ORIGINAL RESEARCH

Impacts of the Zero-Markup Drug Policy on Hospitalization Expenses of Patients with Stroke in Western China: An Interrupted Time Series Analysis

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Background: In 2016, an innovative medical pricing reform called zero-markup drug policy (ZMDP) was implemented in selected pilot cities in China, which focuses on curbing the unreasonable growth of medical expenses. This study aimed to evaluate the impacts of ZMDP on medical expenditure of stroke in western China.

Methods: The quantitative data of inpatients diagnosed with stroke was extracted from the medical insurance system in 7 tertiary public hospitals. An interrupted time series (ITS) was used to analyze the instantaneous level and long-term trend changes of hospitalization expenses per visit from January 2015 to November 2018.

Results: A total of 22,407 stroke inpatients were extracted. The total hospitalization expense per visit had the highest proportion of 20,000 CNY and above (33.66%). After the ZMDP, the median total hospitalization expense and western medicine expense per visit decreased by 631.74 CNY and 966.35 CNY, respectively ($P <0.001$). Before the policy, the total hospitalization expense, traditional Chinese medicine (TCM) expense, examination expense, treatment expense, laboratory expense and surgical expense per visit showed upward trends ($P<0.05$), while the anesthesia expense per visit showed a downward trend ($P<0.001$). When the policy was implemented, the anesthesia expense per visit instantaneously increased by 91.70% ($P<0.001$). After the policy, the total hospitalization expense, western medicine expense, TCM expense, treatment expense and surgical expense per visit changed from upward trends to downward trends ($P<0.05$). The anesthesia expense per visit changed from a downward trend to an upward trend ($P<0.001$), and the examination expense per visit maintained an upward trend ($P=0.005$).

Conclusion: The economic burden of stroke inpatients decreased significantly with the implementation of the ZMDP, especially for the drug expenses. The medical service expenses increased significantly, reflecting the improvement in the value of medical staff's technical labor. However, the unexpected increase in the examination expenses was likely to be associated with the unreasonable medical compensation mechanism.

Keywords: zero-markup drug policy, stroke, interrupted time series, hospitalization expenses, drug expenses

Introduction

Public hospitals are the main component of China's healthcare system, occupying an absolutely dominant position in the healthcare services market. The Chinese government introduced the drug markup policy during a historical period of low socio-economic level and limited government financial resources, allowing public hospitals to sell drugs with a 15% markup on the purchase price, with the aim of maintaining the basic operation of public hospitals and promoting their own development.[1] The policy has played a positive role in improving the operation of public hospitals in the course of their development. However, with the transformation of China's economic system after the reform and opening up, the drug markup gradually evolved into a profit-seeking behavior, and the income from the drug markup became an important part of the income of public hospitals.[2] In the two decades before the policy, China's pharmaceutical expenditures accounted for

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45.7% of the total expenditures on health care.[3] Meanwhile, it is also worth noting that the medical staffs' incomes are linked to drug profits, and problems such as abuse of high-priced drugs and over-prescribing are becoming more frequent.[4] Health services have the special nature of being supply-led and demand-led, and health insurance funds are used irrationally, leading to a rapid increase in patients' medical expenses. At the same time, doctors, stimulated by the profit-seeking mechanism, generate provider-induced demand and prescribe large quantities of unnecessary antibiotics, injections and hormone drugs for patients, which has become a major public health problem in China at this stage.[5–7]

In view of this, in 2009, China initiated a reform of medical and health-care system, whereby drugs are uniformly purchased and distributed through government tenders and sold at the tendered price, with a 15% mark-up on the original price abolished. The zero-markup drug policy (ZMDP) is aimed at separating drug sales from hospital revenue, regulating the profit-making tendency and unreasonable medical behaviors of medical staffs, focusing on the public welfare of public medical institutions, and effectively decreasing the economic burden for patients. Since then, China has carried out pilot reforms in tertiary public hospitals in various provinces and cities to gradually implement the ZMDP. In September 2017, the Chinese government abolished the 15% mark-up on medicines (except for decoction pieces of Chinese medicine) in public hospitals.[8,9] As one of the pilot areas for the ZMDP, seven tertiary public hospitals implemented the ZMDP starting from December 19, 2016 in Luzhou. The local government has compensated the reduced revenue after the ZMDP, promoting hospitals to actively reduce the purchase price of drugs.

