Standardization of medical service indicators: A useful technique for hospital administration

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Abstract

Background

Many comparability problems appear in the process of the performance assessment of medical service. When comparing medical evaluation indicators across hospitals, or even within the same hospital, over time, the differences in the population composition such as types of diseases, comorbidities, demographic characteristics should be taken into account. This study aims to introduce a standardization technique for medical service indicators and provide a new insight on the comparability of medical data.

Methods

The medical records of 142592 inpatient from three hospitals in 2017 were included in this study. Chi-square and Kruskal-Wallis tests were used to explore the compositions of confounding factors among populations. The procedure of stratified standardization technique was applied to compare the differences of the average length of stay and the average hospitalization expense among three hospitals.

Results

Age, gender, comorbidity, and principal diagnoses category were considered as confounding factors. After correcting all factors, the average length of stay of hospital A and C were increased by 0.21 and 1.20 days, respectively, while that of hospital B was reduced by 1.54 days. The average hospitalization expenses of hospital A and C were increased by 1494 and 660 Yuan, whilst that of hospital B was decreased by 810 Yuan.

Conclusions

Standardization method will be helpful to improve the comparability of medical service indicators in hospital administration. It could be a practical technique and worthy of promotion.
Introduction

Healthcare systems across the world are facing the challenges of meeting growing demand, as well as increasing productivity, reducing costs and improving outcomes[1–3]. How to fairly allocate the scarce medical resources in an efficient and effective manner to meet the medical needs of the population while at the same time curb the excessive growth of medical costs is one of the major challenges for governments at all levels[4–6]. To solve this dilemma, various reimbursement mechanisms and medical quality evaluation indicators were introduced[7–9], for instance, diagnosis-related group (DRG), a patient classification system that standardizes prospective payment to hospitals and encourages cost containment initiatives which firstly adopted by the US Medicare Programme as the currency for reimbursing hospitals on a prospective, per-case basis[10]. As a hospital reimbursement and performance monitoring tool, DRG now has been introduced and indigenized in several countries [8, 11, 12]. Chinese health regulator has also actively explored the feasibility of DRG in China and piloted in some areas. Besides, in order to alleviate the problems of biased resource allocation and high patient flows to large hospitals, China implemented a hierarchical medical system[13]. It’s a two-way referral system that enables the basic hospitals to treat common diseases, and patients with intractable diseases are transferred to higher-level hospitals. Optimizing the average length of stay (ALOS) and controlling the average hospitalization expense(AHE) were cited as high priorities for health service providers, behind these policies, and were considered as two important efficiency indicators to assess the medical quality and management level of many health systems [14–16].

However, there are differences in rates of some phenomena between populations. They are usually confounded by the population compositions which cannot be directly compared [17, 18]. Similarly, comparability problems also exist in the assessing of medical services performance. For instance, the costs of surgical patients are higher than those of non-operative patients who have the same disease. Meanwhile, the length of hospital stays and costs for critical patients are usually higher than those of mild patients. When evaluating the medical service indicators among hospitals, disease interference is inevitable as long as there exist attribute and severity differences, which will eventually result in the medical variance. And this difference can even be caused by unreasonable medical expenses. Simply comparing the values without considering the actual condition of the patients is unfair to those hospitals with more critical patients and will dampen their enthusiasm.

Therefore, to improve the evaluation quality and make the medical service indicators results more comparable among hospitals, and among different time periods of the same hospital, the details of population composition such as types of diseases, comorbidities, demographic characteristics, etc. should be taken into account[4, 19]. DRG-based payment approach can control the costs, reduce the care intensity and shorten the hospital stays by grouping similar patients. However, it’s a composite indicator which is not applicable in the assessment of single medical service indicators. Thus, it is imperative for us to find a more appropriate and objective method for the comparation of medical indicators. Standardization method is a commonly used technique for adjusting the confounding effects of population composition to enhance the comparability of indicators among multiple populations [20, 21]. The purpose of this study is to introduce a specific standardization technique for medical service indicators in hospital management by using the first-hand clinical data from three general hospitals. ALOS and AHE, the most commonly used indicators, were taken as example for presentation. Altogether, this study identified the existing needs for the assessment of medical service utilization and provided a new insight for financial reimbursement.
Materials and methods

Study design and data source

The study began on February 1, 2018. A total of 160164 inpatient medical records in 2017 were collected from three tertiary general hospitals, retrospectively. Patients who discharged from the emergency medical department or less than 18 years old were excluded. To protect patients' privacy, their identities were concealed, and only medical record numbers were used. This study was in conformity with the "Ethics review methods for biomedical research involving human" promulgated by the Ministry of Health of The People’s Republic of China and was performed in accordance to the Helsinki Declaration. The protocol has been approved by the Ethics Committee of the First Affiliated Hospital of Zhejiang Chinese Medical University.

