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Gray Relational Analysis of Hospitalization Costs in Acute Pancreatitis

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Abstract

Chinese medical expenses have increased by 30% annually in recent years, far exceeding of 10% of the GDP in the growth rate, which has seriously affected economy development and people's living standards. In order to find the most relational kind of cost in the total hospitalization fee of acute pancreatitis, we collected 295 patient's hospitalization fee from a high level provincial hospital and analyzed the data. We found that the average hospitalization cost was RMB 28315.04 per capita and there was no significant difference in different years (F=0.183, P=0.908). Among all the components, western medicine costs were the main parts of the total cost, as its proportion in the total costs was more than 60% each year.

As for the gray relational analysis, western medicine fee had the highest correlation with total cost (r=0.9956), followed by medical service fee (r=0.9932). We concluded that irrational use of western medicine still existed in hospitals and the western medicine costs were higher than the requirement of the "Guiding Opinions on Pilot Projects of Comprehensive Reform in Urban Public Hospitals". Governments and hospitals should find ways and take measures to control the hospitalization costs of acute pancreatitis, especially the western medicine costs, as well as exploring new methods, Chinese and western medicine combination, for example, for the treatment of acute pancreatitis.

Keywords: Acute Pancreatitis; Gray Relational Analysis; Hospitalization Costs

Background

Among studies on controlling medical expenses, the most concerned issue to scholars was the control of hospitalization expense. Data on medical expenditure in 29 OECD countries shows that hospitalization expense is the mainstay of total medical expenditure in these 29 countries. Besides, hospitalization expense is straightly related to medical burden of hospitalized patients. In other words, the higher the expense of hospitalization is, the heavier the medical burden will be. In terms of growth rate, Chinese medical expenses have increased by 30% annually in recent years, far exceeding 10% of the growth rate of GDP, which has seriously affected economy development and people's living standards [1]. Therefore, exploring the hospitalization expenses components and the reasons for its growth is of great practical significance to the government, social health insurance department, hospitals and patients.

Acute pancreatitis is a kind of common but severe disease with higher cost of hospitalization the characteristics of which are acuteness, fast progression and dangerous condition. It is a common diarrhea in digestive medicine, and its incidence among all kinds of acute abdomen accounts for 3%-5%, of which nearly 80% patients are mild pancreatitis and about 20% patients are severe acute pancreatitis with a mortality rate of 20% -30% [2]. In the United States, the number of hospitalization for acute pancreatitis has increased by no less than 20% over the past 10 years [3]. However, with the development of medical science and technology the mortality rate of acute pancreatitis is also decreasing every year, with the overall mortality rate reaching about 2% [4]. Due to the danger of acute pancreatitis, its high cost of treatment has resulted in both the medical burden on patients' families and extreme pressure on health insurance. Previous researches showed that the annual treatment cost of acute pancreatitis was as high as 2.5 billion U.S. dollars. The average cost of hospitalization for it in the United States was 9,870 U.S. dollars per capita and the average daily hospitalization cost was 1,670 U.S. dollars. The rapid

growth of hospitalized medical expenses not only poses serious financial burden on patients, but also brings unprecedented social development pressure.

Gray Relational Analysis (also known as Gray Correlation Analysis) is an important part of gray system theory, which is also the cornerstone of gray system analysis, prediction and decision-making. It is mainly used to analyze and process incomplete and indefinite information in gray system, to quantify and sequence the factors and to analyze the relationship between different data. There are many studies on the gray relational analysis of other diseases, but we found that there was little research on pancreatitis. In fact, Gray relational analysis is an obvious way to explore the main factors in a system and the other factors will promote or hinder the development of a system. This study analyzed the hospitalization costs of 296 patients with acute pancreatitis from 2012 to 2015 in a large provincial hospital in Shandong Province using gray relational analysis. We analyzed the composition ratio and correlation degree of hospitalization costs and the related reasons, to find some ways and provide data support for controlling the medical cost.

Materials and Methods

Sources of Data

Data of this study comes from electronic information system in a large provincial hospital in Shandong Province, including basic information of patient and hospitalization costs of 295 patients with acute pancreatitis from 2012 to 2015.

Definition of Data

Hospitalization costs include: medical service fee, diagnosis fee, non-surgical treatment fee, surgical treatment fee, traditional Chinese medicine treatment fee, western medicine fee, traditional Chinese medicine fee, blood and blood products costs, supplies costs, and other costs [6]. In this article, the original cost is used for data analysis.

- **Medical Services Fee:** including doctor consultation, prescribing, debridement, rescue fees, intensive care, nursing fees, injections and other costs. It reflected the medical staff's technical labor value.