Stroke is currently the second leading cause of death and the third leading cause of disability globally, and one of the chronic non-communicable diseases (NCDs) that threaten human life and health. In 2019, stroke accounted for 11.6% of all deaths worldwide.[10] Similarly, stroke is the leading cause of death among Chinese residents, with an estimated number of deaths accounting for approximately one-third of global stroke deaths.[11] Stroke is characterized by high morbidity, high mortality, and complex etiology, and may be accompanied by various comorbidities, such as hypertension and diabetes mellitus.[12] In addition, stroke recurrence and related complications generate significant healthcare expenses. One study found that stroke patients with lacunar cerebral infarction had a low early mortality rate but a significantly increased risk of mortality, stroke recurrence, and subcortical dementia in the medium and long term.[13] Meanwhile, cardiogenic stroke is accompanied by severe adverse cardiovascular co-morbidities and higher mortality, for which patients require long-term drug therapy.[14] It is worth noting that the average annual medical expense of stroke patients in urban areas of China is 10,637 CNY, of which drug expenses account for more than 50%. The huge economic burden of medicines has pushed some families into poverty.[15]

Previous studies have found significant short-term reductions in drug expenses of chronic diseases after the implementation of ZMDP,[16,17] but have not assessed the changes in the various expenses and component structure. Meanwhile, most studies on the policy effects of ZMDP have used short-term data before and after the reform, making it difficult to assess future changes in long-term trends, and there are differences in the unintended policy impacts and substitution effects of ZMDP. Therefore, it is necessary to conduct a comprehensive and detailed assessment of the economic burden of ZMDP on stroke inpatients and to analyze the long-term effects of ZMDP on expense structure. This study analyzed the instantaneous level changes and long-term trend changes of hospitalization expenses of stroke patients before and after the implementation of the ZMDP by using the ITS model, and provided the evidence-based experience and policy recommendations for further improvement of medical and health care policies and effective control of excessive growth of medical expenses.

Methods
Study Setting

The study was conducted at Luzhou in Sichuan province, which is located in western China and in the upper reaches of the Yangtze River, with 3 districts and 4 counties under its jurisdiction. Owing to Luzhou's unique location on the border of four provinces (Sichuan, Chongqing, Yunnan and Guizhou), the city's tertiary public hospitals provide medical services covering the city and adjacent regions. The prevalence of chronic diseases and risk factors among residents of the city are maintained at a high level, and the main chronic diseases threatening the residents are stroke, chronic obstructive pulmonary disease and other chronic diseases. As one of the pilot cities, Luzhou implemented the ZMDP of abolishing 15% mark-up of drug sales (except for decoction pieces of Chinese medicine) in 7 tertiary public hospitals

since December 19, 2016. The relevant financial departments made price compensation for the reduced income after the ZMDP, and promoted medical institutions to reduce the purchase price of related drugs.

Data Sources and Outcome Indicators

The data were obtained from the medical insurance system of Luzhou's medical security bureau, from which the settlement data of inpatients in 7 tertiary public hospitals were obtained from 2015 to 2018. Based on the International Classification of Diseases, 10th version (ICD-10), this study screened inpatients with stroke (ICD-10 coded as I60-I64) from January 1, 2015 to November 20, 2018 in 7 tertiary public hospitals.

The data collected included: 1) socio-demographic information: gender, age, ethnicity, and type of health insurance. 2) hospital information: ICD-10 codes, date of visit, date of discharge, and length of stay. 3) expense information: total expenses, western medicine expenses, examination expenses, treatment expenses, materials expenses, surgery expenses, anesthesia expenses, traditional Chinese medicine (TCM) expenses, and laboratory expenses, and other expenses.

Quality Control

Due to the impact of inflation and price changes, and the long-time span of data involved in this study, discounting adjustments were conducted for the 2015–2017 hospitalization expenses based on the Consumer Price Index (CPI) for healthcare published by the China National Bureau of Statistics, using the 2018 hospitalization expenses as the baseline (Table 1).