Measurement of variables

The data set used in this research included the individual patient variables of age, sex, date of admission and discharge, the principal diagnosis and disease code (first listed diagnosis), the number of comorbidities, admission type, length of stay, and total expenses. The principal diagnoses were coded at discharge according to the International Classification of Disease, Tenth Revision (ICD-10). There was no missing data in this analysis.

In order to facilitate the comparison of internal diseases among three hospitals, the principal diagnoses were divided into 22 categories according to ICD10 codes. The categories are as shown in Table 1.

Table 1. The principal diagnoses category and ICD10 code.

| The principal diagnoses category                                                | ICD10 code |
|---------------------------------------------------------------------------------|------------|
| Certain infectious and parasitic disease                                       | A00-B99   |
| Neoplasms                                                                       | C00-D48   |
| Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism | D48-D89   |
| Endocrine, nutritional and metabolic diseases                                  | E00-E90   |
| Mental and behavioural disorder                                                | F00-F99   |
| Diseases of the nervous system                                                 | G00-G99   |
| Diseases of the eyes and adnexa                                                 | H00-H59   |
| Diseases of the ear and mastoid process                                        | H60-H95   |
| Diseases of the circulatory system                                             | I00-I99   |
| Diseases of the respiratory system                                             | J00-J99   |
| Diseases of the digestive system                                               | K00-K93   |
| Diseases of the skin and subcutaneous tissue                                  | L00-L99   |
| Diseases of the musculoskeletal system and connective tissue                  | M00-M99   |
| Diseases of the genitourinary system                                           | N00-N99   |
| Pregnancy, childbirth and the puerperium                                        | O00-O99   |
| Certain conditions originating in the perinatal period                         | P00-P96   |
| Congenital malformations, deformations and chromosomal abnormalities           | Q00-Q99   |
| Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified | R00-R99   |
| Injury, poisoning and certain other consequences of external causes           | S00-T98   |
| External causes of morbidity and mortality                                      | V01-Y98   |
| Factors influencing health status and contact with health services             | Z00-Z99   |
| Codes for special purposes                                                     | U00-U99   |

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Table 2. Stratified standardization method of medical service indicator among three hospitals.

| Factor A(i) | Factor B(j) | Standard population (Nij) | Hospital A(N1) | Hospital B(N2) | Hospital C(N3) |
|-------------|-------------|---------------------------|---------------|---------------|---------------|
|             |             |                           | Indicator (Tij) | Expected (NijTij) | Indicator (Tij) | Expected (NijTij) | Indicator (Tij) | Expected (NijTij) |
| i = 1       | j = 1       | N11                       | T111          | N11 · T111     | T112          | N11 · T112     | T113          | N11 · T113     |
|             | j = 2       | N12                       | T121          | N12 · T121     | T122          | N12 · T122     | T123          | N12 · T123     |
|             | j = 3       | N13                       | T131          | N13 · T131     | T132          | N13 · T132     | T133          | N13 · T133     |
|             |             |                           | ...           | ...            | ...           | ...            | ...           | ...            |
| i = 2       | j = 1       | N21                       | T211          | N21 · T211     | T212          | N21 · T212     | T213          | N21 · T213     |
|             | j = 2       | N22                       | T221          | N22 · T221     | T222          | N22 · T222     | T223          | N22 · T223     |
|             | j = 3       | N23                       | T231          | N23 · T231     | T232          | N23 · T232     | T233          | N23 · T233     |
|             |             |                           | ...           | ...            | ...           | ...            | ...           | ...            |
| Total       | ΣNij        | ΣNijTij1                  | T1            | ΣNijTij2       | T2            | ΣNijTij3       | T3            | ΣNijTij3       |
| Standardized indicator | — | T′ = ΣNijTij / ΣNij |

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Statistical analysis

Standardized indicators are more comparable, which means, it’s important to distinguish the differences between observed indicators into true differences and the differences caused by the component effects of the confounding factors [20, 22].

Suppose there is a medical service indicator (T) that needs to compare among three hospitals, recorded as T1, T2 and T3. The differences originated from confounding factors (e.g. age, disease). The algebraic expression for computing a standardized indicator with two confounding factors is shown as follows.

