

How DRG Payment Reform Shapes Inpatient Neurological Care in an Underdeveloped Region: Evidence from a Controlled Interrupted Time Series Study in Yunnan, China

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Background: This study evaluates the impact of the DRG-based payment reform pilot, initiated in January 2023, in an underdeveloped city in Southwest China. The reform's implications are particularly relevant for resource-limited settings, where healthcare cost control and service efficiency are critical for improving patient care.

Purpose: This study aims to evaluate the impact of this reform on the inpatient service capacity, cost, and efficiency of the Neurology Department in the leading hospital within a county-level medical community.

Material and Methods: We conducted a controlled interrupted time series (ITS) analysis using monthly administrative data from January 2021 to June 2024, focusing on inpatients treated in the Neurology Department of M Hospital, A City, Yunnan Province. Eleven outcome indicators were assessed, including Total DRG Weight, Case Mix Index (CMI), Average Length of Stay (ALOS), and Average Inpatient Cost (measured in Renminbi, RMB). A comparable control group was used to strengthen causal inference.

Results: Following the DRG reform, the Neurology Department experienced a 32.37% increase in Total DRG Weight, a 12.21% rise in CMI, and an 8.94% increase in the number of DRG groups, while ALOS decreased by 9.85%. The ITS model revealed a significant upward trend in Total DRG Weight (trend change = 2.16, $P < 0.01$) and a downward trend in ALOS (trend change = -0.04 , $P < 0.01$). Additionally, the average inpatient cost declined significantly, with a trend reduction of 121.65 RMB per month ($P < 0.01$).

Conclusion: The implementation of DRG-based payment reform in A City was associated with enhanced inpatient service efficiency in the Neurology Department, including improved case complexity management, shorter hospital stays, and reduced costs. However, medical equipment-related expenses remained unaffected, potentially due to increasing patient severity and ongoing technology investments. These findings offer valuable evidence for policymakers aiming to optimize hospital performance through payment system reform in resource-limited settings.

Keywords: diagnosis-related groups, DRG, neurology, payment reform, resource-limited settings, health financing, interrupted time series design, ITS, health system reform

Introduction

The World Health Organization identifies neurological disorders as a leading cause of poor health and disability worldwide.¹ Stroke, Parkinson's, Alzheimer's, epilepsy, headaches, multiple sclerosis, neurological infections, and traumatic brain injuries impose significant global economic and health burdens.² In 2021, over 3 billion people globally suffered from such disorders. With the abundance of medical resources in economically developed countries, over 80% of neurological-related deaths and health losses occur in low- and middle-income countries, including China,³ which has

over 3 million Parkinson's disease patients and over 28 million stroke patients, with stroke being the leading cause of death in the country.⁴

In underdeveloped regions, the rising number of neurological patients has outpaced the slow growth of inpatient services, posing a significant challenge in delivering higher-quality, accessible care.⁵ In 2019, neurological disorders were the leading cause of Disability-Adjusted Life Years (DALYs) in Asia, with stroke, Alzheimer's and epilepsy as major contributors.⁶

Over 70 million people are suffering from epilepsy, 90% of whom received inadequate inpatient treatment in resource-limited settings.⁷ China's neurology resources still lag behind those in the United States and Germany.^{2,8} In China's economically developed Yangtze River Delta region, most hospitals have neurology departments (162 out of 228 or 83.1%), but fewer have stroke centers (80 or 41.0%) and neurology emergency departments (46 or 23.6%).² Rural areas in China, including Yunnan Province, struggle to meet the demand for neurology inpatient services. Resources are concentrated in Kunming, where institutions like Yunnan Provincial Third People's Hospital and the First Affiliated Hospital of Kunming Medical University handle over 4468 inpatient cases annually. Other regions in Yunnan, however, have limited neurology resources and support.

The rising cost of hospitalization places a significant economic burden on the growing number of patients with neurological diseases. Furthermore, in 2022 the average hospitalization costs for patients with cerebral infarction in hospitals directly under Chinese National Health Commission are approximately 21,759.6 RMB, while those for patients with cerebral hemorrhage reach 42,012.1 RMB.⁹ Implemented in the US in 1983, DRGs classify patients based on diagnoses to determine costs and payment,^{10,11} reducing the average length of stay by 8.07% compared to fee-for-service methods.¹² DRGs can improve efficiency, lower hospitalization costs, and help address current challenges in managing neurological diseases.

China began piloting DRGs in May 2019, with 30 pilot cities in the east, central, and west regions.¹³ The pilot cities are distributed across three regions: 12 cities in the eastern region, 8 in the central region, and 10 in the western region. By October, technical specifications and grouping plans were issued. In developed areas, DRGs have shown effectiveness; for instance, in Beijing, DRGs reduced health expenditure by 6.2% and out-of-pocket costs by 10.5%.¹⁴ A 2020 study in Shanghai's Jiading District found that DRGs improved regional service capacity and increased the range of patient conditions treated, with a trend in rising case mix index.¹⁵ In western China, including Sichuan and Yunnan Province, DRGs reform began later, with gradual implementation starting in January 2023. While DRGs have proven effective in controlling inpatient service costs, challenges remain. There are obstacles in DRGs implementation in low- and middle-income areas,¹⁶ including issues with coding standardization, data availability, and information technology.¹¹ The impact of DRGs on performance indicators of inpatient services in underdeveloped regions remains to be explored.

The DRG system classifies inpatient cases based on diagnosis, surgery, age, gender, comorbidities, and complications, grouping them by diagnosis complexity and resource use to standardize pricing and establish a prospective payment system.¹⁷ The China Healthcare Security Diagnosis Related Groups (CHS-DRG) system is a critical framework used to categorize diseases and allocate healthcare resources under the national medical insurance system. In this system, cases are first classified based on the primary diagnosis, utilizing the International Classification of Diseases (10th Revision) coding system, with diseases grouped into major diagnostic categories (MDC) based on anatomical and physiological characteristics. Within each MDC, cases are further subdivided into "surgical", "non-surgical", and "procedural" categories based on treatment modalities. These categories are subsequently grouped into core disease diagnosis-related groups (ADRG), primarily relying on clinical expertise to ensure clinical relevance, with statistical analysis serving as a supplementary tool to enhance classification precision. Finally, the inclusion of patient characteristics, comorbidities, and complications allows for the refinement of classifications into Diagnosis Related Groups (DRG), aligning with resource consumption patterns.¹⁸ This systematic approach ensures the effective categorization of healthcare services, which is essential for equitable payment schemes and optimal resource allocation in the Chinese healthcare system.¹⁹

Further research has explored alterations in diagnosis and treatment strategies for prevalent neurological disorders such as stroke. Interventions like clinical treatment pathways and optimized drug use reduced errors, consumption rates, and length of stay, improving resource efficiency and reducing deficits.²⁰ A study analyzing changes in inpatient duration

and costs for stroke patients following the DRGs reform²¹ revealed that the average length of stay for ischemic stroke patients was reduced by 0.047 days in tertiary hospitals and 0.47 days in secondary hospitals in a Chinese city. Additionally, medical expenses decreased by RMB30.189 per month in tertiary hospitals, whereas they increased by RMB 44.918 per month in secondary hospitals. Another study examined DRGs coding and implementation strategies for ischemic stroke across various countries.²² However, research on the effectiveness and capacity of DRGs for neurological inpatient services in less developed regions, particularly in Asia, remains limited. Further investigation is needed to address these gaps.

