Analysis of Hospitalization Costs in Patients Suffering from Cerebral Infarction along with Varied Comorbidities

Yongmei He †, Sixuan Chen † and Yongcong Chen *

Institute of Social Medicine and Health Management, School of Public Health in Lanzhou University, Lanzhou University, Lanzhou 730030, China

* Correspondence: cyc0946@163.com; Tel.: +86-139-0946-4633
† These authors contributed equally to this work.

Abstract: Objective: This study aimed to study the influence of comorbidities on hospitalization costs for inpatients with cerebral infarction. Methods: The data from the medical records pertaining to 76,563 inpatients diagnosed with cerebral infarction were collected from public hospital records for the period between 1 January 2020 and 30 December 2020 in Gansu Province. EpiData 3.1 software was used for data collation, and SPSS 25.0 was used for data analysis. Numbers and percentages were calculated for categorical variables, the chi-squared test was used to compare differences between groups, and multiple independent-sample tests (Kruskal–Wallis H test, test level $\alpha = 0.05$) and multiple linear regression were used to analyze the influence of different types of comorbidity on hospitalization costs. Results: Among the 76,563 cerebral infarction inpatients, 41,400 were male (54.07%); the average age of the inpatients was 67.68 $\pm$ 10.75 years (the 60~80-year-old group accounted for 65.69%). Regarding the incidence of varied chronic disease comorbidities concomitant with cerebral infarction, hypertension was reported as the most frequent, followed by heart disease and chronic pulmonary disease. The average hospitalization cost of cerebral infarction inpatients is US $1219.66; the hospitalization cost increases according to the number of comorbidities with which a patient suffers ($H = 404.506$, $p < 0.001$); Regarding the types of comorbidities, the hospitalization cost of cancer was the highest, at US $1934.02$, followed by chronic pulmonary disease (US $1533.02$). Regarding the cost of hospitalization for combinations of comorbidities, cerebral infarction + chronic pulmonary disease was the most costly (US $1718.90$), followed by cerebral infarction + hypertension + chronic pulmonary disease (US $1530.60$). In the results of multiple linear regression analysis, cerebral infarction with chronic pulmonary disease had significant effects on hospitalization costs ($\beta = 0.181$, $p < 0.001$), drug costs ($\beta = 0.144$, $p < 0.001$) and diagnosis costs ($\beta = 0.171$, $p < 0.001$). Conclusions: Comorbidities are significantly associated with high hospitalization costs for cerebral infarction patients. Furthermore, relevant health departments should build preventative and control systems to reduce the risk of comorbidities, as well as to improve hospital clinical pathway management and to strengthen and refine the cost-control management of cerebral infarction from the perspective of comorbidities.

Keywords: comorbidity; cerebral infarction; hospitalization cost; chronic disease

1. Introduction

Cerebral infarction (CI), also known as ischemic stroke, is an acute cerebrovascular disease characterized by sudden blockage of an artery, preventing blood supply to a specific area of the brain, constituting the main type of stroke [1,2]. In 2008, the World Health Organization defined comorbidity as the coexistence of two or more chronic conditions in the same individual [3,4]. With changes in lifestyle and the aggravation of ageing, stroke patients experience an increased risk of suffering from multiple chronic diseases. Suffering from comorbidities is a hallmark of stroke and places a heavy economic burden on society [5]. In North America, the cost of stroke ranges from US $3.6 billion in Canada to USD...
34 billion in the US. In the Netherlands, the average hospital cost per patient for cerebral infarction is EUR 5328 (US $6845) [6]. The annual total expenditure for cerebral infarction was more than US $2898.6 million in China in 2011 [7]. The high medical costs as a result of comorbidities represent an important public health concern. The accumulating costs of different diseases vary greatly due to the presence of comorbidities [8]. Recently, many studies have focused on the medical costs of cerebral infarction patients regardless of their comorbidity status. However, there is a lack of research on the hospitalization costs from the perspective of comorbidities—especially in underdeveloped areas in the northwestern regions of China, such as Gansu Province. In this study, we focused on 13 chronic diseases, namely, hypertension, heart disease, diabetes, cancer, emotional and psychiatric disorders, asthma, chronic pulmonary disease, stomach or digestive diseases, arthritis or rheumatic disease, liver disease, kidney disease, memory-related diseases, and dyslipidemia. By accurately identifying the comorbidity patterns of cerebral infarction inpatients, and by exploring their influence on hospitalization costs, we can help relevant departments to formulate better medical insurance policies and health service guidelines, which will ultimately reduce the medical costs of patients with cerebral infarction and help allocate dedicated health resources reasonably. Hence, in this study, we thoroughly analyzed the associations between comorbidity status and hospitalization costs of cerebral infarction inpatients, providing us with the theoretical basis to better control the hospitalization costs of inpatients suffering with cerebral infarction.