T′ = ΣNijTij / ΣNij

Here, the sum of discharges from three hospitals was used as the standard population. Nij denotes the standard population in the jth category of confounding factor (i = 1, 2, 3, ...; j = 1, 2, 3, ...); Tij is the crude value in the jth category; T′ denotes standardized value. The calculation process is shown in Table 2.

In this study, the ALOS and AHE were standardized according to confounding factors stratified and compared among three hospitals. According to literatures, ALOS and AHE were associated with age, females, patients with more comorbidities, patients with a higher DRG weight and the incentives of the financing system [23–25]. Hence, age, gender, comorbidity and principal diagnoses category were considered as confounding factors. T test, Chi-square and Kruskal-Wallis tests were used to verify these factors. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS for windows, version 18.0; Chicago, Illinois, USA). Statistical significance was set at P<0.05 (two-tailed).

Results

Clinical and demographic characteristics

Totally 160164 discharged patients were collected, 17572 cases were excluded according to exclusion criteria, and 142592 cases were analyzed. As shown in Table 3, the ALOS and AHE in total were 11.75 days and 16341 Yuan, respectively. The ALOS of three hospitals from low to high was hospital C (10.55 days) < hospital A (11.50 days) < and hospital B (16.13 days).
Whereas, the AHE was hospital B (11028 Yuan) < hospital C (16663 Yuan) < hospital A (17299 Yuan).

Table 4 provided the baseline characteristics of patients from each hospital. The results indicated that the population compositions, e.g. gender, age, comorbidities and disease classification, were significantly different among three hospitals. The proportion of female were higher than that of male in all three hospitals. The median age of patients in hospital A, hospital B, and hospital C were 57 years (IQR 41~72), 62 years (IQR 45~78), and 53 years (IQR 39~67).

Table 3. Total number of discharges, ALOS and AHE of three hospitals’ discharges.

|                | Hospital A | Hospital B | Hospital C | Total |
|----------------|------------|------------|------------|-------|
| Discharges     | 79,470     | 17,119     | 46,003     | 142,592|
| ALOS           | 11.50      | 16.13      | 10.55      | 11.75 |
| AHE(CNY)       | 17,299     | 11,028     | 16,663     | 16,341|

ALOS, average length of stay; AHE, average hospitalization expense; Total, the common standard

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SD, standard deviation; QL, lower quartile(P25); QU, upper quartile(P75).

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39~67), respectively. Patients in hospital B were older than hospital A and hospital C. The percentage of comorbidities in hospital B (79.1%) was also higher than the other hospitals. Meanwhile, there were some differences in the disease composition among three hospitals. The highest percentage of diseases diagnoses category in hospital A, B, and C was I00-I99 (17.9%), I00-I99 (17.4%), and C00-D48 (30.0%), respectively.

**Standardization of ALOS**

The total number of discharged patients in all three hospitals was taken as a common standard to facilitate comparisons. Assume that the principal diagnoses category played a crucial role in hospitalization days and expense among all confounding factors. Firstly, the standard population were stratified by the principal diagnoses category, and the standardized ALOS was calculated. Then, the ALOS was adjusted by comorbidities and the principal diagnoses category. The standardized processes were shown in Tables 5–7. Similarly, the remaining confounding factors were adjusted in the same way. Table 7 presented the adjusted ALOS in each step. It changed every time after adjusting each of the confoundings. After correcting all factors, the ALOS of three hospitals from low to high was hospital A (11.71 days) < hospital C (11.75 days) < and hospital B (14.59 days). In other words, the ALOS of hospital A and C were increased by 0.21 and 1.20 days, respectively, whilst that of hospital B was reduced by 1.54 days.

**Standardization of the average hospitalization expense**

The calculation method of standardized AHE was the same as standardized ALOS. Its calculation process was shown in Tables 8–10. Table 10 summarized the results of AHE in adjusting