- **Diagnostic Fee:** patients' pathological diagnosis during hospitalization, laboratory diagnosis, imaging diagnosis, endoscopy and other diagnostic items costs.

- **Non-surgical Treatment Fee:** including hyperbaric oxygen, psychotherapy, physical therapy and other costs.

- **Surgical Treatment Fee:** the costs incurred for projects that use invasive means of treatment, including anesthesia fees and various interventions and surgical treatments.

- **Chinese Medicine Treatment Fee:** the costs incurred in the use of traditional Chinese medicine treatment like acupuncture and massage. Traditional Chinese medicine fees were not included.

- **Western Medicine Fee:** the expenses incurred by western medicine during hospitalization, including the cost of antibacterial drugs and other western medicines.

- **Chinese Medicines:** including Chinese patent medicine and herbal medicine costs.

- **Blood and Blood Products Category Fee:** including fees for transfusions, the use of protein products and cytokine products.

- **Consumables Fee:** including one-time medical materials used in the inspection, treatment and surgical procedures.

- **Other Categories Fee:** The sum of the fees that are not included in the above categories during hospitalization.

Statistical Software

Excel 2010 software and SPSS 22 software were used for statistics and analysis of the data.

Analytical Methods

- **Gray System**

There are known white information and unknown black information in the real world. Gray information is the kind of information between them, which will easily lead to the uncertainty of traditional systematic analysis-both "scientific" and "subjectivity". The advantage of gray analysis lies in using "uncertain information" to find out the regulation of the development of things. It depends on neither statistical "big sample data" nor the typical distributions. Gray System has been growing rapidly since it was introduced by Professor Julong De in the early 1980s. Its application has expanded to all aspects of production, living and scientific research. Gray Relation Analysis (also known as Gray Correlation Analysis) is not only an important part of Gray System theory, but also the cornerstone of Gray System analysis, prediction and decision-making. The basic idea is to judge whether the relationship is close by determining the degree of similarity between the reference data columns and the comparative data columns, which reflects the degree of correlation between curves [8].

The Gray Relation Analysis is actually the analysis of the correlation coefficient, by which the correlation degree is obtained. The correlation degree is used to describe the strength, size and order of the relations among factors [9]. By using Gray Relation Analysis, this paper explores the internal factors of hospitalization expenses in 2012-2015, trying to find out the close relationship between total hospitalization expenses and different parts of the expenses in four years of patients with acute pancreatitis and to

understand the changes of the internal structure of hospitalization expenses.

- **Fundamentals**

The total cost as reference data columns:

$$X_0 = \left\{ X_{0\,(k)} \ , \ k = 2012, 2013, 2014, 2015 \right\}$$

where K refers to the time, which is 2012, 2013, 2014, 2015; Other fees as comparative data columns, Then

$$\xi_{i(k)} = \frac{\min\limits_{i} \min\limits_{k} \left| X_{0(K)} - X_{i\,(k)} \right| + \rho \max\limits_{i} \max\limits_{k} \left| X_{0(k)} - X_{i\,(k)} \right|}{\left| X_{0\,(k)} - X_{i\,(k)} \right| + \rho \max\limits_{i} \max\limits_{k} \left| X_{0(k)} - X_{i\,(k)} \right|}$$

is the correlation coefficient between the reference data columns and the comparative data columns at time k. ρ is the resolution coefficient and usually is 0.5.

$$\min\limits_{i} \min\limits_{k} \left| X_{0(K)} - X_{i\,(k)} \right| , \quad \max\limits_{i} \max\limits_{k} \left| X_{0\,(k)} - X_{i\,(k)} \right|$$ are the minimum difference between two levels and the maximum difference between two levels respectively. Correlation degree calculation formula:

$$r_i = \frac{1}{n} \sum_{i=1}^{n} \xi_{i\,(k)} \ , \ k = 2012, \ 2013, \ 2014, \ 2015$$

The degree of association connects the correlation coefficients at different times so that it helps to observe the correlation strengths between them.

Results

General Situation

The treatment cost information of patients was from the hospital electronic information system. There were 189 males and 106 females, 238 surgical patients and 57 non-surgical patients. Demographic characteristics of hospitalized patients as well as hospitalization costs were described and analyzed to understand its basic composition. Patients ranged in age from 15 to 92 (average 55.01). Average hospital stay was 11.35 days. The average hospitalization total cost was RMB 26342.37 (n = 92) in 2012, RMB 29687.60 (n = 60) in 2013, RMB 28547.28 (n = 66) in 2014 and RMB 29403.38 (n=77) in 2015.

