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ORIGINAL RESEARCH

# Impacts of DRG-Based Prepayment Reform on the Cost and Quality of Patients with Neurologic Disorders: Evidence from a Quasi-Experimental Analysis in Beijing, China

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**Purpose:** As one of the pioneering pilot cities in China's extensive Diagnosis Related Groups (DRG) -based prepayment reform, Beijing is leading a comprehensive overhaul of the prepayment system, encompassing hospitals of varying affiliations and tiers. This systematic transformation is rooted in extensive patient group data, with the commencement of actual payments on March 15, 2022. This study aims to evaluate the effectiveness of DRG payment reform by examining how it affects the cost, volume, and utilization of care for patients with neurological disorders.

**Patients and Methods:** Utilizing the exogenous shock resulting from the implementation of the DRG-based prepayment system, we adopted the Difference-in-Differences (DID) approach to discern changes in outcome variables among DRG payment cases, in comparison to control cases, both before and following the enactment of the DRG policy. The analytical dataset was derived from patients diagnosed with neurological disorders across all hospitals in Beijing that underwent the DRG-based prepayment reform. Strict data inclusion and exclusion criteria, including reasonableness tests, were applied, defining the pre-reform timeframe as March 15th through October 31st, 2021, and the post-reform timeframe as the corresponding period in 2022. The extensive dataset encompassed 53 hospitals and encompassed hundreds of thousands of cases.

**Results:** The implementation of DRG-based prepayment resulted in a substantial 12.6% decrease in total costs per case and a reduction of 0.96 days in length of stay. Additionally, the reform was correlated with significant reductions in overall in-hospital mortality and readmission rates. Surprisingly, the study unearthed unintended consequences, including a significant reduction in the proportion of inpatient cases classified as surgical patients and the Case Mix Index (CMI), indicating potential strategic adjustments by providers in response to the introduction of DRG payments.

**Conclusion:** The DRG payment reform demonstrates substantial effects in restraining cost escalation and enhancing quality. Nevertheless, caution must be exercised to mitigate potential issues such as patient selection bias and upcoding.

**Keywords:** diagnosis-related groups, payment reform, neurological disorders, DID, China

## Introduction

Medical services, characterized by heightened technical intricacies and a diverse range of outputs, present challenges for straightforward comparisons.[1] To tackle this issue, the concept of "Case-mix" has emerged, entailing the categorization of patients according to specific characteristics, including clinical features, medical resource consumption, and other pertinent indicators. This approach enables direct comparisons among cases within the same group and facilitates comparisons across different groups through "risk adjustment".[2] Originating in the 1970s, DRG is among the various case mixes. It predominantly



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relies on diagnoses, considering treatment methods and patient demographic characteristics. DRG effectively categorizes medical services into distinct products, laying the groundwork for the formulation of payment standards.[3] In 1983, the United States of America implemented the DRG-based Prospective Payment System (DRG-PPS) for Medicare. This system establishes payment standards for each group through rigorous calculations based on DRG grouping, serving as a method for upfront payments to medical institutions. Widely adopted worldwide for inpatient charge settlements, this payment approach is perceived as a mechanism to incentivize medical service providers to improve efficiency and manage costs.[4]

China stands among the early adopters of DRG.[5] Since 2009, the Chinese government has actively propelled the reform of medical insurance fund payment methods, transitioning from fee-for-service (FFS) to forward-looking and comprehensive payment approaches. DRG-PPS emerges as a pivotal alternative to traditional payment modalities, representing a significant stride in the hybrid payment system of hospitals. Initial forays into DRG payments were confined to fixed fees for straightforward conditions with minimal complications, such as non-suppurative appendicitis, gallstones, and cesarean sections. In 2019, the National Healthcare Security Administration of China initiated a nationwide pilot program for DRG-PPS reform across 30 cities, marking the onset of comprehensive DRG prepayment reforms for all inpatient diseases.[6]

The payment method signifies how service buyers remunerate medical service providers for the services rendered, playing a pivotal role in allocating medical resources, shaping health provider behavior, and achieving health system objectives.[7] In studies conducted in countries employing DRG-PPS, the impact of the reform on the quality of medical services appears to be mixed. Some scholars assert that the implementation of DRG-PPS contributes to an enhancement in the quality of medical services.[8] Conversely, others contend that following implementation, because of governmental, medical insurance, and hospital cost control requirements, physicians may limit services during the diagnosis and treatment processes. This could potentially result in the delivery of lower-cost services rather than those that are more appropriate and of higher quality.[9–11] Furthermore, empirical research on the impact of payment method reforms on medical service quality is primarily concentrated in high-income countries, with limited evidence available for low- and middle-income countries.[12] China's public hospitals predominantly depend on service provision as a revenue source, rather than public funds or government budgets, with medical insurance funds serving as the primary purchaser of medical services. Consequently, hospitals are particularly sensitive to the financial incentives introduced by the reforms in medical insurance fund payment methods.[13,14.]

The costs, quality, and other attributes of different diseases exhibit significant variation, and utilizing data from the entire population does not accurately capture the impacts of the reforms. As a result, we concentrate on a specific group of diseases for analysis. Nervous system diseases encompass a range of conditions resulting from various factors that impair the structure or function of the brain and spinal cord, including neurodegenerative diseases, central nervous system tumors, and neurodevelopmental disorders. Given their current challenges in diagnosis and treatment, these neurological diseases often exhibit poor prognoses.[15] Neurological diseases pose a substantial public health threat due to their high incidence rates and significant economic burdens. Cerebrovascular diseases were one of the top three leading causes of death among Beijing residents in 2022, accounting for 19% of the total deaths. The total cost per case exceeds 16,000 RMB, surpassing 50% of the national per capita disposable income (35,100 RMB). This study concentrates on neurological diseases as the study group, utilizing the DID method to discern changes in outcomes between DRG payment cases and control cases before and after alterations in payment methods.