### Table 5. The standardized ALOS by disease category among three hospitals.

| Disease category | Standard discharges | ALOS | Hospital A Expected discharged bed day | ALOS | Hospital B Expected discharged bed day | ALOS | Hospital C Expected discharged bed day |
|------------------|---------------------|------|---------------------------------------|------|---------------------------------------|------|---------------------------------------|
| A00-B99          | 2337                | 9.46 | 22112                                 | 20.38| 47630                                 | 8.46 | 19778                                 |
| C00-D48          | 23357               | 13.03| 304389                                | 9.38 | 452739                                | 10.54| 246077                                |
| D50-D89          | 1766                | 11.64| 20564                                 | 24.25| 42820                                 | 10.79| 19053                                 |
| E00-E90          | 5367                | 11.19| 60034                                 | 15.05| 80769                                 | 13.23| 71018                                 |
| F00-F99          | 659                 | 18.73| 12344                                 | 17.22| 11350                                 | 16.29| 10733                                 |
| G00-G99          | 4290                | 26.60| 114133                                | 17.11| 73391                                 | 13.34| 57213                                 |
| H00-H59          | 2686                | 4.48 | 12031                                 | 5.28 | 14184                                 | 4.77 | 12812                                 |
| H60-H95          | 1278                | 8.39 | 10725                                 | 9.94 | 12699                                 | 10.22| 13064                                 |
| I00-I99          | 21739               | 18.01| 391543                                | 21.23| 461569                                | 14.34| 31820                                 |
| J00-J99          | 8304                | 13.46| 111793                                | 17.48| 145192                                | 10.97| 91129                                 |
| K00-K93          | 12475               | 9.13 | 113914                                | 14.48| 180651                                | 9.32 | 116247                                 |
| L00-L99          | 1247                | 8.21 | 10238                                 | 19.00| 23693                                 | 12.93| 16127                                 |
| M00-M99          | 8020                | 13.15| 105459                                | 14.60| 117061                                | 10.83| 88686                                 |
| N00-N99          | 9755                | 8.03 | 78313                                 | 12.20| 119046                                | 8.11 | 79065                                 |
| O00-O99          | 11844               | 2.87 | 33981                                 | 6.75 | 79981                                 | 4.09 | 48469                                 |
| Q00-Q99          | 683                 | 9.73 | 6644                                  | 7.77 | 5305                                  | 10.44| 7134                                  |
| R00-R99          | 2479                | 8.88 | 22021                                 | 12.01| 29777                                 | 8.71 | 21604                                 |
| S00-T98          | 8524                | 13.75| 117219                                | 20.08| 171136                                | 14.21| 121095                                |
| Z00-Z99          | 15782               | 8.20 | 129442                                | 11.71| 184731                                | 9.64 | 152184                                |
| Total            | 142592              | 11.50| 1676898                               | 16.13| 2253725                               | 10.55| 1501488                               |
| Standardized ALOS|                    | 11.76| 15.81                                 | 10.53|                                      |
confounding factors. If the compositions of all confounding factors (i.e. gender, ethnicity, age, and education in this study) were the same, the differences in standardized AHE of hospital A

