progressive nature of these diseases limits the potential for large improvements in MBI scores, patients still achieved moderate gains (REs 35.9 to 44.5%). These improvements are in line with previous studies showing meaningful progress despite lower efficiency values.[36-38] Rehabilitation in these patients focuses on optimizing independence, slowing functional decline, and improving quality of life. Although stroke-based REs and REy thresholds were not applied to these groups, the gains across nearly all diagnostic groups show the importance of inpatient neurorehabilitation.

Our results were achieved despite the challenges of the novel coronavirus disease 2019 (COVID-19) pandemic. Descriptive annual trends from 2018 to 2023 did not demonstrate an apparent deterioration in LOS, functional gains, REs, or REy during 2020 and 2021. These findings suggest that our center was able to maintain rehabilitation service delivery throughout the pandemic period.

Our results demonstrate the value of a structured, multidisciplinary rehabilitation approach supported by a dedicated neurological rehabilitation team. As the national referral center for neurological rehabilitation, our facility manages patients with stroke as well as a range of less common neurological conditions. Despite differences in patient populations and outcome measures, outcomes among first-ever stroke patients were usually comparable to those reported in selected international cohorts. This study provides local benchmark data on rehabilitation outcomes, particularly for stroke rehabilitation within a specialized inpatient rehabilitation setting. Such data may serve as a useful reference for evaluating rehabilitation services and planning future service development. In addition, outcome measures such as REs and REy may be useful for monitoring rehabilitation performance and supporting quality improvement initiatives within rehabilitation services.

Nonetheless, this study has several limitations that should be acknowledged. First, this is a

retrospective analysis conducted at a single national rehabilitation center with a dedicated neurological rehabilitation service, which may limit the generalizability of findings to other settings, particularly those without specialized neurological rehabilitation services. Besides that, although several non-stroke neurological disorders werenpatient rehabilitation stay and excluded those with shorter admissions (< 12 days), premature discharge, incomplete data, or high baseline MBI scores. These exclusions may introduce selection bias toward patients who were medically stable and able to complete a structured rehabilitation program. Therefore, the findings may not be generalizable to all patients admitted for inpatient rehabilitation, particularly those who had a short admission or were unable to complete the rehabilitation program. Third, although we used the MBI as our primary functional measure, comparisons with studies using other scales such as the FIM may not be directly comparable. Finally, long-term functional outcomes after discharge were not assessed in this study. Future research should explore sustained recovery and community reintegration following inpatient rehabilitation. In addition, studies evaluating factors associated with REs and REy, including patient characteristics, rehabilitation intensity, and disease-specific variables, are needed. Further multi-center studies involving different rehabilitation settings would strengthen the generalizability of these findings and support the development of national rehabilitation benchmarks.

In conclusion, our study results showed that first inpatient rehabilitation stay at our center yields clinically meaningful and time-efficient recovery, particularly in patients with first-ever stroke. Despite a relatively short LOS, high REs and REy were achieved, reinforcing the strength of a structured, multidisciplinary inpatient rehabilitation approach even during periods of healthcare disruption such as the COVID-19 pandemic. Functional gains were also observed in patients with recurrent stroke and other neurological disorders, supporting the role of inpatient rehabilitation beyond stroke populations. Taken together, these findings emphasize the value of protocol-driven care pathways and support the use of outcome metrics such as REs and REy in benchmarking rehabilitation performance across different neurological conditions.

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Declaration of Conflicting Interests

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Author Contributions

T.C.: Design, data collection and processing, analysis and interpretation, literature review, writing the article, critical reiew, references; N.H.: Idea/concept, control/supervision, data collection and processing, analysis and interpretation, critical review; L.A.F.: Data collection and processing, analysis and interpretation, critical review.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI Disclosure

The authors declare that artificial intelligence (AI) tools were not used, or were used solely for language editing, and had no role in data analysis, interpretation, or the formulation of conclusions. All scientific content, data interpretation, and conclusions are the sole responsibility of the authors. The authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

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