In City A, Yunnan Province, the high prevalence of neurological disorders contrasts with the limited availability of inpatient services. On November 23, 2022, the City A Healthcare Security Bureau issued the “Three-Year Action Plan for DRGs Payment Reform”, which was officially implemented in 2023.²³ M Hospital, as the leading institution in the county-level medical community, oversees the District People’s Hospital, District Traditional Chinese Medicine Hospital, District Maternal and Child Health Hospital, District Center for Disease Control and Prevention, 10 township health centers, and 103 village clinics. With 2142 medical staff, M Hospital M has 36 departments and serves over 20,000 inpatients annually, making it one of the hospitals with the highest number of consultations in City A.

This study utilizes an interrupted time series analysis of eleven indicators related to inpatient service capacity, cost, and efficiency at M Hospital in City A after DRGs reform. It aims to evaluate the impact of DRGs on service capacity, efficiency, and cost reduction, with a particular focus on neurology services compared to other departments, to optimize service delivery for neurological disorders. To strengthen the validity of our comparisons, we selected 35 departments from the same hospital that were unrelated to neurology, including commonly encountered specialties such as general internal medicine, surgery, obstetrics and gynecology, pediatric care, cardiology, and cardiovascular surgery. These departments were chosen to represent a diverse range of medical conditions, with varying levels of disease complexity, providing a robust control group for the analysis.

Materials and Methods

Studying Setting

Yunnan Province, located on the Yunnan-Guizhou Plateau in southwestern China, shares borders with Guizhou, Sichuan, Laos, Myanmar, and Vietnam. In 2022, Yunnan had a permanent population of 46.73 million (3.31% of the national total) and a GDP of 2.90 trillion yuan (1.88% of the national total). Its medical resources are limited, with 27,528 medical institutions (2.66% of the national total) and 109 tertiary hospitals (3.09% of the national total). In late 2019, Yunnan launched the “Implementation Plan for Advancing DRGs Payment Reform”, gradually expanding the reform to eight cities. Kunming, a demonstration site selected in 2021, saw a 15.50% increase in total DRGs and a 12.24% rise in CMI from 2020 to 2022. By 2025, the DRGs/DIP payment system is expected to cover eligible medical institutions across Yunnan.²⁴

A City, as [Figure 1](#), located in southwestern Yunnan near Myanmar relies on highland specialty industries like tea and fruits. Its medical resources are limited, with few tertiary hospitals, including A City People’s Hospital and A City M Hospital. DRGs reform in A City has been slow, with the “Three-Year Action Plan for DRGs Payment Reform” launched in November 2022. Public data show cerebrovascular diseases were the leading cause of death in 2021, with an incidence of brain and nervous system cancers in women of 6.17 per 100,000 in 2019. However, the city’s neurology departments face challenges due to underdeveloped equipment and a shortage of specialists.

Significant disparities exist in neurology department development within Yunnan. Kunming’s tertiary hospitals have well-established neurology departments, while those in other cities are underdeveloped. For example, the First Affiliated Hospital of Kunming Medical University, Yunnan’s oldest neurology specialty, handles over 3500 inpatients and 68,000 outpatient visits annually. M Hospital’s Neurology Department in A City was established in September 2020, evolving from the hospital’s First Internal Medicine Department. The department, with 16 medical staff and 25 inpatient beds, diagnoses and treats conditions like cerebrovascular diseases and central nervous system infections, DRGs codes for major disease categories found [Table S1](#). It joined the DRGs payment reform in January 2023 to enhance medical service quality and efficiency.

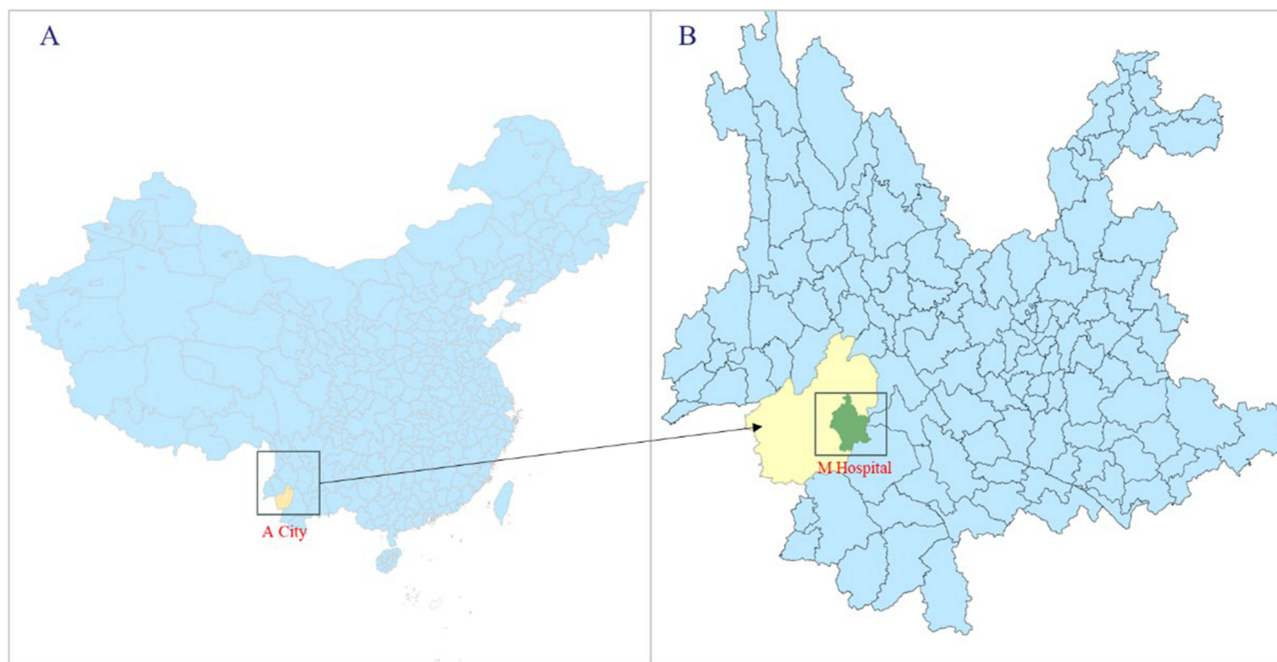


Figure 1 Location of A City and M Hospital in China. **(A)** A City within China (yellow: city, gray: municipal boundaries). **(B)** M Hospital within Yunnan Province (green: coverage area, black: county boundaries).

Outcome Variables

Based on literature review and team discussions, we identified three dimensions comprising 11 indicators, as [Table 1](#). Our primary focus is the impact of DRGs on inpatient service capacity, cost, and efficiency in the Department of Neurology. During the study period (January 2021 to June 2024), three patient deaths occurred, with no adverse safety events. Medical safety and quality indicators were excluded, which we recognize as a potential limitation.