| comorbidity          | Disease category | Standard discharges | Hospital A          | Hospital B          | Hospital C          |
|----------------------|------------------|---------------------|---------------------|---------------------|---------------------|
|                      |                  |                     | ALOS                | Expected discharged bed day | ALOS                | Expected discharged bed day | ALOS                | Expected discharged bed day |
| Single disease       | A00-B99          | 820                 | 6.05                | 4962                | 22.40               | 18368               | 7.12                | 5836                |
|                      | C00-D48          | 10010               | 9.40                | 94110               | 12.75               | 127614              | 6.99                | 69951               |
|                      | D50-D89          | 508                 | 7.30                | 3708                | 13.25               | 6731                | 8.83                | 4484                |
|                      | E00-E90          | 669                 | 6.75                | 4517                | 8.61                | 5759                | 7.12                | 4761                |
|                      | F00-F99          | 93                  | 7.37                | 685                 | 11.21               | 1043                | 4.50                | 419                 |
|                      | G00-G99          | 493                 | 11.84               | 5837                | 9.10                | 4488                | 5.27                | 2596                |
|                      | H00-H59          | 355                 | 3.68                | 1305                | 4.10                | 1456                | 4.16                | 1476                |
|                      | H60-H95          | 549                 | 8.00                | 4392                | 6.61                | 3630                | 9.75                | 5351                |
|                      | I00-I99          | 2308                | 8.12                | 18741               | 10.60               | 24465               | 7.22                | 16654               |
|                      | J00-J99          | 1698                | 8.54                | 14502               | 8.68                | 14738               | 6.35                | 10784               |
|                      | K00-K93          | 4017                | 6.08                | 24435               | 8.85                | 35534               | 6.26                | 25134               |
|                      | L00-L99          | 546                 | 5.76                | 3143                | 7.82                | 4268                | 10.20               | 5571                |
|                      | M00-M99          | 2804                | 9.06                | 25416               | 11.13               | 31195               | 6.24                | 17489               |
|                      | N00-N99          | 3388                | 5.96                | 20203               | 5.32                | 18020               | 5.55                | 18811               |
|                      | O00-O99          | 6229                | 1.40                | 8705                | 5.65                | 35164               | 3.22                | 20080               |
|                      | Q00-Q99          | 253                 | 7.88                | 1994                | 8.00                | 2024                | 8.55                | 2162                |
|                      | R00-R99          | 701                 | 10.18               | 26247               | 15.83               | 40829               | 10.13               | 26119               |
|                      | S00-T98          | 2579                | 6.03                | 4225                | 7.33                | 5138                | 4.92                | 3446                |
|                      | Z00-Z99          | 6807                | 5.31                | 36137               | 7.67                | 52226               | 7.27                | 49465               |
| With comorbidities   | A00-B99          | 1517                | 11.60               | 17602               | 19.46               | 29525               | 9.07                | 13757               |
| disease              | C00-D48          | 13347               | 15.54               | 207417              | 20.85               | 278232              | 13.54               | 180742              |
|                      | D50-D89          | 1258                | 12.56               | 15795               | 24.78               | 31170               | 11.86               | 14920               |
|                      | E00-E90          | 4698                | 11.97               | 56228               | 15.48               | 72730               | 14.01               | 65797               |
|                      | F00-F99          | 566                 | 19.62               | 11107               | 18.55               | 10501               | 19.08               | 10799               |
|                      | G00-G99          | 3797                | 27.57               | 104665              | 18.46               | 70111               | 16.08               | 61040               |
|                      | H00-H59          | 2331                | 4.60                | 10713               | 5.70                | 13292               | 4.86                | 11324               |
|                      | H60-H95          | 729                 | 8.67                | 6323                | 10.71               | 7811                | 10.64               | 7758                |
|                      | I00-I99          | 19431               | 19.31               | 375304              | 22.01               | 427595              | 15.13               | 293909              |
|                      | J00-J99          | 6606                | 14.44               | 95361               | 18.40               | 121546              | 12.98               | 85719               |
|                      | K00-K93          | 8458                | 10.88               | 92009               | 16.12               | 136371              | 10.51               | 88899               |
|                      | L00-L99          | 701                 | 10.66               | 7475                | 24.84               | 17412               | 14.69               | 10299               |
|                      | M00-M99          | 5216                | 14.88               | 77588               | 16.09               | 83944               | 14.20               | 74043               |
|                      | N00-N99          | 6367                | 9.38                | 59721               | 14.02               | 89250               | 9.29                | 59120               |
|                      | O00-O99          | 5615                | 5.13                | 28791               | 7.14                | 40085               | 4.68                | 26266               |
|                      | Q00-Q99          | 430                 | 11.00               | 4732                | 7.56                | 3252                | 11.14               | 4789                |
|                      | R00-R99          | 1778                | 10.17               | 18091               | 13.06               | 23224               | 10.38               | 18454               |
|                      | S00-T98          | 5945                | 15.43               | 91727               | 21.88               | 13016               | 15.79               | 93870               |
|                      | Z00-Z99          | 8975                | 10.21               | 91678               | 14.54               | 130539              | 15.26               | 136943              |
|                      |                  |                     | 142592              | 11.50               | 1675593             | 16.13               | 2149384             | 10.55               | 1549034             |

Standardized ALOS: 11.75

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ALOS, average length of stay.
and C were increased by 1494 and 660 Yuan, while that of hospital B was reduced by 810 Yuan. The outcome is in accordance with ALOS.

**Discussion**

A total of 142592 discharged patients from three hospitals were analyzed in the current study. Our results implied that the differences in compositions of demographic characteristics, comorbidity and principal diagnoses category might impose a substantial impact on comparing observed outcomes among three hospitals. When comparing with the crude value, the

**Table 7. Results of standardized ALOS among three hospitals based on confounding factor stratification.**

| Hospital | Crude value(rank) | Adjusted 1(rank) | Adjusted 2(rank) | Adjusted 3(rank) | Adjusted 4(rank) | Difference |
|----------|------------------|------------------|------------------|------------------|------------------|------------|
| A        | 11.50(2)         | 11.76(2)         | 11.75(2)         | 11.72(2)         | 11.71(1)         | 0.21       |
| B        | 16.13(3)         | 15.81(3)         | 15.07(3)         | 14.55(3)         | 14.59(3)         | -1.54      |
| C        | 10.55(1)         | 10.53(1)         | 10.86(1)         | 11.14(1)         | 11.75(2)         | 1.20       |

ALOS, average length of stay

*: Disease category

**: Disease category and comorbidity

**: Disease category, comorbidity and age

**: Disease category, comorbidity, age and gender

*: Standardized ALOS difference between adjusted 4 and crude value.