Statistical Analysis

The categorical variables were described in counts and percentages, and continuous variables with normal distributions were described in means and standard deviations. Normality of continuous variables was tested by the Kolmogorov–Smirnov (K-S) test, and non-normally distributed variables were described in medians and interquartile range (IQR). The Mann–Whitney U test was used to compare the continuous variables, and the chi-squared test was applied to compare the categorical variables.

The ITS analysis, regarded as the strongest quasi-experimental research design, has been widely applied in the field of policy evaluation to evaluate the group-level instantaneous level and long-term trend changes triggered by interventions over a specific period of time.[18,19] Segmented regression model is commonly used in an ITS analysis, which is proven effective for assessing intervention effects and requires fewer time points.[20,21] In this study, the intervention point was December 18, 2016, when the ZDMP was officially implemented. The pre-ZDMP period was defined as January 1, 2015 to December 18, 2016, while the post-ZDMP period was defined as December 19, 2016 to November 20, 2018. The time variable was selected as the independent variable and counted in months. The ITS regression model was specified as follows:

$$Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

where Y_t is the outcome indicator representing the expenses in month t; X_1 is a continuous variable representing each month during the observation period, coded "1, 2, 3...n"; X_2 is a binary dummy variable, which is coded 0 before the policy was implemented, and is coded 1 after the policy was implemented; X_3 is a continuous variable, which is coded 0 before the policy was implemented, and increases monthly after the policy implementation, coded "0, 1, 2, 3...n".

Table 1 Adjustment of Hospitalization Expenses Based on the CPI

Year	CPI (%)	Pre-Adjustment Expenses	Post-Adjustment Expenses (2018 Baseline)
2015	102.7	Y_1	$Y_1' = Y_1 \times 104.3\% \times 106.0\% \times 103.8\%$
2016	103.8	Y_2	$Y_2' = Y_2 \times 104.3\% \times 106.0\%$
2017	106.0	Y_3	$Y_3' = Y_3 \times 104.3\%$
2018	104.3	Y_4	$Y_4' = Y_4$

Abbreviation: CPI, Consumer Price Index.

In the regression model, β_0 represents the constant term, which reflects the baseline level at t=0; β_1 represents the monthly changes in the trend before the policy implementation, that is, the estimation of the slope of the baseline; β_2 represents the estimation of the instantaneous level changes due to the implementation of the policy; β_3 represents the estimation of the monthly changes in the trend after the policy; and $\beta_1+\beta_3$ represents the monthly trends after the policy.

The Durbin–Watson (D-W) test was applied to test the existence of first order autocorrelation in the error terms, and the Paris-Winsten estimation method was used to correct the D-W value.[22] Moreover, the natural logarithmic transformations were performed on all outcome variables to adjust the non-normality data, and log-line transformations were applied to adjust the expense variables by converting them into percentage changes that directly reflect the relationship between X and Y_t.[23] The data analysis was performed in R software (version 4.0.5). The level of significance was set at 0.05.

Results
Characteristics of Study Population with Stroke
A total of 22,407 inpatients were included in this study, of which 10,075 were included before the implementation of the policy and 12,332 were included after the implementation of the policy. The sociodemographic characteristics of inpatients with stroke by gender, age, ethnic, and types of basic medical insurance before and after the implementation of the policy are displayed in Table 2. The proportion of males before and after the policy was higher than that of females, accounting for 57.56% and 58.29%, respectively. The average age of inpatients was 67.05 years. The proportion of inpatients in the age group of 60 years old and above before and after the implementation of the policy was the highest, accounting for 74.36% and 74.92%, respectively, and the proportion of inpatients aged 50–59 years old and 60 years old and above increased slightly after the implementation of the policy (P=0.026). The Han ethnic populations accounted for 99.9%. The proportion of inpatients who participated in urban and rural resident's basic medical insurance