## Institutional Background

Beijing, the capital of China, sustains a permanent population of 21.843 million as of the end of 2022.[16] Renowned for its abundant medical resources and cutting-edge medical and health technologies, Beijing has positioned itself at the forefront of DRG research and PPS payment reform in China. In 2008, the city successfully initiated China's first DRG localization program (BJ-DRG).[17] Subsequently, in 2011, 108 DRG disease groups were identified, and data simulations were conducted in six hospitals, marking an exploratory phase with no actual payments involved. As part of China's comprehensive push for DRG-PPS reform, Beijing, serving as one of the inaugural pilot cities, implemented a prepayment system reform based on comprehensive disease group data for hospitals of varying levels and affiliations. On March 15, 2022, actual payments were initiated across 66 designated medical institutions. Beijing's social insurance system comprises two main components: the Urban Employee Basic Medical Insurance Plan (UEBMI) and the Urban

and Rural Resident Basic Medical Insurance System (Since 2015, this includes the original Urban Resident Basic Medical Insurance Plan (URBMI) and the New Cooperative Medical Plan (NCMS)).[18] The reform's scope encompasses short- and medium-term hospitalization cases of individuals insured under the city's primary medical insurance (UEBMI) who receive treatment in designated medical institutions. The cost range encompasses all expenses incurred by the insured person during hospitalization, covering examination fees, laboratory tests, surgery fees, treatment fees, medication fees, health material fees, bed fees, and other related costs.

The DRG grouping is rooted in the primary diagnosis found on the medical record's homepage, utilizing anatomy and physiological systems as the primary classification criteria. Cases are categorized into Major Diagnostic Categories (MDC) concerning the International Classification of Diseases, Tenth Edition (ICD-10). The name of the MDC for neurological diseases is "neurological diseases and dysfunctions", and the MDC code is "MDCB". Within each major category, cases are further divided based on treatment methods into three categories: "Surgery" "Non-surgical Procedures" (including special examinations such as catheters, endoscopy, etc.)" and "Internal Medicine " Cases sharing the same primary diagnosis and primary operation are amalgamated into Adjacent Diagnosis Related Groups (ADRG). In this classification process, clinical experience classification takes precedence, considering clinical similarities, with statistical analysis serving as a supplementary tool. Ultimately, cases are further stratified into DRG, accounting for other individual characteristics, comorbidities, and complications of the cases. The DRG is denoted by a four-digit code corresponding to the grouping basis. The first digit signifies the MDC and the second digit indicates the treatment method of the DRG. The third digit denotes the sequence code of the ADRG, and the fourth digit indicates the presence of comorbidities and complications. The MDCB includes 29 ADRGs and 71 DRGs.

# Materials and Methods

## Material

The dataset employed in this research was extracted from the inpatient medical records of hospitals engaged in the DRG payment reform pilot in Beijing. These data were procured from the Beijing Health Big Data and Policy Research Center, a key institutional player in the collection, statistical analysis, and curation of healthcare data in the city, thereby harboring extensive data resources.

The inpatient medical records furnished comprehensive details about the patient's treatment facility, essential patient characteristics, diagnoses, surgeries, and associated costs. On cost data, the medical record not only encompassed overall cost information for inpatient cases but also provided itemized cost details such as diagnosis fees and general examination fees. Concerning diagnostic information, the inpatient medical record meticulously documented the type of disease (based on ICD-10) and surgical operation code (based on ICD-9-CM-3) suffered by the patient. This information facilitated the grouping of cases into DRG based on their clinical characteristics and resource consumption.

Our sample consisted of inpatient cases treated in pilot hospitals, as the DRG payment reform specifically targets patients covered by UEBMI. Consequently, Beijing's UEBMI patients were designated as DRG payment cases, while other patients were considered control cases. Participants in the urban employee medical insurance program were aged 16 and above. This study limited the sample to individuals aged 16 and above to ensure comparability between DRG payment cases and other patients. Acknowledging distinct patterns between for-profit and non-profit hospitals post-reform, this article exclusively focused on non-profit hospitals, excluding cases of hospitalization in for-profit facilities. Additionally, to maintain the integrity of the analysis, inpatient cases at hospitals experiencing level changes during the study period were excluded, as these changes could influence charging standards.

To alleviate the potential impacts of the COVID-19 epidemic on hospitalization costs and duration, this study excluded cases in hospitals specifically designated for confirmed COVID-19 patients, cases in other hospitals with the primary or other diagnoses of COVID-19, and cases from months with more severe epidemics in Beijing (November 2021-February 2022). The sample period before the reform was limited to March 15 to October 31, 2021, while the sample period after the reform was restricted to March 15 to October 31, 2022.

The final sample consisted of approximately 250,696 discharged patients from 53 hospitals. Table 1 illustrates sample statistics for both DRG payment cases and the control cases before and after the policy. Panel A presented patient demographics, including age, gender, marital status, and hospital type. Panel B reported individual-level outcome

**Table 1** Descriptive Statistics Before and After DRG-Based Prepayment Reform

| Variables | Before Policy Change (2021) | | After the Policy Change (2022) | |
|---|---|---|---|---|
| | Control Cases | DRG Payment Cases | Control Cases | DRG Payment Cases |
| | (1) | (2) | (3) | (4) |
| **Panel A: Patient Demographics** | | | | |
| Age (years) | 58.94 | 63.57 | 60.34 | 63.39 |
| | (16.63) | (14.08) | (16.70) | (14.21) |
| Male (%) | 53.37 | 60.87 | 53.65 | 60.31 |
| | (49.89) | (48.80) | (49.87) | (48.93) |
| Sample size | 69,105 | 56,620 | 62,647 | 62,324 |
| **Panel B: Individual-Level outcome variables** | | | | |
| In-hospital mortality (%) | 1.00 | 1.29 | 1.17 | 1.04 |
| | (9.95) | (11.27) | (10.73) | (10.15) |
| Readmission rate within 1 day (%) | 3.57 | 2.37 | 4.06 | 1.77 |
| | (18.56) | (15.22) | (19.73) | (13.20) |
| Readmission rate within 2–15 day (%) | 1.01 | 1.11 | 1.10 | 0.91 |
| | (9.99) | (10.50) | (10.41) | (9.52) |
| Readmission rate within 16–31 day (%) | 0.59 | 0.67 | 0.79 | 0.66 |
| | (7.66) | (8.16) | (8.85) | (8.10) |
| Total Costs per case (RMB) | 40,193.86 | 28,986.05 | 37,669.65 | 26,532.29 |
| | (51,332.42) | (39,866.13) | (47,862.65) | (37,766.06) |
| Length of stay (days) | 11.01 | 10.79 | 10.73 | 9.41 |
| | (7.28) | (6.68) | (7.26) | (5.54) |
| CMI | 1.63 | 1.38 | 1.58 | 1.39 |
| | (0.97) | (0.80) | (0.97) | (0.83) |
| Surgery patients (%) | 31.55 | 16.89 | 23.84 | 13.70 |
| | (46.47) | (37.46) | (42.61) | (34.38) |
| Sample size | 69,105 | 56,620 | 62,647 | 62,324 |
| **Panel C: Hospital-Monthly Level outcome variables** | | | | |
| Patients per month(case) | 168 | 149 | 154 | 165 |
| | (291) | (150) | (247) | (192) |
| Sample size | 412 | 380 | 408 | 377 |

**Notes**: Means and standard deviations (in parentheses) are reported for DRG payment cases and control cases both before and after the adoption of the DRG-based payment.

measures, while Panel C provided hospital-monthly-level outcome measures. Notably, a declining trend in average length of stay and cost indicators was observed for both the reform group and the control group following the policy change. However, opposing trends in the in-hospital mortality rate and readmission rate were noted between the reform group and the control group. The rates increased in the control group and decreased in the reform group.