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and C were increased by 1494 and 660 Yuan, while that of hospital B was reduced by 810 Yuan. The outcome is in accordance with ALOS.

**Table 8. The standardized AHE by disease category among three hospitals (CNY).**

| Disease category | Standard discharges | Hospital A | Hospital B | Hospital C |
|------------------|---------------------|------------|------------|------------|
|                  |                     | AHE        | Expected total charges | AHE        | Expected total charges | AHE        | Expected total charges |
| A00-B99          | 2337                | 11463      | 26788806   | 9593       | 22419431      | 9212       | 21529686   |
| C00-D48          | 23357               | 30928      | 722382474  | 19077      | 445992897    | 18524      | 432659886  |
| D50-D89          | 1766                | 18021      | 31825180   | 16840      | 29738850     | 24752      | 43712046   |
| E00-E90          | 5367                | 11389      | 61122764   | 7834       | 42046113     | 11179      | 59995907   |
| F00-F99          | 659                 | 14798      | 9751802    | 10593      | 69809088     | 14042      | 9253604    |
| G00-G99          | 4290                | 22875      | 98133331   | 12017      | 51545935     | 15186      | 65148920   |
| H00-H59          | 2686                | 9042       | 24286077   | 3690       | 9912165      | 9794       | 26307103   |
| H60-H95          | 1278                | 7192       | 9190847    | 3827       | 4891000      | 9296       | 11878999   |
| I00-I99          | 21739               | 18283      | 397450185  | 13820      | 300438289    | 25692      | 558513625  |
| J00-J99          | 8304                | 22333      | 185455428  | 18216      | 151266055    | 16003      | 332892803  |
| K00-K93          | 12475               | 16184      | 201896389  | 9950       | 124130577    | 12615      | 157378127  |
| L00-L99          | 1247                | 7879       | 9825472    | 9916       | 12364681     | 8592       | 10713677   |
| M00-M99          | 8020                | 22190      | 177966378  | 7550       | 60548556     | 16895      | 135498987  |
| N00-N99          | 9755                | 15898      | 155080858  | 6236       | 60835073     | 11398      | 111183448  |
| O00-O99          | 11844               | 3700       | 43827716   | 2142       | 25373525     | 4226       | 50047351   |
| Q00-Q99          | 683                 | 22420      | 15312810   | 7088       | 4841358     | 17153      | 11715678   |
| R00-R99          | 2479                | 10082      | 24994008   | 8573       | 21253044     | 9835       | 24380231   |
| S00-T98          | 8524                | 31873      | 271688524  | 13660      | 116433629    | 29388      | 250507549  |
| Z00-Z99          | 15782               | 12936      | 204158943  | 8400       | 132563731    | 12925      | 203983889  |
| Total            | 142592             | 17299      | 2671137991 | 11028      | 1623175818   | 16663      | 2317301660 |

ALOS, average length of stay

*: Disease category

**: Disease category and comorbidity

**: Disease category, comorbidity and age

**: Disease category, comorbidity, age and gender

*: Standardized ALOS difference between adjusted 4 and crude value.

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AHE, average hospitalization expense.

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ALOS of hospital A and C were increased by 0.21 and 1.20 days, while that of hospital B was decreased by 1.54 days. The AHE displays the same trend. That is, the standardized AHE of Table 9. The standardized AHE by disease category and comorbidity among three hospitals (CNY).