Table 2 Basic Characteristics of Inpatients Included Before and After the Policy

Variables	Pre-ZMDP (n=10,075)	Post-ZMDP (n=12,332)	χ^2	P
Gender (n,%)			1.21	0.271
Male	5799 (57.56)	7188 (58.29)		
Female	4276 (42.44)	5144 (41.71)		
Age groups (n,%) (years)			12.72	0.026
<18 years	54 (0.54)	49 (0.40)		
18~29 years	57 (0.57)	51 (0.41)		
30~39 years	94 (0.93)	122 (0.99)		
40~49 years	804 (7.98)	872 (7.07)		
50~59 years	1574 (15.62)	1999 (16.21)		
≥60 years	7492 (74.36)	9239 (74.92)		
Ethnicity (n,%)			0.04	0.840
Han	10,073 (99.98)	12,330 (99.98)		
Others	2 (0.02)	2 (0.02)		
Length of stay (n,%)			3.16	0.206
<10 days	3911 (38.82)	4931 (39.99)		

(*Continued*)

Table 2 (Continued).

Variables	Pre-ZMDP (n=10,075)	Post-ZMDP (n=12,332)	χ^2	P
10~19 days	4476 (44.43)	5375 (43.58)		
≥20 days	1688 (16.75)	2026 (16.43)		
Types of insurance (n,%)			2.78	0.096
The employee medical insurance	3496 (34.70)	4411 (35.77)		
The resident medical insurance	6579 (65.30)	7921 (64.23)		

Abbreviation: ZMDP, zero-markup drug policy.

before and after the policy was higher than the proportion of inpatients who participated in urban employee's basic medical insurance, accounting for 65.30% and 64.23%, respectively.

Comparative Analysis of Hospitalization Expenses

The proportion of stroke patients with total hospitalization expense per visit of 20,000 CNY and above was the highest, accounting for 33.66%, while the proportion of stroke patients with total hospitalization expense per visit of less than 2,000 CNY was the lowest, accounting for 0.74%. After the implementation of the policy, the proportion of stroke patients with total hospitalization expense per visit of 20,000 CNY and above decreased from 35.79% to 31.92%, while the proportion of stroke patients with total hospitalization expense per visit of 10,000–15,000 and 15,000–20,000 CNY both increased (Table 3).

After the K–S test, the hospitalization expenses per visit were non-normally distributed ($P < 0.001$), and expenses variables were presented as a median and interquartile range. According to the results in Table 4, after the implementation of the ZMDP, the median value of total hospitalization expense per visit decreased by 631.74 CNY, the median value of western medicine expense per visit decreased by 966.35 CNY, the median value of TCM expense per visit decreased by 117.04 CNY, the median value of examination expense per visit increased by 394.27 CNY, the median value of treatment expense per visit increased by 368.33 CNY, the median value of laboratory expense per visit increased by 150.72 CNY, and the median value of materials expense per visit increased by 79.14 CNY ($P < 0.001$).

Table 3 Frequency Distribution of Total Hospitalization Expense per Visit Before and After the Policy

Total Hospitalization Expense per Visit (CNY)	Pre-ZDMP (n=10,075)		Post-ZDMP (n=12,332)		Total	
	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)
<2000	63	0.63	103	0.84	166	0.74
2000~3999	413	4.10	490	3.97	903	4.03
4000~5999	677	6.72	855	6.93	1532	6.84
6000~7999	785	7.79	1054	8.55	1839	8.21
8000~9999	910	9.03	1274	10.33	2184	9.75
10,000~14,999	2208	21.92	2735	22.18	4943	22.06
15,000~19,999	1413	14.02	1885	15.29	3298	14.72
≥20,000	3606	35.79	3936	31.92	7542	33.66

Abbreviation: ZMDP, zero-markup drug policy.