Year	Number Of Patients	Total Hospitalization Cost	Total Hospitalization Cost Per Capita
2012	92	2423498.11	26342.37
2013	60	1781256.00	29687.60
2014	66	1884120.90	28547.29
2015	77	2264060.90	29403.39

Table 1: Total inpatient costs in 2012-2015.

Per Capita Hospitalization Cost and Its Composition of Inpatients with Acute Pancreatitis

As (Table 2) shows, the total cost in different years were compared and we found no significant difference between the total cost of hospitalization per capita in different years (F=0.183, P=0.908). Western medicine costs are the main component of the total cost. In the past four years, western medicine costs and its proportion of the total hospitalization fee were RMB 18628.99 (70.72%) in 2012, RMB 20234.89 (68.16%) in 2013, RMB 18844.62 (66.01%) in 2014 and RMB 20344.90 (69.19%) in 2015. After comparing the proportion of western medicine fees in the total costs, we found that the difference in the proportion of

western medicine costs in different years were not statistically significant (F=0.133, P=0.940). Besides, the diagnostic costs accounted for a higher proportion of the total cost of hospitalization, which was more than 10% every year.

Discharge year	2012 RMB(percentage)	2013 RMB(percentage)	2014 RMB(percentage)	2015 RMB(percentage)
Total costs	26342.37	29687.60	28547.29	29403.39
medical service fee	1445.57(5.49)	1857.20(6.26%)	1649.52(5.78%)	1618.25(5.50%)
diagnosis fee	2832.47(10.75%)	4087.37(13.77%)	4300.07(15.06%)	4913.03(16.71%)
non-surgical treatment fee	210.32(0.80%)	175.00(0.59%)	345.82(1.21%)	57.53(0.20%)
surgical treatment fee	376.41(1.43%)	424.75(1.43%)	340.83(1.19%)	325.71(1.11%)
traditional Chinese medicine treatment fee	0.43(0.00%)	2.00(0.00%)	1.82(0.00%)	7.27(0.02%)
western medicine fee	18628.99(70.72%)	20234.89(68.16%)	18844.62(66.01%)	20344.90(69.19%)
traditional Chinese medicine fee	33.87(0.13%)	83.80(0.28%)	52.25(0.18%)	47.98(0.16%)
blood and blood products costs	311.04(1.18%)	465.40(1.57%)	537.15(1.88%)	364.97(1.24%)
supplies costs	2458.19(9.33%)	2283.86(7.69%)	2346.15(8.22%)	1703.50(5.79%)
other costs	45.09(0.17%)	73.34(0.25%)	129.05(0.45%)	20.26(0.07%)

Table 2: Per capita hospitalization cost and each composition of the total fees for acute pancreatitis from 2012 to 2015.

The Composition of Medical Expenses and their Relevance

Western medicine fee has the highest correlation with total cost (r=0.9956), followed by medical service fee (r=0.9932), surgical treatment costs (r=0.9867), blood and blood products costs (r=0.9406), diagnosis fee (R=0.9591), non-surgical treatment costs (r=0.9503), traditional Chinese medicine fee (r=0.9406), and traditional Chinese medicine fee (r=0.6849). From table 3 we can see that among all the composition of the total fees, western medicine fee has the highest percentage and the highest relevance in the total fee, while the traditional Chinese medicine fee relevance was the lowest one, which suggested that western medicine fee has the greatest impact on total costs.

Relevance	Western Medicine Fee	Medical Service Fee	Diagnosis Fee	Non-Surgical Treatment Fee	Surgical Treatment Fee	Chinese Treatment Fee	Traditional Chinese Medicine Fee	Blood And Blood Products Costs	Medical Consumables	Other Costs
R	0.9956	0.9932	0.9591	0.9503	0.9867	0.6849	0.9406	0.9682	0.9652	0.9197

Table 3: Composition of medical expenses and the relevance (R).

Discussion

The Gray Relational Analysis is a new way to study the uncertain problem of the data with "poor information". This theory takes the "small sample" and "poor information" system with some known and unknown information as the research objects, using the way of generating, developing and extracting valuable information of some known information to realize the system operation behavior, the correct description of the evolution of the law and effective monitoring [10]. Gray Correlation Analysis method used in this article reduced the dependence of some characteristics of the data type and the sample size as other analysis methods do and overcame the influence of the non-dimensional processing on the index. Its calculation is convenient and the result is intuitive and easy to understand. It is especially suitable for measuring the correlation degree between the different factors, reflecting the main factors objectively and sorting them in line. With the requirements of the actual situation, the analysis results will be more reliable. From (Table 1), patients' age ranged from 15 to 92 (average 55.01).