## Statistical Analysis

In empirical research, the DID method is primarily utilized for evaluating policy effects. Compared to other methodologies, DID boasts a straightforward approach: it first examines the changes in individuals affected by a policy before and after its implementation, followed by an assessment of the changes in individuals unaffected by the policy over the same period. The difference between these two sets of changes serves as an indicator of the impact of policy intervention on individuals. This intuitive understanding, coupled with its simplicity and ease of application, has led to the widespread adoption of the DID method. We employed a DID approach to identify the impact of the DRG payment introduction on the cost and quality of healthcare. The model is articulated as follows:

$$Y_{iht} = \alpha + \beta\, Treat * Post + \gamma X_{iht} + \delta_h + \lambda_t + \theta_{iht} \quad (1)$$

The primary explanatory variable, *Treat*Post*, functions as a binary indicator denoting the DRG reform status. Specifically, if the inpatient case falls under the DRG payment scheme and the admission date is after March 15, 2022, it is assigned a value of 1; otherwise, it is set to 0. The coefficient $\beta$ captures the average impact of the reform. $Y_{iht}$ represents various outcomes for a specific hospitalization case $i$ at hospital $h$ and time $t$. Cost variables encompass total costs per case and detailed indicators such as service costs per case, test costs per case, drug costs per case, and material costs per case. Given the typically skewed distribution of medical costs, all cost variables are log-transformed. Quality metrics include in-hospital mortality, and readmission rates within different time frames (<2 days, 2–15 days, 16–31 days). Healthcare utilization is reflected using the length of stay, the proportion of surgical patients, and CMI. $X_{iht}$ encompasses patient characteristics like gender, age, age squared, marital status, occupation, ADRG, and disease severity. $\delta_h$ represents a set of hospital dummy variables accounting for unobserved, time-invariant heterogeneity between hospitals. $\lambda_t$ represents a series of year and month dummy variables aimed at mitigating the impact of time trends on estimation outcomes. $\varepsilon_{iht}$ denotes the error term clustered at the hospital-monthly level.

To examine the impact of payment reforms on the number of hospitalizations, our analysis utilized hospital-month-level data. The model facilitated a comparative evaluation of changes in both the quantity and composition of patients within the reform group as opposed to the control group. The model was articulated as follows.

$$Y_{pht} = \alpha + \beta\, Treat * Post + \eta\, Treat + \gamma X_{pht} + \delta_h + \lambda_t + \theta_{pht} \quad (2)$$

Where $Y_{pht}$ represents the outcomes for either DRG payment cases or control cases in hospital $h$ and months $t$, the binary variable retreat indicates whether the observation pertains to a DRG payment case. Additionally, serves as a hospital-level control variable, encompassing factors such as hospital grade, category, public hospital status, and the actual count of beds and employees. The institutional fixed effect $\delta_h$, time fixed effect at the year-month level $\lambda_t$, and robust standard errors clustered at the hospital-month level are incorporated for robustness.

A crucial assumption of the DID method is comparable pre-reform trends between the reform group and the control group. To ascertain the validity of our research findings, an event analysis method was employed to assess the dependent variables before and after the DRG prepayment reform. The model specified below aims to examine ex-ante parallel trends and estimate the evolving impact of the DRG prepayment reform.

$$Y_{iht} = \alpha + \sum_{k=-9}^{-5} \beta_k D_i^k + \sum_{k=0}^{4} \beta_k D_i^k + \gamma X_{iht} + \delta_h + \lambda_t + \varepsilon_{iht} \quad (3)$$

$D_i^k$ denotes the dummy variable for each month spanning from 5 months before the DRG prepayment for the case to the 5th month post-reform. The initiation of the reform is denoted as$D_i^0$ Taking November 2022 as the base month parents ($D_i^{-5}$) The insignificance of coefficients $\beta_{-6}$, $\beta_{-7}$,$\beta_{-8}$and $\beta_{-9}$ in the months preceding the reform indicates the establishment of an ex-ante parallel trend. Conversely, the coefficients $\beta_1$, $\beta_2$,$\beta_3$ and $\beta_4$ in each month post-reform signify the policy effects during respective periods. This analysis, inclusive of control variables, fixed effects, and cluster-robust standard errors, adheres to consistent standards found in other formulas.

Additionally, to address potential concerns regarding the representativeness of the sample due to a reduction in hospitalization cases during epidemic months, robustness testing incorporated cases from both November 2021 to February 2022 and November 2022 to February 2023.

# Results

## Healthcare Costs

Hospitalization cost served as a crucial metric, reflecting the cost of medical services and resource consumption. When integrated with quality and efficiency indicators, these expenses offered insights into the effectiveness and rationality of medical resource allocation. Post the DRG-PPS, the bundled payment method may further incentivize medical service providers to curtail costs to enhance revenue.[19] Table 2 delineated the estimated impact of reform on healthcare costs. Column (1) showed a discernible effect of the reform in reducing healthcare costs. Specifically, post the policy, the average total cost per case with neurological diseases witnessed a 12.6% decrease (*p-value* <0.01), predominantly driven

**Table 2** Impact of DRG-Based Prepayment Reform on Healthcare Costs

| Variables | Ln (Total Costs per Case) | Ln (Service Costs per case) | Ln (Test Costs per Case) | Ln (Drug Costs per Case) | Ln (Material Costs per Case) |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| **Panel A: ADRG and disease severity as control variables** | | | | | |
| DRG Payment | −0.126*** | −0.092*** | −0.078** | −0.130*** | −0.125*** |
| Standard error | (0.0162) | (0.0142) | (0.0331) | (0.0226) | (0.0195) |
| Observations | 250,696 | 250,696 | 250,696 | 250,696 | 250,696 |
| **Panel B: ADRG as control variable** | | | | | |
| DRG Payment | −0.119*** | −0.089*** | −0.071** | −0.118*** | −0.118*** |
| Standard error | (0.0159) | (0.0140) | (0.0336) | (0.0230) | (0.0191) |
| Observations | 250,696 | 250,696 | 250,696 | 250,696 | 250,696 |

**Note**: *** $p<0.01$, ** $p<0.05$.

by a substantial reduction in drug costs and material costs. As evidenced in columns (2)– (5), DRG payments lead to a 13% reduction in drug costs and a 12.5% reduction in material costs.