| comorbidity | Disease category | Standard discharges | Hospital A | Hospital B | Hospital C |
|-------------|-----------------|---------------------|------------|------------|------------|
|             |                 |                     | AHE | Expected total charges | AHE | Expected total charges | AHE | Expected total charges |
| Single disease | A00-B99 | 820 | 6275 | 5145175 | 6909 | 5665503 | 6366 | 5220337 |
|             | C00-D48 | 10010 | 23818 | 238421957 | 10858 | 108693356 | 2637 | 126495346 |
|             | D50-D89 | 508 | 11371 | 5776558 | 6601 | 3352026 | 16038 | 8147303 |
|             | E00-E90 | 669 | 15454 | 10388281 | 4807 | 3216062 | 8608 | 5758840 |
|             | F00-F99 | 93 | 14931 | 1388580 | 6373 | 592700 | 3360 | 312453 |
|             | G00-G99 | 493 | 22302 | 10995049 | 3889 | 1917281 | 4365 | 2151797 |
|             | H00-H59 | 355 | 6156 | 2185469 | 1919 | 681313 | 6991 | 2481872 |
|             | H60-H95 | 549 | 7879 | 4325523 | 1701 | 933798 | 9205 | 5053589 |
|             | I00-I99 | 2308 | 17221 | 39745186 | 5546 | 12800335 | 11755 | 27131287 |
|             | J00-J99 | 1698 | 8660 | 14705312 | 3813 | 6475253 | 6377 | 10827328 |
|             | K00-K93 | 1407 | 11636 | 46741687 | 6905 | 2773089 | 9397 | 3774737 |
|             | L00-L99 | 456 | 4827 | 2635635 | 2724 | 1487243 | 5773 | 3152217 |
|             | M00-M99 | 2804 | 22144 | 6209120 | 4851 | 13601322 | 10187 | 28565516 |
|             | N00-N99 | 3388 | 13549 | 45903148 | 3233 | 10954950 | 7653 | 25927867 |
|             | O00-O99 | 6229 | 1467 | 9135990 | 1224 | 7639696 | 2709 | 16872292 |
|             | Q00-Q99 | 253 | 21510 | 5442126 | 10372 | 2624237 | 13525 | 3421815 |
|             | R00-R99 | 701 | 6601 | 4627221 | 3364 | 2357959 | 4398 | 3083307 |
|             | S00-T98 | 2579 | 20014 | 51615634 | 10154 | 26186721 | 19554 | 50430476 |
|             | Z00-Z99 | 6807 | 9331 | 63518847 | 5637 | 38371156 | 9409 | 64048850 |
| With comorbidities | A00-B99 | 1517 | 14722 | 22323689 | 10813 | 16403775 | 10492 | 15916817 |
|             | C00-D48 | 13347 | 35840 | 478355127 | 20889 | 278809685 | 23513 | 313826144 |
|             | D50-D89 | 1258 | 19416 | 24425494 | 17333 | 21805046 | 29509 | 37122366 |
|             | E00-E90 | 4698 | 10671 | 50131763 | 8037 | 37758599 | 11504 | 54043787 |
|             | F00-F99 | 566 | 14787 | 8369685 | 11526 | 6523446 | 16572 | 9379683 |
|             | G00-G99 | 3797 | 22912 | 86979492 | 13394 | 5085213 | 18859 | 7160885 |
|             | H00-H59 | 2331 | 9461 | 22052767 | 4323 | 10075650 | 10196 | 23767504 |
|             | H60-H95 | 729 | 6697 | 4882533 | 4324 | 3152269 | 9375 | 6834513 |
|             | I00-I99 | 19431 | 18423 | 357973670 | 14422 | 280238178 | 27221 | 528924378 |
|             | J00-J99 | 6606 | 25036 | 165390401 | 19712 | 130220426 | 20172 | 133256383 |
|             | K00-K93 | 8458 | 18790 | 158928826 | 10838 | 9166085 | 13869 | 117302249 |
|             | L00-L99 | 701 | 10931 | 7662914 | 13670 | 9582676 | 10407 | 7295507 |
|             | M00-M99 | 5216 | 22210 | 115847048 | 8714 | 45453242 | 21807 | 113745767 |
|             | N00-N99 | 6367 | 17435 | 111010494 | 7028 | 44741011 | 13129 | 8359113 |
|             | O00-O99 | 5615 | 7128 | 40025890 | 2462 | 13826902 | 5248 | 29468289 |
|             | Q00-Q99 | 430 | 23049 | 9910998 | 4215 | 1812356 | 18479 | 7946172 |
|             | R00-R99 | 1778 | 11657 | 20726172 | 9742 | 17321199 | 12216 | 21720420 |
|             | S00-T98 | 5945 | 37440 | 222579672 | 15152 | 90080285 | 33206 | 197411047 |
|             | Z00-Z99 | 8975 | 15444 | 138613380 | 10345 | 92845372 | 21234 | 190577782 |
| Total       |       |       | 142592 | 17299 | 2670956375 | 11028 | 151848767 | 16663 | 2390568552 |

AHE, average hospitalization expense.

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hospital A and C were increased but that of hospital B was reduced when compared with before.