2. Materials and Methods

2.1. Data Sources

The data were acquired from the “Direct Reporting System of Health Statistics Information Network” of the Health Commission of Gansu Province. We extracted data from the medical records pertaining to 76,563 inpatients with cerebral infarction who were discharged from public hospitals between 1 January 2020 and 30 December 2020 in Gansu Province. The Chinese National Bureau of Statistics showed that the average annual exchange rate between USD and RMB was 6.8996 RMB/USD in 2020 [9]. This study did not involve any private information on the patients or any ethical concerns.

Inclusion criteria:
(1) According to the International Classification of Diseases, patients with the primary diagnostic disease code I63.900 were included.

Exclusion criteria:
(1) Total hospitalization cost was zero;
(2) Data were missing or incorrect (which could not be corrected);
(3) Length of hospital stay was less than 1 day or more than 60 days.

2.2. Variables Extracted

(1) Basic inpatient information: gender, age, ethnicity, marital status, hospital level, and the patient’s chosen medical payment method;
(2) Clinical information: discharge diagnosis, history of comorbidities, length of hospital stay, discharge and admission dates, and operation status;
(3) Information relating to medical costs: total hospitalization costs, drug costs, diagnostic costs, treatment costs, costs of medical consumables, medical service costs, rehabilitation costs, and other costs.

2.3. Statistical Analysis

In this study, EpiData 3.1 software was used for data collation, whilst SPSS 25.0 was used for data analysis. The hospitalization costs, drug costs, and diagnostic costs were logarithmic and distributed in an approximately normal manner. Numbers and percentages were calculated for categorical variables. The chi-squared test was used to compare differences between groups. Multiple independent-sample tests (Kruskal–Wallis
H test, test level $\alpha = 0.05$) and multiple linear regression were used to analyze the influence of different types of comorbidity on hospitalization costs. In our study, all tests were two-tailed, and $p < 0.05$ indicated statistical significance.

3. Results

3.1. Basic Information of Inpatients

A total of 76,563 inpatients suffering from cerebral infarction were enrolled, including 41,400 males (54.07%) and 35,163 females (45.93%). The average age of the inpatients was 67.68 ± 10.75 years; 65.69% were 60–80 years old. Han ethnicity accounted for 94.01%, and married patients accounted for 82.22%. Only 12,519 patients (16.35%) did not have any comorbidities, while 64,044 patients (83.64%) suffered with comorbidities. The risk of comorbidity for patients aged 60–80 years was the highest, followed by those aged 40–60 years ($\chi^2 = 0.080, p < 0.001$); males had a significantly higher risk of stroke than females ($\chi^2 = 0.023, p < 0.001$). All differences were statistically significant (Table 1).

Table 1. Sociodemographic characteristics of discharged patients with cerebral infarction (n (%)).

| Variable                  | No Comorbidity Group | Comorbidity Group | Total       | $\chi^2$ | $p$  |
|---------------------------|----------------------|-------------------|-------------|----------|------|
| Gender                    | 7088 (9.26)          | 34,312 (44.82)    | 41,400 (54.08) | 0.023    | <0.001|
| Male                      | 5431 (7.09)          | 29,732 (38.83)    | 35,163 (45.92) |          |      |
| Female                    | 12,519 (16.35)       | 64,044 (83.65)    | 76,563 (100.00) | 0.198    | <0.001|
| Age, years                |                      |                   |             |          |      |
| 19                        | 273 (0.36)           | 746 (0.97)        | 1019 (1.33)  | 0.080    | <0.001|
| 40                        | 3684 (4.81)          | 13,896 (18.15)    | 17,580 (22.96) |          |      |
| 60                        | 7636 (9.97)          | 42,656 (55.72)    | 50,291 (65.69) |          |      |
| 80                        | 926 (1.21)           | 6747 (8.81)       | 7673 (10.02)  | -0.036   | <0.001|
| Ethnicity                 | 11,539 (15.07)       | 60,504 (79.03)    | 72,043 (94.10) |          |      |
| Han                       | 980 (1.28)           | 3540 (4.62)       | 4520 (5.90)   | 0.030    | <0.001|
| Ethnic minorities         |                      |                   |             |          |      |
| Unmarried                 | 1945 (2.54)          | 8955 (11.70)      | 10,900 (14.24) |          |      |
| Married                   | 10,310 (13.47)       | 52,637 (68.75)    | 62,947 (82.22) |          |      |
| Divorced/widowed          | 264 (0.34)           | 2452 (3.20)       | 2716 (3.54)   | 0.198    | <0.001|
| Hospital level            | 897 (1.17)           | 1279 (1.67)       | 2176 (2.84)   |          |      |
| First-level hospital      | 8019 (10.47)         | 28,663 (37.44)    | 36,682 (47.91) |          |      |
| Secondary hospital        | 3603 (4.71)          | 34,102 (44.54)    | 37,705 (49.25) |          |      |
| Tertiary hospital         | 12,519 (16.35)       | 64,044 (83.65)    | 76,563 (100.00) |          |      |