Due to the potential strategic upgrading of diagnoses by healthcare providers to secure greater payment, controlling for ADRG and disease severity may have led to an overestimation of the reform's impact on healthcare costs. For instance, after the implementation of DRG reforms, healthcare providers may have reclassified less severe cases into more severe DRG groups, leading to an artificial decrease in average medical costs among DRG payment cases compared to control cases.[20] Given that providers were likely to upgrade cases within the same disease category, we relaxed the control for disease severity, only incorporating ADRG as a control variable to assess the robustness of our findings. Panel B of Table 2 presented the results, indicating that without controlling for patient severity within the same disease category, the reduction in medical costs decreased by 0.7 percentage points, and the reduction in each cost component was less pronounced. This finding suggested a potential for upward coding behavior, albeit small. However, comprehensive judgment and verification had to be undertaken with other contextual factors.

## Healthcare Quality

In-hospital mortality and readmission rates were pivotal metrics for evaluating the quality of medical services. Holding the levels of medical technology and patient severity constant, lower mortality and readmission rates typically indicated higher-quality medical services.[12] Table 3 delineated the estimated impact of reform on healthcare quality. Following the introduction of DRG payments, a significant reduction in In-hospital mortality and readmission rates among hospitalized cases was observed. Notably, the reform exerted its most substantial impact on readmission rates within 1 day, indicating a pronounced reduction in short-term return cases post-reform. To assess the robustness of our findings, measurements were conducted without controlling for the severity of illness among hospitalized cases. As depicted in Panel B, the reduction in In-hospital mortality and readmission rates exhibited a narrower magnitude when severity control was omitted within the same illness category of patients.

To further investigate underlying factors, we stratified subgroups based on treatment modalities, and the impact of DRG payment reform on mortality and readmission rates across diverse treatment modalities is presented in Table 4. It became apparent that the reform exerted its most pronounced effect on reducing mortality and readmission rates among patients undergoing conservative management.

## Healthcare Utilization

Table 5 presented estimations of patient utilization of medical services, with column (1) delineating the impact of DRG payment reform on the length of stay for inpatient cases. The length of stay served as a metric reflecting the utilization and efficiency of medical resources in healthcare institutions. Amid the DRG prepayment reform, enhancing medical technology and judiciously reducing the average length of stay while upholding medical quality emerged as crucial

**Table 3** The Impact of DRG-Based Prepayment Reform on Healthcare Quality

| Variables | In-Hospital Mortality | Readmission Rate Within 1 Day | Readmission Rate Within 2–15 Day | Readmission Rate Within 16–31 Day |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| **Panel A: ADRG and disease severity as control variables** | | | | |
| DRG Payment | −1.178*** | −2.443*** | −0.632* | −0.593 |
| Standard error | (0.0754) | (0.1064) | (0.0860) | (0.0813) |
| Observations | 250,696 | 250,696 | 250,696 | 250,696 |
| **Panel B: ADRG as a control variable** | | | | |
| DRG Payment | −0.119*** | −0.089*** | −0.071** | −0.118*** |
| Standard error | (0.0159) | (0.0140) | (0.0336) | (0.0230) |
| Observations | 250,696 | 250,696 | 250,696 | 250,696 |

**Notes**: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Table 4** Impact of DRG-Based Prepayment Reform on Healthcare Quality in Different Disease Group Categorie

| Variables | In-hospital mortality | Readmission rate within 1 day | Readmission rate within 2–15 day | Readmission rate within 16–31 day |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| **Panel A: Surgery** | | | | |
| DRG Payment | −0.802* | −2.280 | 2.223* | 0.285 |
| Standard error | (0.1278) | (0.2249) | (0.1870) | (0.1763) |
| Observations | 67,482 | 67,484 | 67,484 | 67,484 |
| **Panel B: Non-surgical Procedures** | | | | |
| DRG Payment | −0.119*** | −0.855 | 3.629** | −0.859 |
| Standard error | −0.0159 | (0.2938) | (0.2954) | (0.3461) |
| Observations | 14,808 | 14,808 | 14,808 | 14,808 |
| **Panel C: Internal Medicine** | | | | |
| DRG Payment | −1.316*** | −2.196*** | −0.611* | −1.053** |
| Standard error | (0.0918) | (0.1105) | (0.0867) | (0.0920) |
| Observations | 168,404 | 168,404 | 168,404 | 168,404 |

**Notes**: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Table 5** Impact of DRG-Based Prepayment Reform on Healthcare Utilization

| Variables | Length of Stay | Surgical Patient |
|---|---|---|
| | (1) | (2) |
| **Panel A: ADRG and disease severity as control variables** | | |
| DRG Payment | −0.959*** | −0.131** |
| Standard error | (0.0841) | (0.0628) |
| Observations | 250,696 | 250,696 |
| **Panel B: ADRG as control variable** | | |
| DRG Payment | −0.913*** | −0.128** |
| Standard error | (0.0805) | (0.0625) |
| Observations | 250,696 | 250,696 |

**Notes**: *** $p<0.01$, ** $p<0.05$. Hospitalized patients who underwent at least one surgical. procedure was defined as surgery patients.

strategies for cost savings and enhanced benefits. The study findings revealed a significant reduction in the length of stay by approximately 1 day due to the payment reform. In alignment with the outcomes in Table 3, a marginal decrease in the reduction in length of stay was observed when not controlling for the severity of illness among hospitalized cases.

Examining the proportion of discharged patients undergoing surgery provided insights into the disease structure and the diagnostic and treatment capabilities of surgical and non-surgical patients. Column (2) detailed the results for the proportion of surgical patients, indicating a noteworthy decrease in the proportion of inpatients with neurological diseases undergoing at least one operation (−0.131, *p-value* <0.05) following the DRG payment reform. Even when not controlling for the disease severity of hospitalized cases, the coefficient remained essentially unchanged (−0.128, *p-value* <0.05). This result suggested an increase in the proportion of patients receiving conservative treatment, implying that payment reform may indeed influence the structure of the patient group.