Table 4 Comparative Analysis of the Hospitalization Expenses per Visit Before and After the Policy

Variables	Pre-ZDMP (n=10,075) M (Q1, Q3)	Post-ZDMP (n=12,332) M (Q1, Q3)	Z	P
Total	14,936.06 (9294.22, 25,792.67)	14,304.32 (8895.99, 23,782.55)	−4.918	<0.001
Western medicine	4665.99 (2230.87, 9178.57)	3699.64 (1752.81, 7033.70)	−17.227	<0.001
TCM	1488.48 (432.90, 3102.03)	1371.44 (388.48, 3017.94)	−3.564	<0.001
Examination	1531.20 (386.29, 2710.88)	1925.47 (1066.00, 2925.05)	−21.116	<0.001
Anesthesia	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	−5.504	<0.001
Treatment	1459.62 (384.80, 3931.68)	1827.95 (590.76, 4827.90)	−12.916	<0.001
Laboratory	856.65 (0.00, 1515.07)	1007.37 (0.00, 1679.27)	−10.494	<0.001
Materials	116.46 (0.00, 669.31)	195.60 (0.00, 795.09)	−8.909	<0.001
Surgery	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	−5.287	<0.001
Others	414.11 (197.69, 1535.83)	717.12 (348.00, 3133.58)	−27.681	<0.001

**Abbreviations**: ZMDP, zero-markup drug policy; TCM, traditional Chinese medicine.

The ITS Analysis of Monthly Hospitalization Expenses

In order to visualize the changes before and after the implementation of the policy, this study converted the data to the original scale based on the linear regression results, and the fitted graph of the monthly changes in the hospitalization expenses per visit is shown in Figure 1. The model parameters are shown in Table 5. The D-W value or adjusted D-W value was from 1.794 to 2.036, indicating that the data met the autocorrelation test requirements.[24] Before the implementation of the policy, the total hospitalization expense, TCM expense, examination expense, treatment expense, laboratory expense, surgical expense and other expenses per visit showed significant upward trends, with increasing by 0.70% per month (β_1=0.007, $P < 0.001$), 3.05% per month (β_1=0.03, P=0.007), 2.02% per month (β_1=0.02, $P < 0.001$), 3.25% per month (β_1=0.032, $P < 0.001$), 1.01% per month (β_1=0.01, P=0.006), 2.02% per month (β_1=0.02, P=0.005) and 8.00% per month (β_1=0.077, $P < 0.001$), respectively. On the contrary, the anesthesia expense per visit showed a significant downward trend, with decreasing by 3.54% per month (β_1=−0.36, $P < 0.001$). However, the trend changes in western medicine expense and materials expense per visit were statistically insignificant ($P > 0.05$). When the policy was implemented, the anesthesia expense per visit increased by 91.70% instantaneously (β_2=0.651, $P < 0.001$). After the implementation of the policy, the total hospitalization expense, western medicine expense, TCM expense, treatment expense, surgical expense, and other expenses per visit changed from upward trends to downward trends, with decreasing by 1.09% per month ($\beta_1 + \beta_3$=−0.011, $P < 0.001$), 2.37% per month ($\beta_1 + \beta_3$=−0.024, $P < 0.001$), 1.39% per month ($\beta_1 + \beta_3$=−0.014, P=0.011), 2.37% per month ($\beta_1 + \beta_3$=−0.024, $P < 0.001$), 0.50% ($\beta_1 + \beta_3$=−0.005, P=0.017) and 1.98% per month ($\beta_1 + \beta_3$=−0.02, $P < 0.001$), respectively. On the contrary, the anesthesia expense per visit changed from a downward trend to an upward trend, increasing by 0.90% per month ($\beta_1 + \beta_3$=0.009, $P < 0.001$). The examination expense per visit maintained an upward trend with a monthly increase of 0.40% ($\beta_1 + \beta_3$=0.004, P=0.005). However, the trend changes in laboratory expense and materials expense per visit were statistically insignificant ($P > 0.05$).

Discussion

Based on current studies, this study is the first to assess changes in the instantaneous levels and long-term trends of various hospitalization expenses for stroke patients before and after a policy intervention, with an additional focus on changes in cost structure.