3.2. Association between Hospitalization Costs and the Number of Comorbidities

The average hospitalization cost of a patient suffering from a cerebral infarction was US $1219.66, and the average drug cost and diagnosis cost were US $391.77 and US $340.04, respectively. The average hospitalization cost of cerebral infarction patients without any comorbidities was estimated to be US $1174.31. On the other hand, the costs for patients suffering from one, two, three, and four or more chronic diseases were US $1224.41, US $1237.90, US $1247.30, and US $1322.27, respectively. Drug costs and diagnosis costs were the main components of hospitalization costs. The hospitalization costs ($H = 404.506, p < 0.001$), drug costs ($H = 153.385, p < 0.001$), and diagnosis costs ($H = 491.911, p < 0.001$) increased with the number of comorbidities. Statistically, these differences were significant, as shown in Table 2.
Table 2. The status of costs in different numbers of comorbidities for cerebral infarction patients (US $).

| Number of Comorbidities | Hospitalization Costs | Drug Costs | Diagnosis Costs | Treatment Costs | Medical Consumables Costs | Medical Service Costs | Nursing Costs | Rehabilitation Costs | Other Costs | Rank |
|-------------------------|-----------------------|------------|-----------------|----------------|--------------------------|----------------------|--------------|----------------------|------------|------|
| 0 (n = 12,519)          | 1174.31               | 352.88     | 314.30          | 188.61         | 115.76                   | 67.00                | 46.37        | 66.36                | 23.02      | 1    |
| 1 (n = 21,614)          | 1224.41               | 398.26     | 338.22          | 176.28         | 115.12                   | 90.59                | 60.43        | 40.92                | 4.58       | 2    |
| 2 (n = 23,146)          | 1237.90               | 402.38     | 330.07          | 180.70         | 139.68                   | 85.88                | 58.31        | 33.21                | 7.69       | 3    |
| 3 (n = 16,014)          | 1247.30               | 393.84     | 364.97          | 169.61         | 120.55                   | 91.14                | 59.12        | 45.47                | 2.59       | 4    |
| ≥4 (n = 3270)           | 1322.27               | 414.56     | 395.28          | 188.15         | 114.46                   | 89.65                | 66.36        | 50.83                | 2.98       | 5    |
| Total                   | 1219.66               | 391.77     | 340.04          | 178.66         | 123.27                   | 85.48                | 57.51        | 37.19                | 5.74       | 6    |

3.3. The Status of Hospitalization Costs in Different Types of Comorbidity

Among the types of comorbidity, the number of patients with comorbid hypertension (n = 45,626) was the highest, followed by heart disease (n = 27,646) and chronic pulmonary disease (n = 12,055); the hospitalization cost of cerebral infarction comorbid with cancer was the highest (US $1934.02), followed by chronic pulmonary disease (US $1533.02), asthma (US $1488.22), memory-related diseases (US $1439.01), and diabetes (US $1391.31) (Table 3).

Table 3. The status of costs in different types of comorbidities for cerebral infarction patients (US $).

| Type of Comorbidity | n     | Drug Costs | Treatment Costs | Diagnosis Costs | Material Costs | Medical Service Costs | Nursing Costs | Rehabilitation Costs | Other Costs | Hospitalization Costs |
|---------------------|-------|------------|-----------------|-----------------|---------------|----------------------|--------------|----------------------|------------|----------------------|
| Cancer              | 3253  | 576.05     | 316.59          | 468.05          | 306.84        | 113.42               | 88.74        | 60.05                | 4.28       | 1934.02              |
| Chronic pulmonary   | 12,055| 503.90     | 224.60          | 410.02          | 144.62        | 102.97               | 96.29        | 46.06                | 4.57       | 1533.02              |
| Asthma              | 412   | 508.30     | 225.25          | 445.58          | 118.64        | 96.88                | 68.01        | 23.88                | 1.69       | 1488.22              |
| Memory-related      | 1557  | 482.22     | 170.17          | 383.08          | 103.72        | 98.66                | 112.97       | 84.69                | 3.51       | 1439.01              |
| Diabetes            | 11,642| 439.92     | 196.73          | 409.36          | 127.19        | 84.87                | 65.40        | 62.03                | 5.82       | 1391.31              |
| Kidney disease      | 6719  | 418.68     | 184.62          | 402.24          | 96.40         | 96.74                | 67.21        | 64.14                | 2.32       | 1332.36              |
| Arthritis or        | 1815  | 346.40     | 204.91          | 316.20          | 186.24        | 91.63                | 46.99        | 29.42                | 2.56       | 1224.34              |
| Rheumatism disease  | 45,626| 394.25     | 172.19          | 339.44          | 116.05        | 87.12                | 56.28        | 41.12                | 5.82       | 1212.28              |
| Hypertension        | 27,646| 370.42     | 156.70          | 329.04          | 136.28        | 85.60                | 52.67        | 32.31                | 2.43       | 1165.44              |
| Heart disease       | 7436  | 362.28     | 142.46          | 361.92          | 68.73         | 85.32                | 53.59        | 55.08                | 2.27       | 1131.64              |
| Liver disease       | 5565  | 342.61     | 152.28          | 336.93          | 64.16         | 75.24                | 35.24        | 34.32                | 2.50       | 1043.28              |
| Dyslipidemia        | 6826  | 319.16     | 138.54          | 285.17          | 91.57         | 93.86                | 47.74        | 26.20                | 2.50       | 1004.73              |
| Stomach or          | 2951  | 274.97     | 130.03          | 284.34          | 52.47         | 122.38               | 45.02        | 28.72                | 1.60       | 940.12               |