Diving deeper into the changes in the number of patients and CMI across different treatment modalities before and after the reform, the estimates were derived from Equation (1) and Equation (2). As presented in Table 6, the average monthly hospital visits witnessed an increase post-reform (0.172, *p-value* <0.01). However, a notable observation from the *treat* coefficient reveals that, compared with the control group, the number of patients undergoing surgical treatment in the reform group significantly decreased (−0.607, *p-value* <0.01), while the number of patients opting for conservative treatment experienced a significant increase (0.129, *p-value* <0.05). This finding aligns with the trend reflected in the proportion of surgical patients.

CMI served as an indicator of the technical difficulty level of cases admitted to the hospital. A higher CMI value signified a greater average technical difficulty level in treating the disease and vice versa. The study identified a significant downward trend in CMI after the reform (−0.013, *p-value* <0.01). Moreover, this decline was observed across various treatment subgroups, indicating a substantial decrease in technical difficulty levels across different modalities.

**Table 6** Impact of DRG-Based Prepayment Reform on the Volume and Difficulty of Consultation

| Variables | Ln (Patients Per Month) | CMI |
|---|---|---|
| | (1) | (2) |
| **Panel A: Full Sample** | | |
| DRG Payment | 0.172*** | −0.013*** |
| Treat | −0.127*** | |
| Standard error | (0.0384) | (0.0016) |
| Observations | 4,063 | 250,696 |
| **Panel B: Surgery** | | |
| DRG Payment | 0.303*** | −0.009** |
| Treat | −0.607*** | |
| Standard error | (0.0515) | (0.0035) |
| Observations | 1,375 | 67,482 |
| **Panel C: Non-surgical Procedures** | | |
| DRG Payment | 0.194*** | −0.006*** |
| Treat | 0.011 | |
| Standard error | (0.0595) | (0.0010) |
| Observations | 1,149 | 14,808 |
| **Panel D: Internal Medicine** | | |
| DRG Payment | 0.072** | −0.005*** |
| Treat | 0.129** | |
| Standard error | (0.0344) | (0.0011) |
| Observations | 1,536 | 168,404 |

**Notes**: *** $p<0.01$, ** $p<0.05$. The Ln (Patients per month) is at the hospital-month level. The CMI is at the individual level.

**Table 7** Distribution of Disease Severity Among Patients Paid by DRG Payment Cases

| Variables | Before Policy Change (2021) | | After the Policy Change (2022) | | Difference in Value | |
|---|---|---|---|---|---|---|
| | Cases | Percentage | Cases | Percentage | Cases | Percentage |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Surgery | 3,230 | 7.48% | 4,120 | 8.78% | 890 | 1.30% |
| Non-surgical Procedures | 2,333 | 5.40% | 2,909 | 6.20% | 576 | 0.79% |
| Internal Medicine | 37,615 | 87.12% | 39,913 | 85.03% | 2,298 | −2.09% |
| Full Sample | 43,178 | 100.00% | 46,942 | 100.00% | 3,764 | 0.00% |

To explore whether there was an increase in admissions of patients with mild symptoms post-reform, an analysis of the proportion of Major Complications or Comorbidities (MCC) and Complications or Comorbidities (CC) cases was conducted.[21] Table 7 reports the results. The proportion of MCC and CC signified the percentage of cases with severe or common complications and comorbidities, offering insights into the distribution of disease complexity. For DRG payment cases, in the post-reform period, we witnessed an increase in the proportion of MCC and CC cases in surgical and non-surgical procedures instances, accompanied by a decrease in internal medicine cases. This finding indicates a reduction in the complexity of treating diseases within the internal medicine domain after the reform.

## Validity Tests and Robustness Checks

The ex-ante trends were verified using an event study methodology, a framework that traces dynamic impacts in comparison to the period before the implementation of DRG payments. This analysis aimed to determine whether the observed effects were merely an extension of pre-existing trends. We observed no pre-existing differential change in outcomes between the DRG payment cases and control cases before the policy reform. All changes in differences between the two groups were not statistically significant relative to the first month of the study period, suggesting that our findings were valid. See Figures 1 and 2 for parallel trend test plots.