To assess inpatient service capacity, we included total DRGs weight, CMI, and the number of disease types in DRGs, reflecting improvements in the department’s ability to manage diverse diseases and case volumes. For inpatient service cost, we examined the average length of stay (days), average cost per inpatient stay (RMB), average medication cost per inpatient stay (RMB), medication cost ratio (%), average material cost per inpatient stay (RMB), and material cost ratio (%), to evaluate the effect of DRGs on hospital service expenses. Inpatient service efficiency was assessed using the Cost Efficiency Index (CEI) and Time Efficiency Index (TEI).

Table 1 Outcome Variables

Evaluation Dimensions	No	Outcome Variables
Inpatient service capacity	Y1	Total DRGs weight ²¹
	Y2	Case mix index (CMI) ²¹
	Y3	Number of disease types in DRGs ²⁵
Inpatient service cost	Y4	Average length of stay (days) ²⁶
	Y5	Average cost per inpatient stay (RMB) ²⁷
	Y6	Average medication cost per inpatient stay (RMB) ²⁸
	Y7	Medication cost ratio (%) ²⁹
	Y8	Average material cost per inpatient stay (RMB) ³⁰
	Y9	Material cost ratio (%) ²⁹
Inpatient service efficiency	Y10	Cost efficiency index (CEI) ³¹
	Y11	Time efficiency index (TEI) ²¹

CEI: Calculated by multiplying the total cost for each DRG group by the proportion of cases for that group, summing these values across all DRG groups, and then dividing the result by the total number of hospital cases. TEI: Determined by multiplying the average length of stay (LOS) for each DRG group by the proportion of cases for that group, summing these values across all DRG groups, and dividing the result by the total number of hospital cases. An index value of 1 indicates average resource consumption for treating similar conditions across Yunnan Province, reflecting the overall impact of DRGs on service efficiency.

Core Variable Calculation Formulas

The DRG weight (RW) is calculated based on the increased resource consumption associated with more severe conditions. It reflects the relative cost of each DRG group by considering both the severity of the disease and the resources consumed. The calculation formula is as follows:

$$\text{DRG Weight(RW)} = \frac{\text{Average cost or expense for the specific DRG case}}{\text{Average cost or expense for all cases in the region}} \quad (1)$$

The Case Mix Index (CMI) represents the average weight of cases treated at a particular hospital. It is directly related to the severity of diseases treated in that hospital, reflecting the complexity of cases and the associated resource utilization. The CMI is calculated using the following formula:

$$\text{CMI} = \frac{\sum (\text{DRG weight} \times \text{Number of cases for the respective DRG at the hospital})}{\text{Total number of cases at the hospital}} \quad (2)$$

The other calculation formulas for all variables are detailed in [Table S2](#) in supplementary.

Data Sources

Data were obtained from the information system of M Hospital in A City, Yunnan Province, covering the period from January 1, 2021, to June 30, 2024. This dataset includes records of 89,671 patients admitted and discharged across the Neurology Department and 35 other departments over a span of 42 months, encompassing all patients involved during the specified time period. The dataset comprises monthly variations in 11 variables, such as Total DRGs Weight, CMI, and Number of Disease Types in DRGs, among others, to evaluate the impact of the DRGs payment reform on the inpatient service capacity, costs, and efficiency within the Neurology Department. Each participant was fully informed about the purpose of the research and the use of their health data. It was emphasized that their personal information would remain confidential and not be disclosed in any reports or publications. The consent form was signed by each patient, ensuring compliance with ethical standards and protecting patient privacy. All data were anonymized before analysis to ensure that no personally identifiable information was included.

Statistical Analysis

Descriptive statistics were used to analyze changes in 11 outcome variables in the Neurology Department and other departments before (2021.01–2022.12) and after (2023.01–2024.06) the DRGs prepaid system reform. The analysis included the mean, standard deviation (SD), and change ratio (%). The change ratio was calculated as the difference between the mean post- and pre-reform, divided by the pre-reform mean, providing an objective measure of indicator changes. To ensure the robustness of the Interrupted Time Series (ITS) analysis, we have included residual plots in the revised manuscript. We also have included a Bonferroni correction for multiple comparisons, and the detailed procedure is provided in [Table S3](#) in Appendix.

Interrupted time series analysis (ITS) is increasingly employed in the health field to evaluate policy impacts,³² with scholars applying it to assess the effects of DRGs payment reform.^{33,34} The study utilized Stata 16 software to organize income data from June 2019 to June 2024. We used ITS model to evaluate the impact of the DRGs reform, implemented in January 2023, on inpatient service capacity, cost, and efficiency in the Neurology Department (experimental group) and other departments (control group) at Hospital M in A City, Yunnan Province. “ITS” code provided in the [Table S3](#).³⁵ The ITS model was developed as follows:

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \beta_4 Z + \beta_5 Z T_t + \beta_6 Z X_t + \beta_7 Z X_t T_t + \varepsilon_t \tag{3}$$

Y_t represent the aggregated outcome variable measured at each equally spaced time point t , and T_t denote the time since the start of the study. X_t is a binary indicator variable for the reform, where the pre-reform period is coded as 0 and the post-reform period as 1. $X_t T_t$ represents the interaction term between the reform and time. Additionally, Z is a binary variable indicating cohort assignment, with treatment or control as the two categories. ε_t is the first-order autoregressive random error term.

The coefficients β_0 to β_3 describe the control group: β_0 is the baseline level, β_1 is the pre-reform slope, β_2 is the immediate post-reform change in level, and β_3 is the change in slope after the reform. The coefficients β_4 to β_7 represent the gap between the treatment group and the control: β_4 is the difference in baseline level, β_5 is the difference in pre-reform slope, β_6 is the difference in immediate post-reform level change, and β_7 is the difference in post-reform slope change. We use 3 measures to calculate are the postreform trend for the treatment group. $\beta_1 + \beta_3 + \beta_5 + \beta_7$ equal the treatment group’s trend in the postreform period; $\beta_5 + \beta_7$ represent the difference between the treatment and control group’s trends in the postreform; $\beta_1 + \beta_3$ represent the control group’s trend in the postreform period. We utilized the Durbin-Watson test to assess autocorrelation, and a value close to 2 confirmed the absence of autocorrelation in the model.

Control Group Composition and Rationale

The control group consisted of 35 other departments, chosen to highlight the distinctive changes observed in the neurology department. Key differences include disease type variations, as neurological diseases like stroke and epilepsy show unique care patterns, and the underrepresentation of neurology in existing research, which tends to focus on diseases like tuberculosis³⁶ and cancer.¹⁷ Moreover, few studies have utilized a controlled Interrupted Time Series (ITS) design with a control group, filling a critical gap in the literature. The specific neurological diseases included in the study can be found in the [Supplementary Table 1](#).

Results

Descriptive Analysis

The study used descriptive analysis to compare changes in the Inpatient Service Capacity, Costs, and Efficiency of the Neurology Department and the other departments before and after the DRG-based payment reform (see [Table 2](#)). The selection of 35 unspecified departments as the control group was intended to highlight the specific challenges and improvements in neurological care, emphasizing the differences in diagnostic, treatment efficiency, and outcomes.