3.4. The Status of Hospitalization Costs in Different Combinations of Comorbidities

The 20 most frequently related comorbidities accompanying cerebral infarction are listed in Figure 1. Based on the average hospitalization costs, the top seven were reported to be (1) cerebral infarction + chronic pulmonary disease (US $1718.90), (2) cerebral infarction + hypertension + chronic pulmonary disease (US $1530.60), (3) cerebral infarction + hypertension + diabetes (US $1375.56), (4) cerebral infarction + heart disease + chronic pulmonary disease (US $1318.41), (5) cerebral infarction + hypertension + diabetes + heart disease (US $1304.49), (6) cerebral infarction + diabetes (US $1292.39), and (7) cerebral infarction + hypertension + heart disease + kidney disease (US $1283.33) (Figure 1).
3.5. Multiple Linear Regression Analysis of the Impacts of Comorbidities on Hospitalization Costs for Cerebral Infarction Patients

Among the chronic disease types, patients suffering with a cerebral infarction along with chronic pulmonary disease had the greatest effect on hospitalization costs ($\beta = 0.181, p < 0.001$), followed by cancer ($\beta = 0.156, p < 0.001$). Cerebral infarction along with emotional and psychiatric disorders had the greatest effect on drug costs ($\beta = 0.370, p < 0.001$), followed by chronic pulmonary disease ($\beta = 0.144, p < 0.001$). Cerebral infarction along with chronic pulmonary disease had the greatest effect on diagnostic costs ($\beta = 0.171, p < 0.001$), followed by emotional and psychiatric disorders ($\beta = -0.149, p < 0.001$) (Table 4).
Table 4. Multiple linear regression analysis of the impacts of comorbidities on hospitalization costs.