The results showed that the median total hospitalization expense per visit of stroke patients decreased after the implementation of the ZMDP, in which the median western medicine expense per visit decreased significantly. The implementation of the ZMDP effectively controlled the rapid growth of total hospitalization expense and western
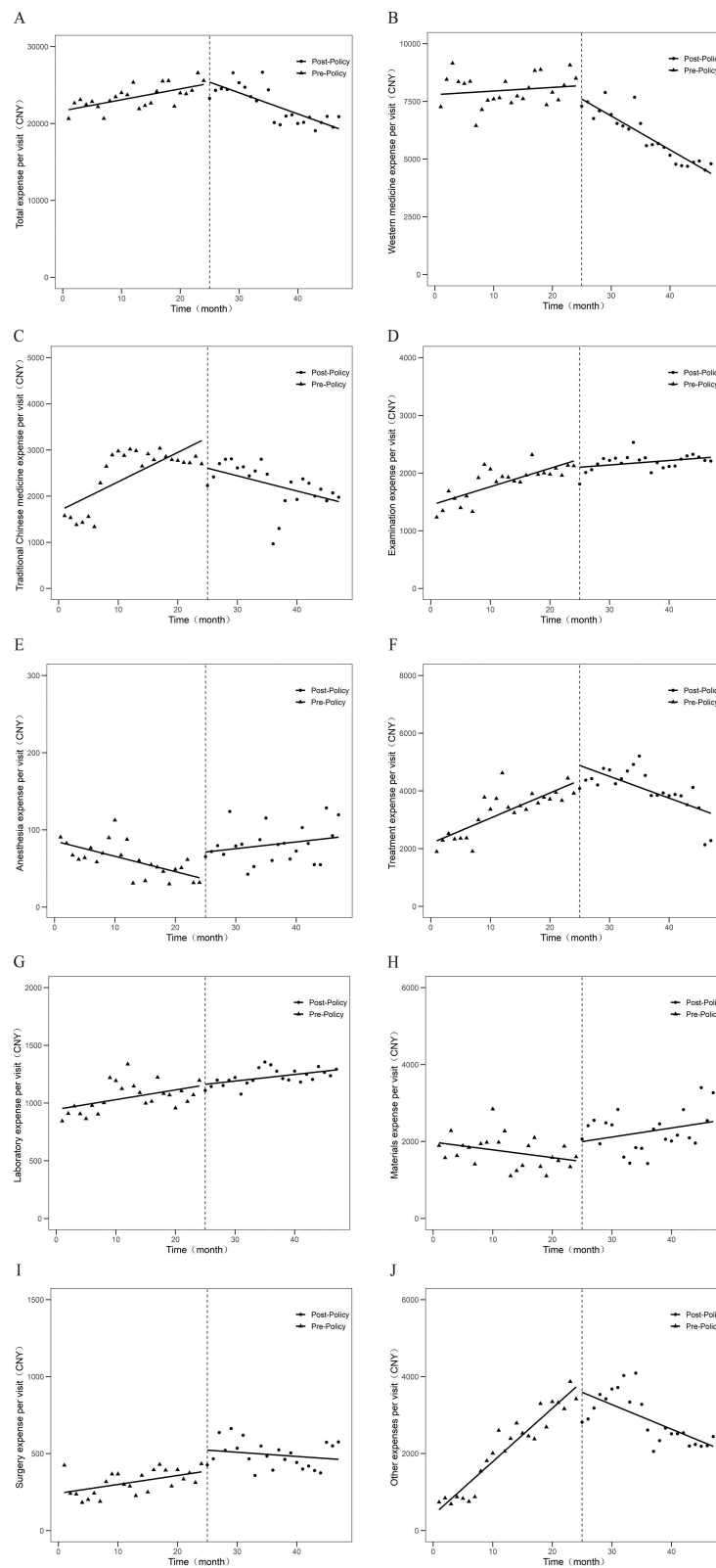
Figure 1 Monthly changes in hospitalization expenses per visit of inpatients with stroke.
Notes: (**A**) Total hospitalization expense per visit; (**B**) western medicine expense per visit; (**C**) TCM expense per visit; (**D**) examination expense per visit; (**E**) anesthesia expense per visit; (**F**) treatment expense per visit; (**G**) laboratory expense per visit; (**H**) materials expense per visit; (**I**) surgery expense per visit; (**J**) other expenses per visit.