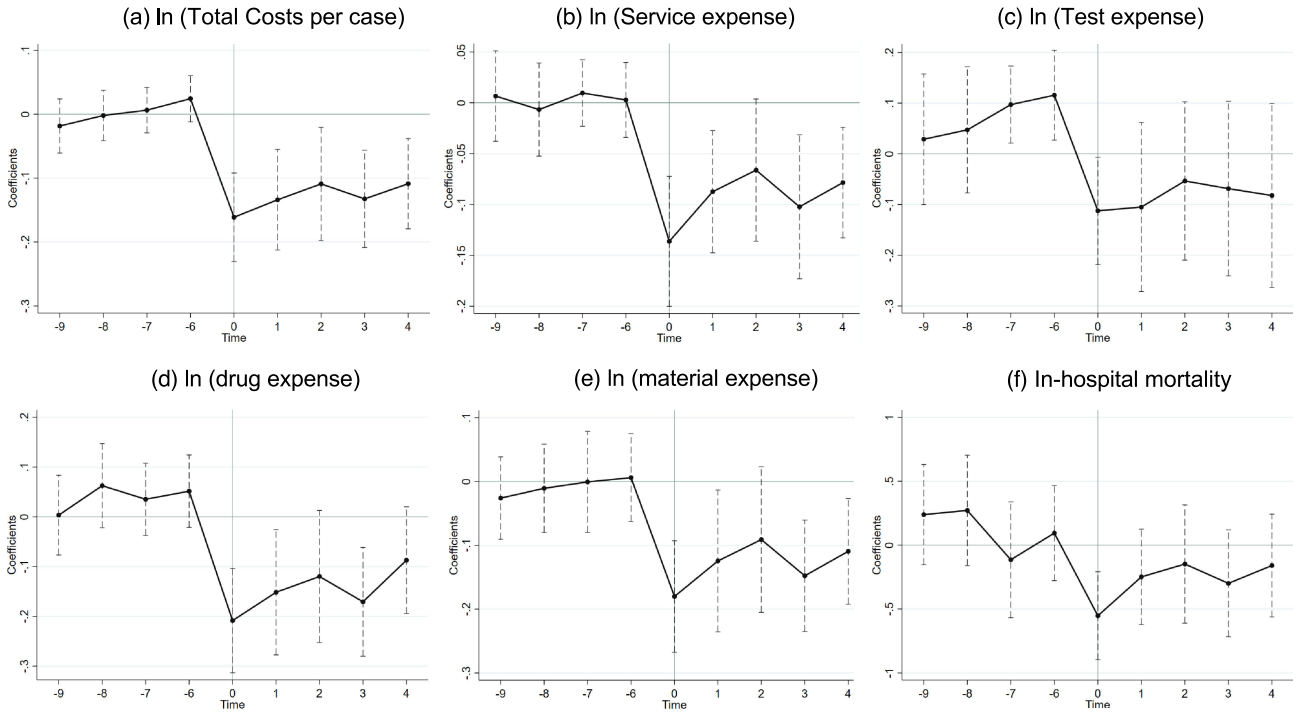


**Figure 1** Parallel trend tests for indicators related to healthcare costs and quality.
**Notes**: (**a**) ln (Total Costs per case), (**b**) ln (Service expense), (**c**) ln (Test expense), (d) ln (drug expense), (**e**) ln (material expense), (**f**) In-hospital mortality.

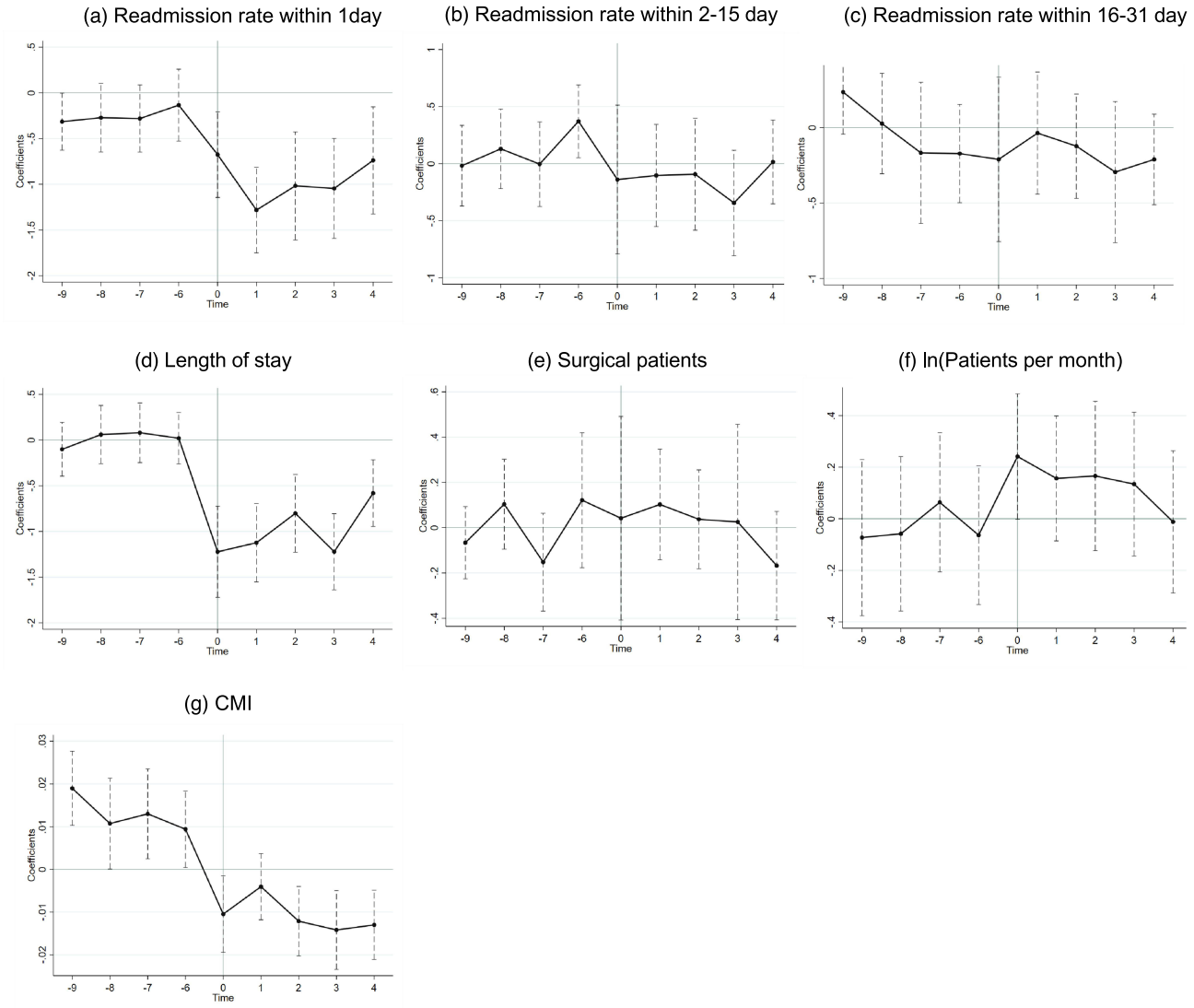


**Figure 2** Parallel trend tests for indicators related to healthcare utilization.
**Notes**: (**a**) Readmission rate within 1 day. (**b**) Readmission rate within 2–15 day, (**c**) Readmission rate within 16–31 day, (**d**) Length of stay. (**e**) Surgical patient (**f**) ln (Patients per month). (**g**) CMI.

We performed robustness tests to ensure the reliability of our findings. Recognizing that a decrease in hospitalization cases during epidemic months could potentially affect sample representativeness issues, we incorporated hospitalization cases from November 2021 to February 2022 and November 2022 to February 2023 for robust testing. Tables 8–10 showed the results of DID for the expanded sample range. The outcomes of the robustness analysis indicated that the regression results of the robustness analysis are consistent with the baseline regression.