| Variable                                | Hospitalization Costs | Drug Costs | Diagnosis Costs |
|-----------------------------------------|-----------------------|------------|-----------------|
|                                        | Beta      | t         | 95% CI          | Beta       | t         | 95% CI        | Beta       | t         | 95% CI        |
| (Constant)                              | 7.356 ** | 504.918   | 7.385 - 7.328   | 5.685 **  | 244.702   | 5.731 - 5.640 | 6.860 **  | 365.512   | 6.896 - 6.823 |
| Gender (Ref. = female)                  | -0.048 **| -12.684   | -0.041 - 0.056  | -0.057 **| -9.398    | -0.045 - 0.069| -0.029 **| -5.891    | -0.019 - 0.039|
| Age (Ref. = 60)                         | 0.148 ** | 8.985     | 0.180 - 0.115   | -0.014   | -0.551    | 0.037 - 0.065 | 0.073 *   | 3.462     | 0.115 - 0.032 |
| 40                                      | 0.022 ** | 4.790     | 0.031 - 0.013   | 0.007    | 0.987     | 0.022 - 0.007 | -0.001    | -0.182    | 0.011 - 0.013 |
| 80                                      | 0.050 ** | 7.822     | 0.063 - 0.038   | 0.073 ** | 7.131     | 0.093 - 0.053 | 0.053 **  | 6.290     | 0.069 - 0.036 |
| LN length of hospital stay              | 0.535 ** | 129.207   | 0.543 - 0.527   | 0.822 ** | 122.883   | 0.835 - 0.809 | 0.163 **  | 30.466    | 0.174 - 0.153 |
| Hospital level (Ref. = Tertiary hospital) |          |           |                |          |           |                |          |           |                |
| First-level hospital                    | -0.042 **| -3.771    | -0.020 - 0.064  | -0.042 * | -2.313    | -0.006 - 0.078| -0.109 **| -7.446    | -0.081 - 0.138|
| Secondary hospital                      | 0.466 ** | 116.274   | 0.474 - 0.458   | 0.405 ** | 63.806    | 0.417 - 0.392 | 0.586 **  | 113.117   | 0.596 - 0.575 |
| Payment (Ref. = medical insurance)     |          |           |                |          |           |                |          |           |                |
| Public expense                          | 0.029 *  | 3.003     | 0.047 - 0.101   | -0.124 **| -8.304    | -0.095 - 0.154| 0.044 **  | 3.641     | 0.068 - 0.020 |
| Out-of-pocket                           | 0.225 ** | 16.228    | 0.252 - 0.197   | 0.125 ** | 5.708     | 0.167 - 0.082 | 0.189 **  | 10.602    | 0.224 - 0.154 |
| Other                                   | 0.067 ** | 4.234     | 0.099 - 0.036   | -0.156 **| -6.215    | -0.107 - 0.205| 0.014     | 0.693     | 0.055 - 0.026 |
| Type of comorbidity (Ref. = cerebral infarction) |          |           |                |          |           |                |          |           |                |
| Hypertension                            | -0.040 **| -10.292   | -0.033 - 0.048  | -0.025 **| -3.954    | -0.012 - 0.037| -0.077 **| -15.205   | -0.067 - 0.087 |
| Diabetes                                | 0.069 ** | 12.976    | 0.080 - 0.059   | 0.003    | 0.402     | 0.020 - 0.013 | 0.143 **  | 20.612    | 0.156 - 0.129 |
| Heart disease                           | -0.025 **| -6.230    | -0.017 - 0.033  | 0.041 ** | 6.295     | 0.054 - 0.028 | -0.029 **| -5.482    | -0.019 - 0.039 |
| Emotional and psychiatric disorders     | -0.096 **| -9.710    | -0.077 - 0.116  | -0.370 **| -23.669   | -0.340 - 0.401| -0.149 **| -11.670   | -0.124 - 0.174 |
| Chronic pulmonary disease               | 0.181 ** | 33.911    | 0.191 - 0.170   | 0.144 ** | 16.927    | 0.160 - 0.127 | 0.171 **  | 24.726    | 0.184 - 0.157 |
| Stomach or digestive disease            | -0.096 **| -14.217   | -0.083 - 0.109  | -0.070 **| -6.448    | -0.049 - 0.092| -0.108 **| -12.417   | -0.091 - 0.125 |
| Liver disease                           | -0.041 **| -6.198    | -0.028 - 0.053  | -0.110 **| -10.565   | -0.089 - 0.130| 0.074 **  | 8.675     | 0.091 - 0.057 |
| Kidney disease                          | 0.023 *  | 3.363     | 0.036 - 0.010   | -0.017   | -1.592    | 0.004 - 0.039 | 0.119 **  | 13.346    | 0.137 - 0.102 |
| Asthma                                  | 0.053 *  | 2.016     | 0.104 - 0.001   | 0.132 *  | 3.196     | 0.213 - 0.051 | 0.105 *   | 3.124     | 0.170 - 0.039 |
| Arthritis or rheumatic disease          | 0.012    | 0.928     | 0.036 - 0.013   | -0.084 * | -4.252    | -0.045 - 0.123| -0.056 *  | -3.462    | -0.024 - 0.087 |
| Memory-related diseases                 | -0.019   | -1.455    | 0.007 - 0.045   | -0.003   | -0.122    | 0.039 - 0.044 | -0.030    | -1.720    | 0.004 - 0.064 |
| Cancer                                  | 0.156 ** | 16.552    | 0.174 - 0.137   | 0.135 ** | 9.081     | 0.164 - 0.106 | 0.141 **  | 11.589    | 0.165 - 0.117 |
| Dyslipidemia                            | -0.057 **| -7.878    | -0.043 - 0.071  | -0.065 **| -5.690    | -0.043 - 0.088| 0.033 **  | 3.741     | 0.053 - 0.017 |
| R²                                      | 0.371    | 0.258     | 0.230           |          |           |                |          |           |                |

Ref. = control group; * p < 0.05, ** p < 0.001.
4. Discussion

Among the types of chronic disease, hypertension and heart disease were more prone to occurring in patients alongside cerebral infarction. Related research showed that hypertension was a hallmark comorbidity of stroke. Moreover, large-artery atherosclerosis (LAA) stroke and small-vessel occlusion (SVO) stroke were closely related to hypertension. Moreover, studies have shown that cardioembolic stroke is associated with atrial fibrillation, valvular heart disease, and ischemic heart disease [10,11]. Hypertension transmits pulsating and turbulent blood flow to the brain’s microcirculation, which increases endothelial dysfunction and atherosclerosis, ultimately promoting the development of stroke. Heart disease and cerebral infarction have common risk factors and a similar underlying pathogenesis; for example, atrial fibrillation (AF) increases the risk of patients suffering from cerebral infarction also suffering from heart disease [12]. Our study found that patients suffering from chronic pulmonary disease have an increased risk of developing cerebral infarction ($\beta = 0.181$, $p < 0.001$). Relevant studies have shown that cerebral infarction patients are often associated with stroke-related pneumonia in the clinic, and the rate of comorbidity has been reported as high as 10–47% [13]. Chronic obstructive pulmonary disease can increase the risk of atherosclerotic stroke, which is an independent risk factor of cerebral infarction [14]. Patients presenting with cerebral infarction often also manifest with symptoms of dysphagia and a weakened cough reflex. The reason for this could be because secretions from the trachea become difficult to cough out after a stroke, resulting in their deposition in the respiratory tract and consequent chronic pulmonary infections [15–17]. A Danish study found that almost half of patients with occult lung cancer were identified three months (or more) after suffering from a stroke (notably, smoking was a common risk factor for both) [18]; therefore, it is necessary to identify patients who are at a high risk of suffering from chronic diseases that are related to cerebral infarction—especially hypertension, heart disease, and chronic lung diseases. It is also critical to strengthen the prevention and control of cerebral infarction and associated comorbidities.