Table 5 ITS Regression Results of Hospitalization Expenses per Visit Before and After the Policy

Variables		Ln Total Expense	Ln Western Medicine Expense	Ln TCM Expense	Ln Examination Expense	Ln Anesthesia Expense	Ln Treatment Expense	Ln Laboratory Expense	Ln Materials Expense	Ln Surgery Expense	Ln Other Expenses
Intercept (β_0)	Estimated value	9.977***	8.948***	7.395***	7.253***	4.487***	7.657***	6.823***	7.578***	5.472***	6.557***
	Log-linear transformation	21,524.64	7691.491	1626.825	1411.336	87.854	2114.402	917.737	1953.716	236.936	703.156
Baseline trend (β_1)	Estimated value	0.007**	0.003	0.030**	0.020***	−0.036***	0.032***	0.010**	−0.012	0.020**	0.077***
	Log-linear transformation	0.007	−[a]	0.030	0.020	−0.035	0.033	0.010	−[a]	0.020	0.080
Change in level (β_2)	Estimated value	−0.011	−0.074	−0.272	−0.117	0.651***	0.061	−0.033	0.304	0.262	−0.290
	Log-linear transformation	−[a]	−[a]	−[a]	−[a]	0.917	−[a]	−[a]	−[a]	−[a]	−[a]
Change in slope (β_3)	Estimated value	−0.018***	−0.027***	−0.044*	−0.016**	0.045***	−0.056***	−0.005	0.022	−0.025*	−0.097***
	Log-linear transformation	−0.018	−0.027	−0.043	−0.016	0.046	−0.054	−[a]	−[a]	−0.025	−0.092
D-W value		1.470	1.427	0.842	1.246	1.910	0.919	1.116	1.612	1.587	0.740
Adjusted D-W value		1.817	1.848	1.794	1.910	−[b]	1.833	2.036	1.954	1.823	2.019

Notes: *P < 0.05; **P < 0.01; ***P < 0.001; −[a]Log-linear transformation was not performed at P > 0.05; −[b]The Paris-Winsten estimation method was not performed since there was no first-order autocorrelation in the error terms.
Abbreviations: TCM, traditional Chinese medicine; D-W, Durbin–Watson.

medicine expense of stroke patients, and alleviated the economic burden of patients. As a kind of delayed disease, the incidence rate of stroke in the elderly population is significantly higher than that of other age groups, and it is usually accompanied by comorbidities such as hypertension, diabetes mellitus and coronary heart disease, and the recurrence rate after the onset of the disease is high.[12,25] Pharmacological treatment is currently the main treatment modality, and lipid-lowering drugs are widely used in clinical practice, combined with antiplatelet and antihypertensive drugs, mainly clopidogrel hydrogen carbonate and aspirin, to inhibit thrombogenesis and reduce recurrent ischemic events.[26–28] In addition, stroke patients need to take neuroprotective drugs such as piracetam to promote the recovery of cerebral neural function, and use the Shuxuetong injection, a purified extract of TCM for adjuvant treatment to relieve symptoms of vasospasm.[29,30] After the implementation of the ZMDP, the TCM expense per visit in stroke patients showed a downward trend. Although the scope of ZDMP does not cover the decoction pieces of Chinese medicine, some TCMs not on the list have been affected by the policy, resulting in a reduction of selling prices. It is worth noting that stroke inpatients had the highest proportion of drug expenses, despite ischemic stroke, as one of the subtypes of stroke, is primarily treated by surgical interventions, but still accounts for a high proportion of drug expenses. There are several reasons for the high proportion of drug expenses for stroke. Firstly, Chinese hospitals calculate expenses incurred during surgical treatment, such as medical consumables expenses, drug expenses, and anesthesia expenses, separately, whereas surgical expenses include only the technical operation expenses of medical staff. Secondly, Chinese hospitals implement the strict medical technology charging standards, and most of the charging standards have not been adjusted for a long time, while the prices of drugs and medical consumables are widely influenced by the regulation of the market, and have been on a rising trend in recent years.[31,32] As a result, the surgery expenses in Chinese hospitals are underestimated, while the drug expenses usually account for a relatively high proportion.