Table 2 The Change of Inpatient Service Capacity, Costs, and Efficiency of Neurology Department and the Other Departments

Neurology Department						The Other Departments				
Variables	Pre-Reform (SD)		Post-Reform (SD)		CR (%)	Pre-Reform (SD)		Post-Reform (SD)		CR (%)
	2021.01–2022.12		2023.01–2024.06			2021.01–2022.12		2023.01–2024.06		
Total DRG weight (total weight)	86.84	(14.00)	114.94	(16.04)	32.37	2108.82	(254.41)	2329.18	(278.05)	10.45
Case mix index (CMI)	1.03	(0.06)	1.16	(0.09)	12.21	1.04	(0.02)	1.05	(0.02)	0.79
Number of DRGs	23.92	(3.59)	26.06	(4.08)	8.94	311.88	(18.11)	325.00	(24.93)	4.21
Average length of stay (days)	7.60	(0.65)	6.85	(0.28)	−9.85	7.64	(0.29)	7.18	(0.34)	−6.03
Average cost per inpatient stay (RMB)	5184.23	(486.23)	5017.03	(753.86)	−3.23	5765.78	(248.23)	5528.43	(302.68)	−4.12
Average medication cost per inpatient stay (RMB)	1069.51	(199.90)	890.19	(225.20)	−16.77	1099.17	(148.79)	999.07	(136.76)	−9.11
Medication cost ratio (%)	20.63	(3.26)	17.51	(2.20)	−15.12	19.05	(2.34)	18.02	(1.87)	−5.40
Average material cost per inpatient stay (RMB)	32.75	(45.73)	58.50	(13.48)	78.61	433.29	(68.71)	550.33	(137.44)	27.01
Material cost ratio (%)	0.67	(1.00)	1.17	(0.18)	73.42	7.52	(1.24)	9.92	(2.31)	31.86
Cost consumption index	1.01	(0.04)	0.98	(0.02)	−2.44	1.07	(0.03)	1.06	(0.02)	−0.90
Time consumption index	1.01	(0.05)	1.02	(0.03)	0.93	0.99	(0.04)	0.99	(0.03)	0.21

Abbreviations: SD, Standard Deviation; CR, Change Ratio (%).

Post-reform, the Neurology Department showed significant improvements in inpatient service capacity: Total DRG weight increased by 32.37%, Case Mix Index (CMI) by 12.21%, and Number of DRGs by 8.94%. The Average Length of Stay (days) decreased by 9.85%. Average Cost per Inpatient Stay (RMB) decreased by 3.23%, Average Medication Cost per Inpatient Stay (RMB) dropped by 16.77%, and the Medication Cost Ratio (%) fell by 15.12%. Regarding efficiency, the Cost Consumption Index decreased by 2.44%, while the TEI saw a 0.93% reduction.

However, the Average Material Cost per Inpatient Stay (RMB) rose by 78.61%, with the Material Cost Ratio (%) increasing by 73.42%. To clarify, the material cost surge in 2023 is mainly due to significant investments in advanced medical equipment and infrastructure at the hospital. These upgrades, aimed at enhancing diagnostic and treatment capabilities, included the acquisition of high-cost items such as a thrombolysis bed, hyperbaric oxygen chambers, CT and MRI machines, and EEG systems. Additionally, the hospital improved its diagnostic services with electromyography (EMG), sleep and respiratory monitoring equipment, transcranial Doppler ultrasound, and tools for cerebrospinal fluid testing and blood drug concentration monitoring.

Compared to the other departments, the Neurology Department outperformed in Total DRG weight (32.37% vs 10.45%), CMI (12.21% vs 0.79%), and Number of DRGs (8.94% vs 4.21%), with a more substantial reduction in the Average Length of Stay (-9.85% vs -6.03%). Cost-wise, the Neurology Department's Average Cost per Inpatient Stay saw a smaller decrease (-3.23% vs 4.12%), but had greater reductions in Average Medication Cost (-16.77% vs -9.11%) and Medication Cost Ratio (-15.12% vs -5.40%), with larger increases in Material Costs and Material Cost Ratio compared to the other departments. The Neurology Department also experienced a greater decline in CEI (-2.44% vs -0.90%) and a higher increase in TEI (0.93% vs 0.21%).

Interrupted Time-Series Analysis Impact on Inpatient Service Capacity

As demonstrated in Table 3 and Figure 2, the implementation of DRGs reform has to some extent improved the neurology department's inpatient service capacity. Post-reform, the Total DRGs weight's trend of the neurology ($\beta_1 + \beta_3 + \beta_5 + \beta_7$) department increased by 2.16 ($P < 0.01$). The reform's immediate effect on CMI is shown in

Table 3 ITS Results of DRGs Reform on Inpatient Service Capability

Coefficients and Other Values			Y1		Y2		Y3	
			Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
The other 35 departments (control group)	Pre-reform	Mean value at the baseline (β_0)	2132.88	<0.001	1.03	<0.001	306.80	<0.001
		Pre-trend (β_1)	-2.09	0.811	0.00	0.405	0.44	0.513
	Post-reform	Post-level change (β_2)	36.40	0.849	0.00	0.989	-11.53	0.480
Post-trend change (β_3)		26.81	0.042	0.00	0.794	1.81	0.175	
Difference in 2 groups	Pre-reform	Pre-level difference (β_4)	-2048.08	<0.001	-0.04	0.082	-282.20	<0.001
		Pre-trend difference (β_5)	2.27	0.796	0.00	0.131	-0.50	0.464
	Post-reform	Post-level difference (β_6)	-28.90	0.880	-0.03	0.373	15.07	0.361
		Change in slope difference pre-to-post (β_7)	-24.83	0.049	0.01	0.005	-1.83	0.176
Post-reform trend		Treatment group ($\beta_1 + \beta_3 + \beta_5 + \beta_7$)	2.16	0.001	0.01	<0.001	-0.08	0.666
(treatment group)		Control group ($\beta_1 + \beta_3$)	24.72	0.014	0.00	0.665	2.25	0.037
		Difference ($\beta_5 + \beta_7$)	-22.56	0.026	0.01	<0.001	-2.33	0.033
Model significance		F	450.37		20.44		1076.35	
		P-value	<0.001		<0.001		<0.001	
Durbin-Watson statistic		Original	2.15		1.92		1.93	
		Transformed	1.96		1.91		2.01	

Notes: Y1 represents Total DRGs weight (total weight), Y2 represents Case mix index (CMI), Y3 represents Number of disease types in DRGs. This is a Generalized Linear Model (GLM) with a Gaussian family, identity link function, and Newey-West standard errors adjusted for a lag of 1.