In terms of medical costs, the hospitalization costs of patients suffering from a cerebral infarction along with one or more comorbidities were significantly higher than those not suffering with a comorbidity. The greater the number of comorbidities, the higher the hospitalization costs of cerebral infarction patients. Studies have shown that the superposition, coexistence, and combination of multiple chronic diseases can exacerbate a patient’s disease, leading to additional overutilization of health services and the consumption of medical resources, ultimately increasing medical expenditures [19]. Relevant studies have shown that the numbers of coexisting chronic diseases are associated with the levels of health service utilization and health expenditure. The duration of hospital stay and health expenditure increased by 1.73- and 1.34-fold for each additional comorbid chronic disease, respectively [20]; this represents an extremely significant rise in costs. Multiple studies from France have shown that when multiple chronic diseases coexist, the interaction between diseases produces clear super-accumulation, resulting in significantly increased healthcare-related costs [21]. American studies have also shown that suffering from comorbidities is an important factor that affects medical costs. The comorbidity index increases hierarchically, i.e., the higher the comorbidity index, the higher the hospitalization costs [22]. Therefore, controlling the numbers of comorbidities in patients with cerebral infarctions is crucial to reducing the consumption of medical resources and the costs of hospitalization.

Among the types of comorbidities commonly associated with cerebral infarctions, the hospitalization cost of cancer was the highest, followed by chronic pulmonary disease.

Among combinations of comorbidities, cerebral infarction + chronic pulmonary disease resulted in the highest hospitalization costs; thus, chronic lung disease is a disease that cannot be ignored in the context of our discussion. In addition, although the number of cerebral infarction patients who also suffered with hypertension and heart disease was the greatest, the cost of their hospitalization was relatively low, which might be closely related to Chinese medical insurance policies that are implemented in relation to diabetic and hypertensive drugs. As part of China’s healthcare reformation, hypertensive drugs
have been uniformly included in Medicare payments, and the associated reimbursement rate is now above 50%. The implementation of the “basic medical insurance + serious illness insurance system” policy has also greatly reduced the out-of-pocket payment ratio of hospitalization costs for cerebral infarction patients also suffering with hypertension and heart disease [23,24]. In contrast, the proportion of treatment drugs related to cancer and chronic pulmonary disease is low, and the proportion of out-of-pocket expenses of these patients is high, so the hospitalization costs of cerebral infarction combined with cancer or chronic pulmonary disease are higher. Studies have shown that the direct economic burden of chronic obstructive pulmonary disease patients accounts for almost 1/3 of the average annual household income of patients in China [25]. In Italy, the average annual cost per patient to treat chronic obstructive pulmonary disease is EUR 3911.70 [26]. Studies have confirmed that patients suffering with stroke and pulmonary disease have a high risk of comorbidities. The average hospital stay for a stroke patient with a comorbid chronic lung infection was 2.6 times longer than that of a patient without a chronic lung infection (13 days vs. 5 days); moreover, the average annual medical hospitalization cost was 3.5 times higher (US $21,043 vs. US $6206) [27–29]. Based on the aforementioned information, we believe that it is necessary to implement a reasonable increase in the set reimbursement of medical insurance that is related to medications for cerebral infarction and chronic pulmonary disease drugs. It is also necessary to introduce a variety of effective measures to reduce the hospitalization costs of patients suffering from comorbidities.

Multiple linear regression analyses between hospitalization costs and types of co-morbidities related to cerebral infarction revealed that chronic pulmonary disease had a significant influence on hospitalization and drug costs. On the one hand, chronic pulmonary disease is a progressive and irreversible disease, manifesting as a persistent cough or as asthma, which greatly affects patients’ quality of life, resulting in higher clinical medical needs as well as drug dependence. On the other hand, chronic pulmonary disease is characterized by polypharmacy and pharmacotherapeutic complexity. A patient’s medication compliance, drug-related side effects, and drug interactions all result in increased healthcare costs [30]. Cerebral infarction comorbid with chronic pulmonary disease not only increases the length of hospitalization but also results in high consumption of medical resources, which leads to high hospitalization costs. At present, the policies related to cost-control and intervention strategies used by the Chinese health authorities with respect to cerebral infarctions and their related comorbidities are not perfect. Hence, the relevant health departments should focus more of their attention on the medical costs of cerebral infarctions occurring alongside chronic pulmonary diseases, while also attempting to reduce the risk of cerebral infarction combined with chronic lung diseases.