The total hospitalization expense and drug expenses of stroke patients did not change significantly at the instantaneous level when the policy was implemented, but thereafter showed a month-by-month decreasing trend, which may be due to the lagged effect of the policy interventions, consistent with the findings of Zhu et al.[33] One possible explanation is that continuous interventions such as ZMDP usually require a period of time as a transition period for adjustment from implementation to effect, resulting in the effects being delayed until after the transition period. The examination expense showed a month-to-month increase after the implementation of the policy. Consistent with the previous studies, hospitals may not have rationalized the reform policy when the ZMDP was implemented, and the government's financial compensation to public hospitals was not in place in a timely manner, and the economic loss formed in the short term will have an impact on the operation of the hospitals.[7,34] Some hospitals may increase their revenues by increasing the number of consumable materials and checkups in order to mark up for the economic loss caused by ZMDP.[35] In the long term, it seems that the growth rate of inpatients' examination expense per visit narrowed significantly after the policy implementation compared with that before the policy implementation, and the reason may be related to China's policy of abolishing the markup on medical consumables and the reform of clinical pathway in public hospitals.[7] Thus, although the overall level of consumables and examination expenses is still at a high level, the reform of China's healthcare system in recent years has had a significant effect, and the structure of patients' healthcare expenses has been optimized in a sustained and long-term process.

Clinical treatment, surgery, anesthesia, and other medical service programs are closely related to the total hospitalization expense. The higher the price of medical services, the higher the technical labor value of medical staffs.[34] The results of the ITS analysis showed that the instantaneous level of anesthesia expense for stroke inpatients increased at the time of policy implementation, reflecting the improvement in the value of medical staff's technical labor. Although the Chinese government explicitly requires medical service providers to further increase the price of medical services and mobilize the medical staffs' motivation, the problems of a low-price base for medical service programs, and the imperfection of the ZMDP related supporting policies and compensation mechanisms still exist in the current stage.[36] In addition, there is a certain degree of difficulty in promoting and charging for medical service programs due to the price control imposed by the health insurance sector on the reimbursement of some medical service programs and the difficulty in pricing new medical technologies.[37] When the contributions of medical staff cannot be acknowledged, their work motivation will decline, and some of them will be driven by interests to generate induced demand, and unreasonable behaviors such as over-diagnosis and treatment and repeated examinations will occur.[38] Therefore, it is recommended to continuously

optimize the structure of hospitalization expenses, strengthen internal supervision of hospitals, and deepen clinical path management.

This study has several limitations. Firstly, due to the availability of data, this study was not able to assess the changes in indirect expenses, intangible expenses, financial burden on uninsured stroke inpatients, and the expenses and mortality for patients with recurrent stroke and related complications. Secondly, the hospitals involved in this study were all tertiary public hospitals, and there was no cross-sectional comparison of hospitalization expenses for stroke inpatients at different levels of hospitals. Thirdly, although this study controlled the impact of long-term trend changes triggered by historical factors on outcome indicators before the intervention by setting multiple observation time points, it was not able to fully control the confounding factors, which affected the comparability of hospitalization expenses. In the future, more relevant data need be collected to assess the effects of the ZMDP on the economic burden of inpatients with stroke.

Conclusion

ZMDP is an effective attempt to reduce the financial burden of stroke inpatients and optimize the structure of medical expenses, with a significant decrease in patients' drug expenses. The expenses of medical service programs have increased, reflecting the improvement in the value of medical staff's technical labor. However, patients' examination expenses increased unexpectedly after the implementation of ZMDP, which may be related to the unreasonable medical compensation mechanism. The results of this study have a certain reference value for low- and middle-income countries to carry out medical reform. Further studies will be conducted by increasing the evaluation index and sample size for the assessment of different subtypes of stroke, stroke recurrence and associated complications to evaluate related health policies' long-term impact in a broader range.

Data Sharing Statement

The datasets used and analyzed in the current study are available from the corresponding author, upon reasonable request.

Ethics Approval and Informed Consent

The study has been granted exemption by the Biomedical Ethics Committee of Southwest Medical University (No. SWMUIRB-MCSC-20240226-0001). This study was conducted using anonymized informational data, and the patients' right to informed consent was ensured. All methods were performed in accordance with the Declaration of Helsinki and the Measures for the Ethical Review of Biomedical Research Involving Human Subjects issued by China.

Disclosure

The authors report no conflicts of interest in this work.

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