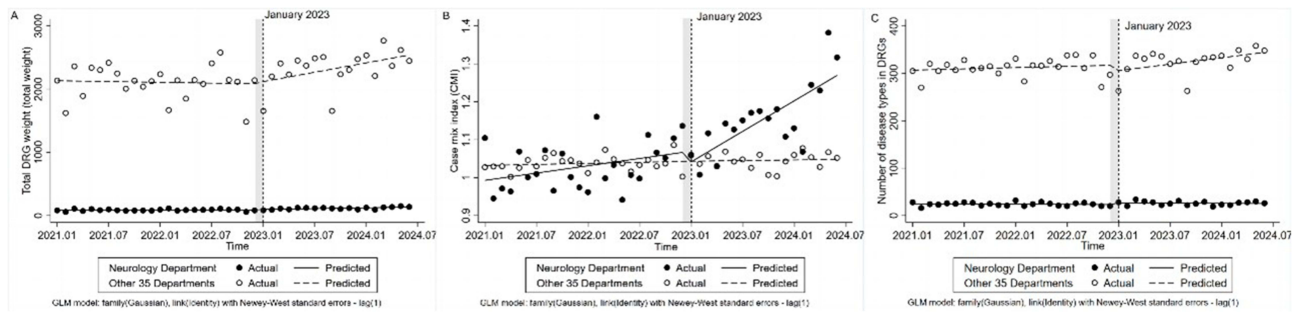


Figure 2 Impact of DRGs Reform on Neurology Department Service Capability: (A) Total DRGs Weight, (B) Case Mix Index and (C) Disease Type Diversity. The gray area represents the Chinese Lunar New Year (December 2022 to January 2023).

Figure 2B, where the slope of the department's CMI level exhibits an upward trend. After the reform, the CMI value of the department ($\beta_5 + \beta_7$) increased by 0.01 relative to the M Hospital's other 35 departments ($P < 0.01$).

Impact on Inpatient Service Cost

The interrupted time series analysis reveals the impact of DRGs reform on the temporal and economic costs of inpatient services in the neurology department, as shown in Table 4 and Figure 3. Post-reform, the trend of average length of stay decreased by 0.04 ($P < 0.01$). As shown in Figure 3B, the average cost per inpatient stay changed in both value and slope, with a post-reform trend decrease of 121.65 ($P < 0.01$). In other departments, the average cost per stay decreased by 45.55 RMB ($P < 0.01$).

Figure 3C shows a significant change in the slope of average medication costs. After the reform, the slope in other departments increased by 252.52 RMB ($P < 0.01$), with a level decrease of 12.29 RMB ($P < 0.05$), while in neurology, the trend decreased by 39.71 ($P < 0.01$). The medication cost ratio (%) rose by 4.22 in other departments ($P < 0.01$) but decreased by 0.30 in neurology ($P < 0.01$). Statistically significant post-reform differences were observed between neurology and other departments for length of stay, cost per stay, and medication costs ($P < 0.05$).

Impact on Inpatient Service Efficiency

The impact of the DRGs reform on the efficiency of inpatient services in the neurology department was limited. Changes in the CEI and TEI before, during, and after the reform were not significant, as shown in Table 5 and Figure 4. However, there was a gap effect between the other departments and the neurology department on the CEI, with the latter index increasing by 0.01 post-reform ($P < 0.01$).

Residual Plot

The Residual Plot of ITS Analysis for Total DRGs Weight, Case Mix Index, and Other DRGs Indicators (Y1 - Y11) serves as an essential diagnostic tool in evaluating the performance of the Interrupted Time Series (ITS) model. By examining the residuals, as Figure 5, we can assess the adequacy of the model's fit to the data and verify the underlying assumptions of the analysis, such as linearity, independence, and homoscedasticity. A random distribution of residuals around zero would indicate that the model is correctly specified, while any discernible pattern or trend in the residuals may suggest model mis-specification or the presence of unaccounted-for variables. Furthermore, the residual plot allows for the identification of outliers and influential data points, which may significantly affect the results of the analysis. Ultimately, this diagnostic step ensures the robustness of the ITS model and enhances the reliability of policy impact evaluations based on DRGs-related indicators.

Discussion

To our best knowledge, this study is the first in underdeveloped regions to employ interrupted time series design to assess the impact of DRGs reform on neurology inpatient services performance. In January 2023, M Hospital in A City, Yunnan Province, implemented DRGs payment reform. Post-DRG reform, the Neurology Department saw increases in DRG

Table 4 ITS Results of DRGs Reform on Inpatient Service Cost for Y4-Y9

Coefficients and Other Values			Y4		Y5		Y6		Y7		Y8		Y9	
			Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
The other 35 departments (control group)	Pre-reform	Mean value at the baseline (β_0)	7.53	<0.01	5735.79	<0.01	1235.08	<0.01	21.53	<0.01	440.68	<0.01	7.66	<0.01
	Post-reform	Pre-trend (β_1)	0.01	0.255	2.61	0.713	-11.82	0.014	-0.22	<0.01	-0.64	0.773	-0.01	0.781
Difference in 2 groups	Post-reform	Post-level change (β_2)	-0.11	0.502	95.03	0.448	252.52	<0.01	4.22	<0.01	87.81	0.305	1.13	0.43
		Post-trend change (β_3)	-0.06	<0.01	-45.55	0.01	-12.29	0.032	-0.08	0.284	5.02	0.345	0.18	0.032
	Pre-reform	Pre-level difference (β_4)	0.64	0.016	-924.39	<0.01	-109.89	0.267	1.69	0.206	-403.20	<0.01	-6.83	<0.01
		Pre-trend difference (β_5)	-0.06	0.002	29.81	0.031	6.98	0.336	-0.01	0.923	0.23	0.932	0.00	0.97
	Post-reform	Post-level difference (β_6)	0.36	0.193	366.53	0.273	-33.79	0.782	-1.47	0.418	-48.39	0.581	-0.53	0.72
		Change in slope difference pre-to-post (β_7)	0.07	0.003	-108.53	<0.01	-22.58	<0.01	-0.05	0.715	0.58	0.313	-0.16	0.076
Post-reform trend (treatment group)		Treatment group ($\beta_1 + \beta_3 + \beta_5 + \beta_7$)	-0.04	<0.01	-121.65	<0.01	-39.71	<0.01	-0.36	<0.01	-1.00	0.007	0.00	0.280
		Control group ($\beta_1 + \beta_3$)	-0.06	<0.01	-42.94	<0.01	-24.10	<0.01	-0.30	<0.01	4.38	0.415	0.17	0.049
		Difference ($\beta_5 + \beta_7$)	0.01	0.409	-78.71	<0.01	15.605	0.002	-0.06	0.490	-5.39	0.319	-0.16	0.061
Model significance		F	16.43		18.43		9.97		12.59		71.73		27.01	
		P-value	<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Durbin-Watson statistic		Original	2.19		1.93		1.42		1.01		1.72		1.96	
		Transformed	2.02		1.97		2.02		2.04		1.96		1.95	

Notes: Y4 represents Average length of stay (days), Y5 represents Average cost per inpatient stay (RMB), Y6 Average medication cost per inpatient stay (RMB), Y7 represents Medication cost ratio (%), Y8 represents Average material cost per inpatient stay (RMB), Y9 represents Material cost ratio (%). This is a Generalized Linear Model (GLM) with a Gaussian family, identity link function, and Newey-West standard errors adjusted for a lag of 1.