5. Conclusions

Comorbidities are significantly associated with high hospitalization costs for cerebral infarction patients. Furthermore, relevant health departments should build prevention and control systems to not only reduce the risk of patients developing comorbidities but also improve the clinical management pathways and hospitalization cost-control system, as well as better refining the cost-control management of cerebral infarction from the perspective of comorbidities.

Author Contributions: Y.H. made substantial contributions to the conception or design of the study, including analysis and interpretation of data and design of the first draft of the manuscript. S.C. performed the relevant analysis and wrote sections of the manuscript. Y.C., as the corresponding author, takes primary responsibility for communication with the journal during the manuscript submission, peer-review, and publication processes, and ensured that all of the journal’s administrative requirements were met. All authors contributed to manuscript revision and read and approved the submitted version. All authors agree to be accountable for all aspects of this work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.
Institutional Review Board Statement: This study did not involve any ethical issues or private information of patients, and the study did not require ethical approval.

Informed Consent Statement: Patient consent was waived due to the medical records of the study did not involve the personal information and privacy of patients, and the researchers did not know the correspondence between patients and medical records during the entire research process, and did not involve ethical and in-formed consent issues.

Data Availability Statement: Restrictions apply to the availability of these data. Data were obtained from the Health Commission of Gansu Province, and data sharing is not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References
1. Zhang, J.Y.; Li, J.W.; Zhang, L.H.; Wang, Y.Y.; Mei, J.J.; Guo, J.; Li, R.Q. Research progress of Chinese medicine regulating P38/AKT signaling pathway to improve ischemic stroke. Chin. J. Exp. Tradit. Med. Formulae 2022, 28, 265–275. [CrossRef]
2. Paul, S.; Candelario, J.E. Emerging neuroprotective strategies for the treatment of ischemic stroke: An overview of clinical and preclinical studies. Exp. Neurol. 2021, 335, 113518. [CrossRef] [PubMed]
3. World Health Organization. The World Health Report 2008: Primary Health Care Now More than Ever; World Health Organization: Geneva, Switzerland, 2008.
4. Xu, X.B.; Li, D.; Sun, Y.; Shu, Q.; Xiao, L.; Xu, S.R.; Hu, S.; Jiang, Y.S.; Xin, Y. Analysis of chronic diseases comorbidity among the elderly in China based on association rules. Chin. J. Prev. Control Chronic Dis. 2021, 29, 808–812.
5. Cipolla, M.J.; Liebeskind, D.S.; Chan, S.L. The importance of comorbidities in ischemic stroke: Impact of hypertension on the cerebral circulation. J. Cereb. Blood Flow Metab. 2018, 38, 2129–2149. [CrossRef] [PubMed]
6. Lapchak, P.A.; Zhang, J.H. The High Cost of Stroke and Stroke Cytoprotection Research. Transl. Stroke Res. 2017, 8, 307–317. [CrossRef] [PubMed]
7. Hu, D.; Dong, J.; Zhu, J.; Zhang, R.H.; Tang, M.L.; Shu, Y.; He, W. Analysis on the composition and influencing factors of hospitalization costs for cerebral infarction patients in a tertiary hospital from 2007 to 2011. Chin. J. Health Stat. 2014, 31, 707–709.
8. Zou, S.; Wang, Z.; Bhura, M.; Zhang, G.; Tang, K. Prevalence and associated socioeconomic factors of multimorbidity in 10 regions of China: An analysis of 0.5 million adults. J. Public Health 2022, 44, 36–50. [CrossRef]
9. National Bureau of Statistics. Available online: http://www.stats.gov.cn/tjsj/zxfb/202102/t20210227_1814154.html (accessed on 16 August 2020).
10. Wang, P.; Sun, Y.; Yi, D.; Xie, Y.; Luo, Y. Clinical features of Chinese patients in different age groups with spontaneous intracerebral hemorrhage based on multicenter inpatient information. Neurol. Res. 2020, 42, 657–664. [CrossRef]
11. Rosales, J.S.; Alet, M.J.; Lereis, V.A.P.; Ameriso, S.F. Fall in the Proportion of Atherothrombotic Strokes during the Last Decade. J. Stroke Cerebrovasc. Dis. 2020, 29, 105257. [CrossRef]
12. Gallacher, K.I.; Jani, B.D.; Hanlon, P.; Nicholl, B.I.; Mair, F.S. Multimorbidity in Stroke. Stroke 2019, 50, 1919–1926. [CrossRef]
13. Yu, B.Q.; Tian, X.; Zhou, S.N.; Wu, S.; Liu, H. Related factors for pulmonary infections in acute stoke patients. Chin. J. Nosocomiol. 2015, 25, 3965–3966+3978.
14. Chen, B.; Dai, H.E.; Chen, L.X. The Value of Inflammatory Mechanism in Chronic Obstructive Pulmonary Disease with Ischemic Stroke. Shenzhen J. Integr. Tradit. Chin. West. Med. 2019, 29, 5–7.
15. Wang, H.; Li, S.L.; Bai, J.; Wang, D.X. Perioperative Acute Ischemic Stroke Increases Mortality after Noncardiac, Nonvascular, and Non-Neurologic Surgery: A Retrospective Case Series. J. Cardiotorhac. Vasc. Anesth. 2019, 33, 2231–2236. [CrossRef] [PubMed]
16. Chamorro, A.; Amaro, S.; Vargas, M.; Obach, V.; Cervera, A.; Gómez-Choco, M.; Torres, F.; Planas, A.M. Catecholamines, infection, and death in acute ischemic stroke. J. Neuro. Sci. 2007, 252, 29–35. [CrossRef] [PubMed]
17. Yu, X.; Ding, C.Y.; Wang, X.Y.; Luo, G.C.; Chen, H. Association of peripheral blood NLRP3 inflammasome gene polymorphisms with pulmonary infection in patients with ischemic stroke. Chin. J. Nosocomiol. 2021, 31, 1634–1638.
18. Babore, A.D.; Tybjerg, A.J.; Andersen, K.K.; Olsen, T.S. Occult lung cancer manifesting within the first year after stroke. J. Stroke Cerebrovasc. Dis. 2020, 29, 105023. [CrossRef]
19. Wolff, J.L.; Starfield, B.; Anderson, G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. Arch. Intern. Med. 2002, 162, 2269–2276. [CrossRef] [PubMed]
20. Chen, M.S.; Li, S. Studying the influence of comorbidity on the number of outpatient visits, length of hospitalization, and catastrophic health expenditure. Chin. J. Health Policy 2021, 14, 17–24.
21. Cortaredona, S.; Ventelou, B. The extra cost of comorbidity: Multiple illnesses and the economic burden of non-communicable diseases. BMC Med. 2017, 15, 216. [CrossRef]
22. Charlson, M.E.; Charlson, R.E.; Peterson, J.C.; Marinopoulos, S.S.; Briggs, W.M.; Hollenberg, J.P. The Charlson comorbidity index is adapted to predict costs of chronic disease in primary care patients. J. Clin. Epidemiol. 2008, 61, 1234–1240. [CrossRef]
23. State Council: More than 50% reimbursement of outpatient medication for hypertension and diabetes under medical insurance. For Your Health 2019, 10, 2.
24. Xu, M.M.; Liu, D.; Yang, C.Y. Study on the effect of implementing basic medical insurance+critical illness insurance in Rural areas of China—A case study of hospitalized farmers with heart disease in Men Tou Gou District, Beijing. *Price Theory Pract.* 2020, 4, 112–115+178.