**Table 8** Results of the Robustness Test of Healthcare Costs

| Variables | Ln (Total Costs per Case) | Ln (Service Costs per Case) | Ln (Test Costs per Case) | Ln (Drug Costs per Case) | Ln (Material Costs per Case) |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| DRG Payment | −0.134*** | −0.102*** | −0.087*** | −0.132*** | −0.131*** |
| Standard error | (0.0130) | (0.0117) | (0.0263) | (0.0181) | (0.0158) |
| Observations | 366,178 | 366,178 | 366,178 | 366,178 | 366,178 |

**Note**: *** $p<0.01$.

**Table 9** Results of the Robustness Test of Healthcare Costs of Healthcare Quality

| Variables | In-Hospital Mortality | Readmission Rate Within 1 Day | Readmission Rate Within 2–15 Day | Readmission Rate Within 16–31 Day |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| DRG Payment | −0.779*** | −2.523*** | −0.421 | −0.258 |
| Standard error | (0.0586) | (0.1056) | (0.0708) | (0.0732) |
| Observations | 366,180 | 366,180 | 366,180 | 366,180 |

**Notes**: *** $p<0.01$.

**Table 10** Results of the Robustness Test of Healthcare Costs of Healthcare Utilization

| Variables | Length of Stay | Surgical Patients | Ln (Patients Per Month) | CMI |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| DRG Payment | −0.936*** | −0.080 | 0.092*** | −0.011*** |
| Standard error | (0.0685) | (0.0523) | (0.0685) | (0.0014) |
| Observations | 366,178 | 366,180 | 2,355 | 366,178 |

**Note**: *** $p<0.01$.

## Discussion and Conclusion

In March 2022, Beijing initiated the implementation of DRG prepayment, specifically for UEBMI. Employing individual-level and hospital-monthly level data, we applied the DID method to assess the impact of the DRG-based prepayment reform. In summary, the DRG prepayment reform has demonstrated positive outcomes for patients with neurological diseases. Post-reform, overall, in-hospital mortality and readmission rates witnessed a significant decline, primarily attributable to a reduction in short-term return patients. The reform led to a noteworthy 12.6% decrease in average total hospitalization costs and a 0.96-day reduction in average hospitalization days signifying active efforts by medical institutions to curtail hospitalization time and costs. These findings suggest an improvement in the efficiency of medical services and an initial manifestation of the cost-control effects of the reform.[22] However, the study results indicated a significant reduction in the proportion of surgical operations among discharged patients after the reform. This trend is more pronounced among DRG payment cases, suggesting a noteworthy impact on the composition of the patient cohort. The reform appears to have influenced a shift in the patient demographic, with an increased proportion opting for conservative treatments over surgical interventions.

Moreover, the reform has led to a decrease in the CMI, indicating a reduction in the average difficulty of diagnosis and treatment within hospitals. Aligned with the DRG prepayment principle, the reform incentivizes medical institutions to align services with patients' actual medical needs. Hospitals are encouraged to handle more severe illnesses or complex cases with a higher CMI, leading to increased Medicare payments. Typically, surgical treatments are applied to patients with more severe conditions or those requiring complex interventions, resulting in higher CMIs for related diseases. Therefore, medical institutions are motivated to accurately assess the severity of patients' conditions, attract more severe or complex cases, and provide suitable medical services to align with the CMI for enhanced medical insurance payments. Nevertheless, this behavior was not observed in our study. The patient's structure could be partially to blame for this. Despite excluding hospitalization cases related to the epidemic, the study period still overlaps with the ongoing global pandemic, potentially introducing environmental and policy factors that could affect the study sample. It also serves as a reminder that the DRG prepayment reform might make treating severe cases economically less attractive. Healthcare professionals and hospitals might be inclined to focus on milder cases to optimize economic returns. Doctors tend to choose patients, especially to turn away serious ones, according to a poll on how payment reform influences physician behavior.[23]

Internal medicine serves as the predominant treatment approach for patients dealing with neurological diseases, encompassing approximately 70% of all cases. After the reform, a noteworthy increase in cases managed through pharmaceutical interventions was observed. The simultaneous decrease in both patient hospitalization costs and length of stay indicated a reduction in the medical resources required by patients and a significant improvement in the efficiency of medical services. The decline in mortality and the 31-day readmission rate implied an enhancement in the quality of medical services. Furthermore, the reduction in the CMI value signified a decrease in the complexity of patients' conditions. Coupled with the observation that the proportion of internal medicine cases with relatively low diagnostic and treatment difficulty increased post-reform, this implied that a greater number of patients with mild illnesses may have been admitted following the reform.

Upon analyzing the proportion of MCC and CC cases, a noteworthy observation was made for DRG payment cases of the Internal Medicine, the proportion of MCC and CC cases witnessed a 2.09% decrease after the reform. Although the proportion of MCC and CC cases in the Internal Medicine among control cases also experienced a decline, the extent was relatively smaller in comparison to DRG payment cases. This implied that after the reform, the complexity associated with treating disorders in the field of internal medicine has diminished.

Moreover, to assess the possibility of overestimating the impact of the reforms due to upward coding behavior, we examined changes in the outcome variables without controlling for patient severity within the same disease group. The study discovered that the reductions in medical costs, length of stay, mortality, and readmission rates for hospitalized cases all showed a certain narrowing of the extent, indicating the potential presence of upward coding behavior. However, as the magnitude of the change was not substantial, additional validation through future studies, coupled with insights from clinical practice, is imperative.

From a policy perspective, our findings resonate with the global understanding that no payment method is flawless.[24] It is crucial to distill insights from the implementation of DRG payment reforms, formulate corresponding policy instruments, strengthen the positive incentives of policies, and mitigate or prevent unintended consequences. Many developed nations, upon adopting DRG payment systems, implemented monitoring mechanisms to scrutinize and identify negative behaviors such as coding errors, patient selection, and increased readmission rates.[25] In alignment with this approach, the National Healthcare Security Administration of China has implemented a series of policies and measures to reinforce the oversight of medical insurance funds and the identification of medical behaviors. The overarching goal is to enhance the efficiency of medical resource utilization, reduce medical expenses, and improve the overall healthcare experience for the populace.

Our study was not without limitations. Firstly, the ideal conditions for applying a DID approach necessitate that the change in outcomes in the treatment group mirrors the change in outcomes in the control group in the absence of the policy. While our models passed the parallel trends test, other alterations in healthcare policies or internal hospital management policies during our study window might have exerted distinct effects on the reform and control groups, making it challenging to disentangle the impact of these concurrent policies. Secondly, we excluded hospitalization cases linked to the epidemic, yet as the study period persists during the ongoing global pandemic, the sample might be influenced by certain environmental and policy factors. Thirdly, stratifying the sample by treatment might overlook existing patient selection dynamics. Lastly, we assessed the impact of the DRG payment policy after 7 months. The transmission of the reform policy to medical institutions and personnel takes time. The full manifestation of the reform's effectiveness is yet to be realized, and the medium and long-term repercussions of the policy warrant further monitoring and exploration.