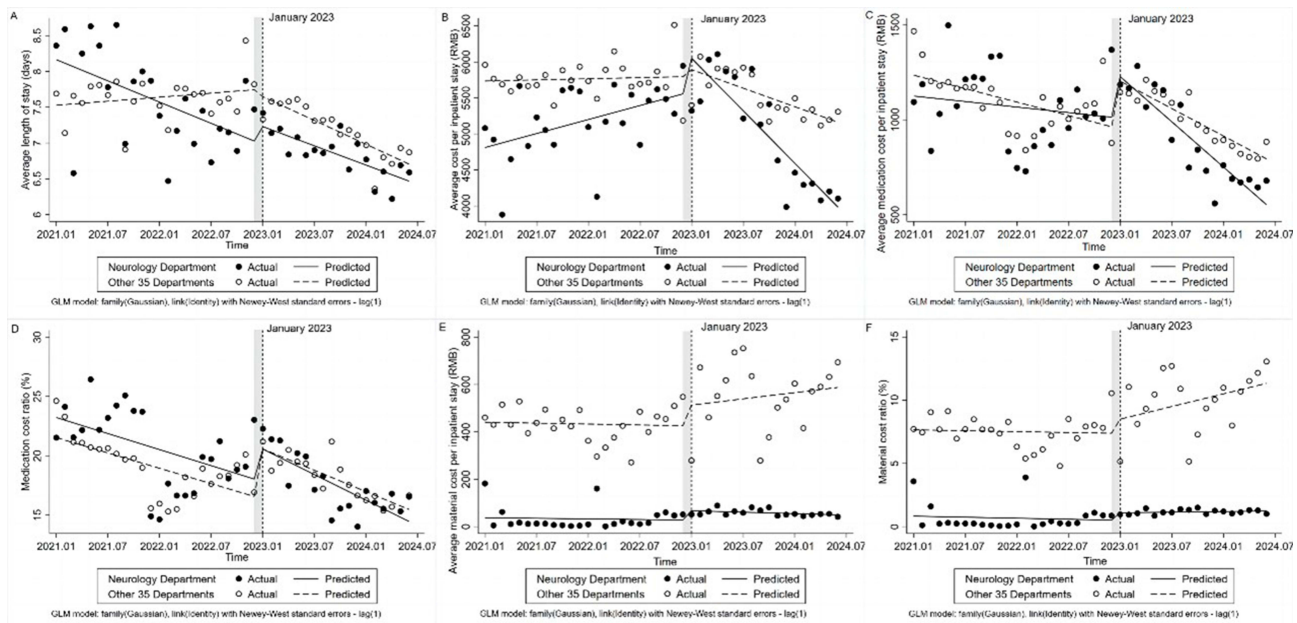


Figure 3 Impact of DRGs Reform on Service Cost in Neurology Department: **(A)** Average Length of Stay (Days), **(B)** Average Cost per Inpatient Stay (RMB), **(C)** Average Medication Cost per Inpatient Stay (RMB), **(D)** Medication Cost Ratio (%), **(E)** Average Material Cost per Inpatient Stay (RMB) and **(F)** Material Cost Ratio (%). The gray area represents the Chinese Lunar New Year (December 2022 to January 2023).

weight (32.37%), CMI (12.21%), and reductions in length of stay (−9.85%) and medication costs (−16.77%). It outperformed other departments in DRG weight, CMI, and efficiency, with a smaller decrease in overall costs but larger drops in medication expenses. Using interrupted time series analysis, post-reform, the neurology department’s total DRGs weight exhibited a significant upward trend, increasing by 2.16 ($P < 0.01$), while the trend of average length of

Table 5 ITS Results of DRGs Reform on Inpatient Service Efficiency for Y10 and Y11

Coefficients and Other Values			Y10		Y11	
			Coefficient	P-value	Coefficient	P-value
The other 35 departments (control group)	Pre-reform	Mean value at the baseline (β_0)	1.06	<0.01	0.99	<0.01
		Pre-trend (β_1)	0.00	0.598	0.00	0.977
	Post-reform	Post-level change (β_2)	0.01	0.715	0.01	0.579
		Post-trend change (β_3)	0.00	0.018	0.00	0.569
Difference in 2 groups	Pre-reform	Pre-level difference (β_4)	−0.01	0.512	0.02	0.623
		Pre-trend difference (β_5)	0.00	0.002	0.00	0.888
	Post-reform	Post-level difference (β_6)	0.00	0.943	0.02	0.476
		Change in slope difference pre-to-post (β_7)	0.01	<0.01	0.00	0.431
Post-reform trend (treatment group)	Treatment group ($\beta_1 + \beta_3 + \beta_5 + \beta_7$)		0.00	0.142	−0.00	0.01
	Control group ($\beta_1 + \beta_3$)		−0.00	0.028	−0.00	0.400
	Difference ($\beta_5 + \beta_7$)		0.00	0.005	−0.00	0.206
	Model significance		F	27.01		2.14
		P-value	<0.01		0.049	
Durbin-Watson statistic	Original		1.96		1.52	
	Transformed		1.95		1.67	

Note: Y10 represents CEI and (3B) Time consumption index, Y11 represents TEI.

stay decreased by 0.04 ($P < 0.01$). Additionally, the average cost per inpatient stay experienced a post-reform decline, with a trend decrease of 121.65 ($P < 0.01$). The reform improved service capacity and reduced costs, providing evidence for similar reforms in underdeveloped regions.

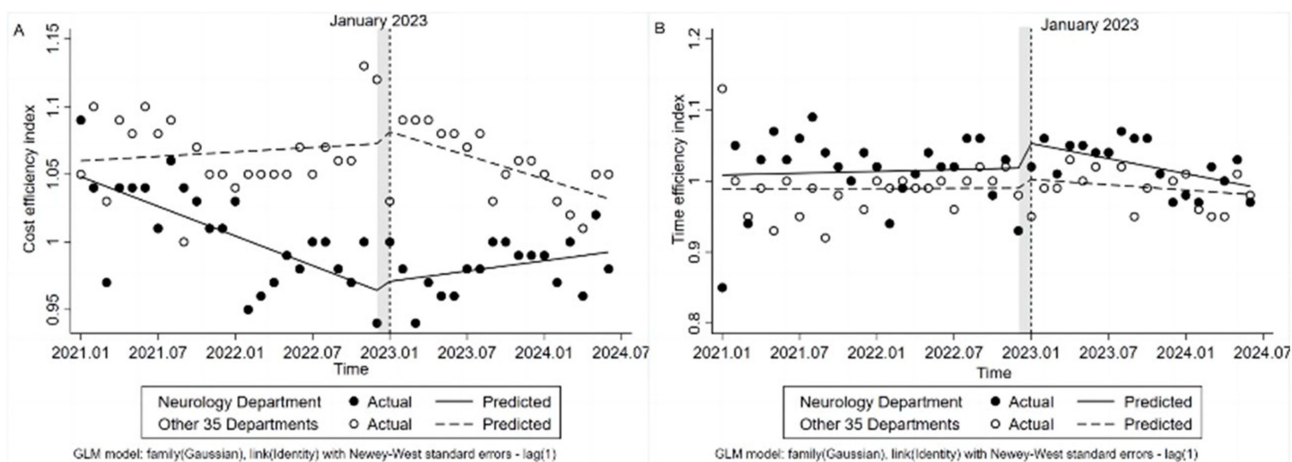


Figure 4 Impact of DRGs Reform on Service Efficiency in Neurology Department: (A) CEI and (B) Time consumption index. The gray area represents the Chinese Lunar New Year (December 2022 to January 2023).