As far as we know, standardization technique is commonly used for comparing rates, such as cure rates, death rates and birth rates, between different groups or populations[17, 18, 26]. However, there currently has been no report on the application of standardization method in hospital administration. Our findings indicated that the idea of stratified standardization can also be applied to the evaluation of medical services. Our study presented a detailed analysis and discussion of the standardization method, including the determination of common standard, identification of confounding factors, and hierarchical standardization of ALOS and AHE. The results demonstrated that after adjusting confounding factors the real differences in ALOS and AHE among three hospitals were much smaller than the original values, although the order did not change dramatically. For instance, the difference between the maximum and the minimum values of ALOS was reduced from 5.58 days to 2.88 days after adjusting disease category, comorbidity, age and gender. And the trend of AHE is consistent with that of ALOS which suggested that the adjusted medical service indicators are more reflective of the quality of care between hospitals.

Under the reform of public hospitals in China, the evaluation mechanisms of public hospitals are becoming more and more competitive. The standardization method could effectively increase the comparability of medical service indicators and has positive significance for the formulation of public hospital policy. Standardized indicators could improve the fairness of hospital assessment and reduce speculation. In order to control the average hospital expense, some medical institutions adopt unreasonable ways to reduce the expense, such as re-admission of long-term inpatients and admission of mild patients who do not require hospitalization. The impact of these opportunistic behaviors could be adjusted through standardization during assessment. On the other hand, it is conducive to promoting the implementation of hierarchical medical system, reducing the burden of large hospitals and enhancing the capacity of primary medical services. China has vigorously promoted the implementation of the hierarchical medical system to provide different levels of medical services according to the patients’ conditions and to realize rational allocation of medical resources[13]. Although the hierarchical medical system has many advantages, its impact is still limited. Large hospitals are still overcrowded, while primary medical institutions are to some extent unwanted. Through the standardization of medical data, it is possible to make the problem more obvious for health department and make it easy to identify those high-level hospitals that treated a large number of patients with mild illnesses. Based on this, the government and health department can better

### Table 10. Results of standardized AHE among three hospitals based on confounding factor stratification (CNY).

| Hospital | Crude value(rank) | Adjusted 1(rank) | Adjusted 2(rank) | Adjusted 3(rank) | Adjusted 4(rank) | Difference |
|----------|-------------------|------------------|------------------|------------------|------------------|------------|
| A        | 17299(3)          | 18733(3)         | 18731(3)         | 18835(3)         | 18793(3)         | 1494       |
| B        | 11028(1)          | 11383(1)         | 10649(1)         | 10145(1)         | 10218(1)         | -810       |
| C        | 16663(2)          | 16251(2)         | 16765(2)         | 17229(2)         | 17323(2)         | 660        |

AHE, average hospitalization expense

*a*: Disease category

*b*: Disease category and comorbidity

*c*: Disease category, comorbidity and age

*d*: Disease category, comorbidity, age and gender

*e*: Standardized AHE difference between adjusted 4 and crude value.

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supervise these hospitals and eventually optimize the system model to achieve the rational allocation of medical resources.

The application and continuous evaluation of clinical pathways (CP) in health-care settings benefit the institutionalization of culture of quality in hospitals [27]. The standardized method can be used to adjust the assessment indexes in each stage of CP. The process of disease diagnosis and treatment will be more normative after standardized indicators were applied. Moreover, the symptoms of inpatients are complex and diverse, the adoption of a “one-size-fits-all” approach will inevitably dampen doctors’ enthusiasm. The hierarchical standardization of medical indicators is likely to promote the classification management of disease and provide direction for continuous improvement of medical quality.

The allocation of funds and health resources as well as the control of deficits of the national health system are the major and long-standing problems, which are also at the heart of health care reform. [28]. Through the standardization of the composition of medical expenses, it will be possible to find and solve the core problem of “expensive medical treatment”. Currently, DRG approach has been recognized and our standardization method could be a complement to it. It provides a standard for more precise grouping of DRGS and an objective basis for differentiated financial subsidies.

In drawing meaningful conclusions from this study, it is important to be cognizant of its limitations. Not all the confounding factors have been taken in to consideration. Only age, sex, and disease category were selected in this analysis. Some specific details of disease diagnosis, such as tumor stage, were not included as confounding factors. Notwithstanding these limitations, this study highlights an approach and some suggestions in the comparison of medical indicator evaluation. In addition, these standardized indicators no longer reflect reality, they are only a reference level for comparisons between hospitals and departments within hospitals.

Conclusions

There are many comparability problems in the assessment of medical service performance. In this study, by taking ALOS and AHE as examples, we introduced a specific technique for standardization, which will be helpful to improve the comparability of medical service indicators. In addition to the confounding factors described in this paper, other potential confounding factors may also contribute to the standardization. Our findings showed that our standardization method could be a practical technique and worthy of promotion.

Supporting information

S1 File. Data set.
(XLSX)

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