## Data Sharing Statement

The data analyzed in this study is subject to the following licenses/ restrictions: the data that support the findings of this study are available from the Beijing Municipal Health Big Data and Policy Research Center, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Requests to access these datasets should be directed to MNG.

## Ethics

It has been confirmed that this study is in accordance with the Declaration of Helsinki.Ethics approval and consent to participate Ethics committee approval was obtained from the Institutional Review Board of Beijing Tiantan Hospital, Capital Medical University (KY2024-060-02). Patient consent was waived by the Institutional Review Board of Beijing Tiantan Hospital, Capital Medical University because no contact with patients was conducted and patient anonymity was assured. Relevant administrative permissions were received from the Beijing Health Big Data and Policy Research Center which provided a dataset for the study. All methods were performed according to the relevant guidelines and regulations.

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## Disclosure

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Bala MV, Zarkin GA. Application of cost-effectiveness analysis to multiple products: a practical guide. *Am J Manag Care*. 2002;8(3):211–218.
2. Iezzoni L. *Risk Adjustment for Measuring Health Care Outcomes*. 4th ed. Chicago: Health Administration Press; 2012.
3. Fetter RB, Shin Y, Freeman JL, Averill RF, Thompson JD. Case mix definition by diagnosis-related groups. *Med Care*. 1980;18(2 Suppl):iii–53.
4. Mathauer I, Wittenbecher F. Hospital payment systems based on diagnosis-related groups: experiences in low- and middle-income countries. *Bull World Health Organ*. 2013;91(10):746–756A. doi:10.2471/BLT.12.115931
5. Jian W, Lu M, Chan KY, et al. Payment reform pilot in Beijing hospitals reduced expenditures and out-of-pocket payments per admission. *Health Aff*. 2015;34(10):1745–1752. doi:10.1377/hlthaff.2015.0074
6. National Healthcare Security Administration. Notification of national pilot cities for DRG payment. Available from: http://www.nhsa.gov.cn/art/2019/6/5/art_37_1362.html. Accessed August 11, 2020.
7. Han YL. The mechanism and pathway of the health insurance payment reform from retrospective to prospective mode on the medical provider's behavior. *Chin J Health Policy*. 2021;14(3):21–27.
8. Li CQ, Da T, K Z. Analysis of Impact of Payment Methods on Medical Quality. *Chin Health Econ*. 2011;30:63.
9. Leu A, Wepf H, Elger B, Wangmo T. Experts' perspectives on SwissDRG: second class care for vulnerable patient groups? *Health Policy*. 2018;122(6):577–582. doi:10.1016/j.healthpol.2018.03.001
10. Koné I, Maria Zimmermann B, Nordström K, Simone Elger B, Wangmo T. A scoping review of empirical evidence on the impacts of the DRG introduction in Germany and Switzerland. *Int J Health Plann Manage*. 2019;34(1):56–70. doi:10.1002/hpm.2669
11. Ndayishimiye C, Tambor M, Dubas-Jakóbczyk K. Barriers, and facilitators to healthcare provider payment reform - A scoping literature review. *Risk Manag Health Policy*. 2023;16:1755–1779. doi:10.2147/RMHP.S420529
12. Zou K, Li HY, Zhou D, Liao ZJ. The effects of diagnosis-related groups payment on hospital healthcare in China: a systematic review. *BMC Health Serv Res*. 2020;20(1):112. doi:10.1186/s12913-020-4957-5
13. Barber SL, Borowitz M, Bekedam H, Ma J. The hospital of the future in China: china's reform of public hospitals and trends from industrialized countries. *Health Policy Plan*. 2014;29(3):367–378. doi:10.1093/heal/czt023
14. Xu J, Jian W, Zhu K, Kwon S, Fang H. Reforming public hospital financing in China: progress and challenges. *BMJ*. 2019;365:l4015. doi:10.1136/bmj
15. Zhang Y, Fu J, Yuan Z, et al. The role of cell senescence in the occurrence and development of neurological diseases. *Chin Med Univ J*. 2023;52(09):847–851.
16. Bureau of Statistics National and Bureau of Statistics Beijing Survey Team. Beijing's 2022 national economic and social development statistical bulletin; 2023:12.
17. Deng XH. Development, application, and promotion of DRGs in China. *Chin J Hosp Adm*. 2015;31(11):809–812.
18. Bureau of Medical Insurance and Maternity Insurance. Key indicators of health insurance and maternity insurance for the semi-annual period of 2023; 2023.
19. Zhang T, Lu B, Song Y, Chen M. Impacts of outpatient payment reforms on volume and expenditures in public hospitals: evidence from a quasi-experimental analysis in Zhejiang, China. *Risk Manag Health Policy*. 2023;16:415–424. doi:10.2147/RMHP.S400385

20. Qian M, Zhang X, Chen Y, Xu S, Ying X. The pilot of a new patient classification-based payment system in China: the impact on costs, length of stay and quality. *Soc Sci Med*. 2021;289:114415. doi:10.1016/j.socscimed.2021.114415
21. Wei A, Ren J, Feng W. The impact of DRG on resource consumption of inpatient with ischemic stroke. *Front Public Health*. 2023;11:1213931. doi:10.3389/fpubh.2023.1213931
22. Zhang T, Lu B, Yan Z, Huang X, Lu W. Impacts of a new episode-based payment scheme on volume, expenditures, and efficiency in public hospitals: a quasi-experimental interrupted time-series study in Jinhua, China. *Risk Manag Health Policy*. 2022;15:1659–1669. doi:10.2147/RMHP.S376516
23. Zhang L, Sun L. Impacts of diagnosis-related groups payment on the healthcare providers' behavior in china: a cross-sectional study among physicians. *Risk Manag Health Policy*. 2021;14:2263–2276. doi:10.2147/RMHP.S308183
24. Cook A, Averett S. Do hospitals respond to changing incentive structures? Evidence from Medicare's 2007 DRG restructuring. *J Health Econ*. 2020;73:102319. doi:10.1016/j.jhealeco.2020.102319
25. Quentin W, Scheller-Kreinsen D, Blümel M, Geissler A, Busse R. Hospital payment based on diagnosis-related groups differs in Europe and holds lessons for the United States. *Health Aff*. 2013;32(4):713–723. doi:10.1377/hlthaff.2012.0876