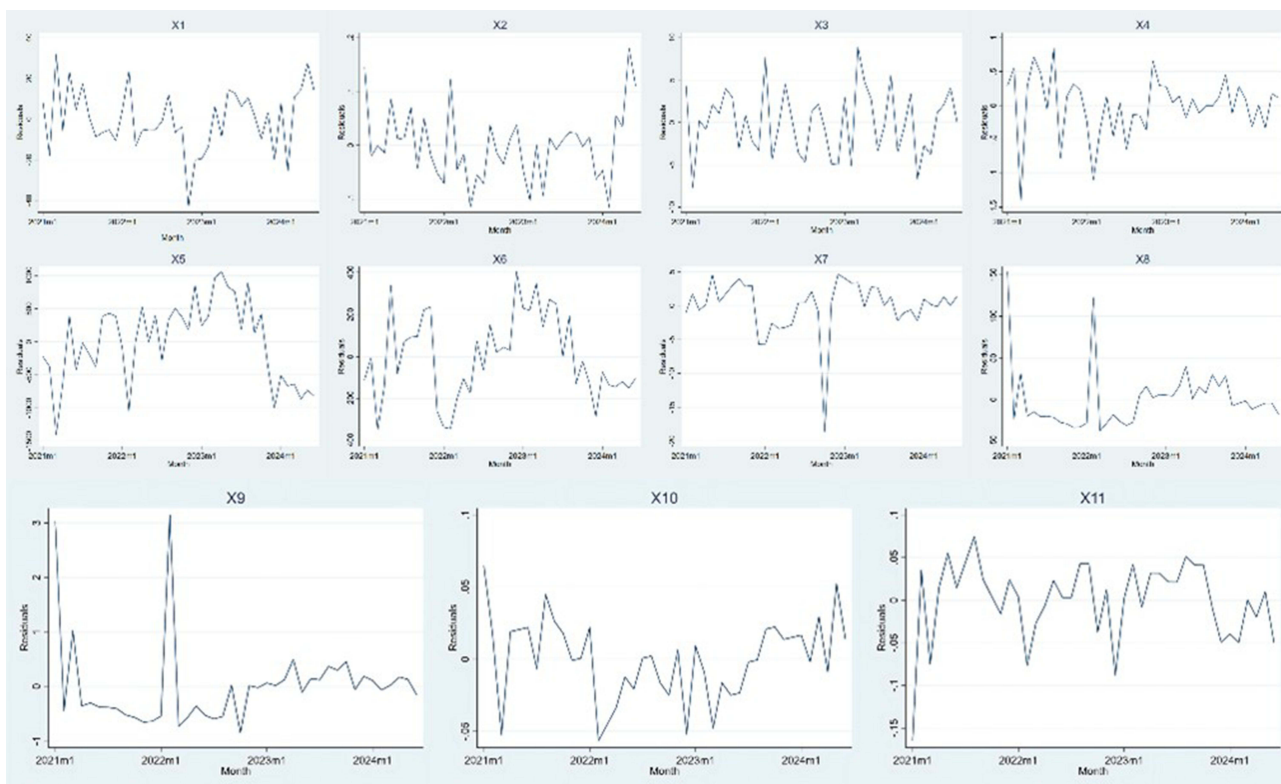


Figure 5 Residual Plot of ITS Analysis for Total DRGs Weight, Case Mix Index, and Other DRGs Indicators (Y1 - Y11).

In this study, the Neurology Department’s inpatient service capacity improved post-reform, with a 32.37% increase in total DRG weight, a 12.21% rise in CMI, and an 8.94% growth in the number of DRGs. Post-DRGs reform, M Hospital’s Department of Neurology has increasingly admitted patients with more complex conditions and higher DRGs codes to elevate charge levels and improve profit margins. As an indicator of case complexity, the increase in CMI suggests that the department had an economic incentive to admit more severe or complex cases, aligning with higher DRG codes.³⁷ This trend is consistent with findings from other studies, such as in Hunan Province, where the average annual CMI growth rate was 0.95% post-DRGs reform.³⁸ The reform also improved medical record accuracy, leading to more precise diagnoses and coding. However, the impact of the COVID-19 pandemic in 2022–2023, with many patients presenting

concurrent respiratory conditions, may have influenced these results. These findings differ from those in Beijing,¹⁰ where hospitals under DRG-based payment systems focus on cost control and may adjust patient mix to enhance profitability.¹⁰ Similarly, in Shanghai's Jiading district, CMI decreased by 0.103 ($P < 0.05$) from 2013 to 2019,³⁹ reflecting a strategic shift towards reducing the proportion of severe or surgical cases under DRGs policies. DRGs may more effectively enhance inpatient service capacity in economically underdeveloped areas.

A City's DRGs reform reduced neurology department service time and cost. Post-reform, the trend of neurology department's average length of stay decreased by 0.04. The reduction in time costs in this study is less pronounced compared to other countries. In Germany, from 2004 to 2014, the average length of stay decreased by 0.46 days,⁴⁰ while in England, from 2002 to 2014, the average length of stay for elective and emergency treatments decreased by 1.2 days following DRGs reform.^{41,42} In Sichuan, China the average length of stay decreased by 1.35 days from 2018 to 2021 after the reform.⁴³ The phenomenon may be due to the growing complexity of patient conditions, as the DRGs system pressures the department to attract higher-code cases with complications. Additionally, as the lead hospital in a medical consortium managing 103 village clinics, it receives referrals of complex cases, particularly in neurology, where patients often have underlying diseases and complications.

After the DRGs reform, neurology saw a larger reduction in average inpatient costs per stay, decreasing by 108.53 RMB compared to other departments. In China, the total inpatient cost for stroke patients was lowest under fee-for-service (FFS) compared to global budget, bundled payments, and capitation. In Japan, the 2003 DRGs reform for acute myocardial infarction reduced cumulative hospital costs by 1061 USD.^{44,45} The DRGs reform in a Chinese city led to a reduction of 131.526 RMB and 21.631 RMB in public tertiary and secondary hospitals,²¹ respectively, for ischemic stroke patients with major complications. The core of the DRGs reform in reducing inpatient services for neurology patients is to optimize diagnostic and treatment pathways for various conditions, thus controlling costs. It also lowers medication expenses by improving medical record accuracy, enabling precise diagnosis and treatment, and reducing unnecessary prescriptions. Despite reduced inpatient costs, the medication cost ratio increased by 0.18%. This increase may be due to the need for upgrading outdated equipment, like MRI (Magnetic Resonance Imaging), in economically underdeveloped areas, which raises operating costs.