25. Lou, P.A.; Yu, J.X.; Zhang, L.; Zhang, N.; Chen, P.P.; Zhang, L.; Han, L.C. Analysis on economic burden of COPD patients in Tongshan County. *Chin. J. Dis. Control Prev.* 2010, 14, 1129–1131.

26. Dal Negro, R.; Berto, P.; Tognella, S.; Quarenzi, L.; Global Outcomes in Lung Disease Study Group. Cost-of-illness of lung disease in the TriVeneto Region, Italy: The GOLD Study. *Monaldi Arch. Chest Dis.* 2002, 57, 3–9.

27. Lakshminarayan, K.; Tsai, A.W.; Tong, X.; Vazquez, G.; Peacock, J.M.; George, M.G.; Luepker, R.V.; Anderson, D. Utility of dysphagia screening results in predicting poststroke pneumonia. *Stroke* 2010, 41, 2849–2854. [CrossRef] [PubMed]

28. Katzan, I.L.; Cebul, R.D.; Husak, S.H.; Dawson, N.V.; Baker, D.W. The effect of pneumonia on mortality among patients hospitalized for acute stroke. *Neurology* 2003, 60, 620–625. [CrossRef] [PubMed]

29. Yuan, M.Z.; Li, F.; Tian, X.; Wang, W.; Jia, M.; Wang, X.F.; Liu, G.W. Risk factors for lung infection in stroke patients: A meta-analysis of observational studies. *Expert Rev. Anti Infect. Ther.* 2015, 13, 1289–1298. [CrossRef]

30. Khor, Y.H.; Glaspole, I.; Goh, N.S.L. Therapeutic burden in interstitial lung disease: Lessons to learn. *Respirology* 2019, 24, 566–571. [CrossRef]