The average length of hospitalization was 11.35 days, which was in line with the findings of the domestic surveys [11]. However, the Clinical Pathway of mild Acute pancreatitis, issued on 2009, set the standard length of hospitalization at 7-10 days. There is positive correlation between hospitalization costs and hospitalization days and the hospitalization days were basically stable in these four years with little fluctuation in hospitalization costs. The average hospitalization costs were RMB 28315.04, which was twice as the average hospitalization cost RMB 13,529.61 in treatment of acute pancreatitis antibacterial medicine use survey analysis made by Liu Xiaojie and Zhao Shu 10 years ago [12]. We speculate the reason is that in our study, this hospital level is high and the condition of patients in this hospital was serious so that both the hospitalization days and costs were high than the previous researches.

From (Table 2), in per capita hospitalization cost and its composition of inpatients with acute pancreatitis, western medicine costs (RMB 19514.6 in average) is the main component of the total cost. The proportion of western medicine costs from 2012 to 2015 was 70.72%, 68.16%, 66.01% and 69.19% respectively (P=0.964), accounting for 68.52% of the average medicine, exceeding 2/3 of the total hospitalization expenses, which was the same as the previous conclusions [10,13,14]. The proportion of western medicine in four years remains high. We speculate the possible reasons as follows: First, although the hospital is controling the medical expenses under the big policy environment of canceling the medicine addition, there is still room for supervision of rational use of western medicine. In other words, irrational use of western medicine still exists in hospitals; Second, it is associated with the characteristics of the disease and the patients' structure in this hospital. Non-surgical treatment of acute pancreatitis needs adequate western medicine to control inflammation. In addition, the proportion of patients before and after surgery and patients treated with chemotherapy is high, so the required medicines are relatively more.

(Table 3) shows that the western medicine costs correlation degree is the highest (r=0.9956) among all kinds of composition in the total costs, followed by medical service fee (r=0.9932), and traditional Chinese medicine fee correlation degree is the lowest(r=0.6849). The evaluation results are consistent with the actual situation of the hospital. According to the degree of relevance, this hospital can take targeted measures to control the total cost of hospitalization. In addition, according to the data, we found that the lowest kind of cost is traditional Chinese medicine fee. Some researchers pointed out that the combination of traditional Chinese medicine and Western medicine treatment of acute pancreatitis had obvious advantages, as there are easy accesses to traditional Chinese medicine such as the treatment of severe acute pancreatitis with rhubarb and Xuanming powder combined with early enteral nutrition [15]. And the use of other methods of integrative medicine in the observation of the disease can reduce hospital costs and shorten the hospitalization stay [16]. As Chinese government has promoted the development of traditional Chinese medicine in recent years, we should try to find ways to cure acute pancreatitis of traditional Chinese medicine, and combine traditional Chinese medicine and western medicine, the outlook of which is impressive.

Conclusion

This paper took the hospitalization cost structure and its proportion of 295 acute pancreatitis patients in a large provincial hospital in Shandong province from 2012 to 2015 as an example, analyzed the hospitalization cost structure and proportion of patients with acute diseases, and explored the highest correlation with the total cost by Gray Relational Analysis. This study showed that western medicine costs accounted for the highest in the total cost of hospitalization (more than 65% each year). At the same time, with the total cost increasing, western medicine costs will rise. This result, consistent with similar studies domestic and overseas, are contradictory the "Guiding Opinions on Pilot Projects of Comprehensive Reform in Urban Public Hospitals" which strived to reduce the proportion of western medicine in the pilot cities public hospitals (excluding Chinese herbal medicines) to 30% in 2017.

This indicated that after the new medical reform expenditure control policy, western medicine costs have not been controlled to a reasonable level, and their proportion in the total costs is too high. The results of this study suggested that the hospital should continue to reduce the proportion of western medicine costs on the basis of ensuring the treatment effect and the control of total

cost. The hospital should also adjust the costs to a relatively reasonable range, for example, exploring new medicine research and development, standardizing medicine bidding and purchasing and exploring Chinese and western medicine combined with the treatment of acute pancreatitis.

Shortcomings and Prospects

The data of this study comes from the patient's electronic information system of a high level provincial hospital in Shandong province. The database lacks other variables that could help to analyze other details and to find more possible reasons which we wanted to explore, such as the economic status of the patients, the severity of the illness, the reimbursement of medical insurance expenses, etc. We referred to other researches and studies, and combined them with the actual situation on the ground. We hope that in the future based on the improved hospital database, we will get more comprehensive information about inpatients with pancreatitis and further study and we can explore the factors influencing hospitalization costs so as to achieve the ultimate goal of improving medical quality and controlling medical expenses.

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