The TEI showed minimal impact post-reform, while the CEI increased by 0.01 compared to the other departments. Compared to other relatively economically developed areas in Yunnan Province, the DRGs system has brought the two variables of inpatient neurology services in City A to parity with those in other regions. The impact of DRGs on time efficiency and cost efficiency in economically underdeveloped regions appears minimal. This is likely due to the DRGs reform increasing the average length of stay, group costs, and case numbers in the neurology department. Essentially, A Hospital's adjustment under DRGs has led to more complex patient conditions and higher case volumes, resulting in stable Cost Efficiency Index (CEI) and Time Efficiency Index (TEI). In Shanghai, the DRGs reform has led to an increase in inpatient service resource consumption, with the Time Efficiency Index (TEI) level rising by 0.12 ($P < 0.05$) and the trend declining by 0.01 ($P < 0.05$).³⁹ This may be related to the shift in inpatient services towards more resource-intensive medical services, a trend observed in economically developed regions following DRGs reform. Healthcare institutions in economically underdeveloped regions should regularly assess and adjust treatment plans to ensure profitability under the DRGs payment system, improving the efficiency of medical insurance funds.

In discussing the economic impacts of the reform, it is important to address the apparent contradiction between the significant material cost surge of 78% and the overall cost reduction observed. Interviews and consultations with department heads reveal that the surge in material costs is largely attributed to substantial investments in medical equipment and infrastructure following the reform. Specifically, since 2023, the establishment of a specialized stroke unit, along with the addition of a thrombolysis bed, four hyperbaric oxygen chambers, and new diagnostic equipment, has significantly contributed to this increase. The newly acquired equipment includes CT and MRI machines, EEG systems (EEG-1200C, dynamic), EMG and evoked potential devices, multi-channel sleep apnea monitoring devices, vascular ultrasound machines, transcranial Doppler systems, cerebrospinal fluid testing equipment, and anti-epileptic blood drug concentration monitoring instruments. These upgrades, aimed at improving diagnostic capabilities and patient care, have led to a marked increase in material costs, which must be carefully considered when interpreting the broader economic effects of the reform. This increase in costs does not necessarily contradict the overall trend of cost reduction in other

areas but highlights the complexities introduced by new technologies and specialized equipment in modern medical practice. Similar evidence⁴⁶ includes a 2004 study that evaluated the cost of a single-person hyperbaric oxygen chamber.⁴⁷ The results showed that the initial setup cost ranged from £64,800 to £110,000, with annual costs (including 10 years of depreciation) ranging from £40,069 to £57,618, and per-treatment costs ranging from £30 to £41. Another study, conducted in Germany, assessed the cost of acute-phase care in stroke units. The study found that imaging studies accounted for 10% of the total cost, while laboratory tests accounted for 14%.⁴⁸

Limitations and Future Research

This study has several limitations. First, while the focus on neurology fills a critical gap in knowledge, it is limited to a single hospital setting. The findings may not be generalizable to other institutions, and the results need to be validated through multi-site studies to ensure broader applicability across different healthcare environments and regional contexts.

Second, while the issue of material cost surges post-reform is discussed, there is a lack of contextualization, particularly regarding MRI fee structures and supply chain issues in underdeveloped regions. Concrete examples, such as the cost of MRI procedures and regional disparities in supply chain access, would clarify how these factors contribute to material cost increases and their impact on hospital operations.

Third, although the impact of COVID-19 during 2022–2023 is mentioned, its effects were neither quantified nor adjusted for in the analysis, which could confound the results of the DRG reform. The pandemic disrupted hospital workflows, patient volumes, and medical resource allocation, and further research is needed to adjust for these factors and examine their influence on the reform's outcomes.

Furthermore, while this study focuses on major diseases likely to lead to catastrophic health expenditures, it does not address chronic diseases, which involve multiple complex factors and have distinct reimbursement mechanisms, such as outpatient reimbursement and special disease categories. Although this limitation may prevent a complete understanding of the impact of health insurance payment reforms on medical outcomes and financial protection for ethnic minorities, focusing on major diseases lays a solid foundation for future studies on chronic disease care.

Additionally, key patient outcome metrics such as readmission rates and mortality are absent, limiting the comprehensive assessment of the reform's effectiveness. Future research should incorporate these indicators to assess the impact of the reform not only on cost-efficiency but also on patient health outcomes.

Lastly, the substantial pre-reform differences in baseline costs and trends between the control groups—such as variations in surgical volume, case complexity, and specialty—were not fully accounted for in the causal interpretation. These differences need to be addressed to ensure a more accurate understanding of the reform's effects.

Conclusion

This study investigates the impact of the DRG-based payment reform on neurology inpatient services in A City, Yunnan Province, which was implemented in January 2023. The findings indicate significant improvements in service efficiency, including a 32.37% increase in DRG weight, a 12.21% rise in the Case Mix Index (CMI), and an 8.94% increase in the number of DRG categories. These changes reflect better management of case complexity and a more diverse patient mix. Furthermore, average inpatient length of stay (ALOS) decreased by 9.85%, and medication costs per inpatient stay dropped by 16.77%, underscoring the reform's efficiency in reducing service time and cost. However, a surge of 78% in material costs was observed, which contradicts the overall reduction in costs. This increase is largely attributable to substantial investments in advanced medical equipment, including MRI and CT machines, EEG systems, and other diagnostic tools, which were implemented to enhance diagnostic capabilities and improve patient care. While these upgrades are essential for improving the quality of care, they significantly impacted material costs, a factor that warrants further examination in future studies.

Additionally, the comparison between the neurology department and other departments must be considered with caution. The lack of detailed control group composition and the potential differences in specialties, such as the varying complexity of neurological cases, could undermine the validity of cross-department comparisons. Future research should account for these disparities to ensure a fair comparison. The study also revealed a minimal improvement in time efficiency, as indicated by the 0.93% reduction in the Time Efficiency Index (TEI), which calls attention to the need for

strategies to address time efficiency trade-offs. Furthermore, while the impact of COVID-19 is acknowledged, its potential confounding effect on the results remains unquantified. Future research should consider adjusting for pandemic-related disruptions to more accurately evaluate the reform's impact. In conclusion, while the DRG reform has proven effective in improving efficiency and reducing costs in the neurology department, the increased material costs and the need for further exploration of time efficiency trade-offs highlight areas for improvement. Multi-site validation and the inclusion of quality metrics in future studies will provide a more holistic understanding of the reform's effects, both in China and in similar resource-limited settings across undeveloped areas.

Data Sharing Statement

The data underpinning the findings of this study are accessible through the Medical Records Department of M Hospital in City A. However, the availability of these data is subject to limitations, as they were utilized under a specific license for the current study and are not, therefore, freely available to the public. Nonetheless, the data may be obtained from the corresponding author upon reasonable academic request and with the approval of the ethical review process. Please contact the author at the Email address dusixian16@163.com for further inquiries.

Ethics Approval and Consent to Participate

The data underpinning the findings of this study are accessible through the Medical Records Department of M Hospital in City A. Data were collected directly from clinical departments and were also submitted to the Yunnan Provincial Health Commission for assessing the effects of the DRGs reform. Ethics approval for this study was obtained from the Ethics Review Committee at Huazhong University of Science and Technology, Tongji Hospital (approval number: 21YJA630062).

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Disclosure

The authors report no conflicts of interest in this work.

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