BMC Health Services Research

RESEARCH Open Access

Validation of the Patient Driven Payment Model (PDPM) in China

Yue Xu[1†], Mengjia Zhi[1†], Ningjun Shao[2] and Linlin Hu[1*]

Abstract

Background Post-acute care is rapidly developing in China; yet, a payment method for post-acute care has not been established. The Patient Driven Payment Model (PDPM) is a new case-mix system developed in the United States of America for classification of skilled nursing facility patients. This study aimed to examine the validity of an adapted version of PDPM for classifying post-acute care patients in China.

Methods First, 13,496 post-acute care patients in seven facilities of Jinhua City from January 2018 to December 2020 were sampled and assigned to PDPM groups according to their clinical characteristics, functional status, and special care needs. Then, the effectiveness of grouping was analyzed by the percentage of variance in resource use explained by the classification (R^2), the reduction in variance (RIV), the class-specific coefficients of variation (CVs), and the weighted means for each group (case-mix indexes, CMIs).

Results Under the adapted version of PDPM, each patient is classified into a group for each of the four case-mix adjusted components: (1) physical therapy and occupational therapy (PT&OT), (2) speech-language pathology (SLP), (3) nursing, and (4) non-therapy ancillary (NTA). Each component utilizes different criteria for classification. The adapted PDPM explained 11.1%, 6.1%, 14.0%, and 10.6% of the variance in PT&OT, SLP, nursing, and NTA cost per day, respectively, for the sample patients (all $p < 0.001$), which were similar to the results in the United States of America. The CV achieved good homogeneity in 10 PT&OT groups (CV: 0.17–0.69), 12 nursing groups (CV: 0.09–0.66), and 6 NTA groups (CV: 0.38–0.64). The CMIs of groups spanned a 9-fold range in PT&OT (CMI: 0.22–1.96), 11-fold range in nursing (CMI: 0.59–6.33), and 4-fold range in NTA (CMI: 0.72–2.91).

Conclusions Our findings provide preliminary evidence that the PDPM is a reliable and valid case-mix system for classifying post-acute care patients in China, which could inform future payment policy for post-acute care in China.

Keywords Patient driven payment model, Validation, Post-acute care, Case-mix, Payment system

[†]Yue Xu and Mengjia Zhi contributed equally to this work.

*Correspondence:
Linlin Hu
hulinlin@sph.pumc.edu.cn
[1]School of Health Policy and Management, Chinese Academy of Medical Sciences & Peking Union Medical College, 9 Dongdan Santiao, Beijing 100730, China
[2]Jinhua Healthcare Security Administration, 999 Danxi North Road, Jinhua 321000, China

Background

Case-mix systems have been developed worldwide to classify patients based on different characteristics, among which case-mix classification based on resource utilization is widely used in payment system development [1]. Diagnosis related groups (DRGs) are a type of case-mix that has been widely used as a payment system for inpatient care in many countries, which mainly use diagnosis, operative procedures and patients' individual characteristics such as age, sex and comorbidities as classification variables [2]. Diagnosis intervention packet (DIP) is a Chinese innovation grouping method based on DRGs but with more detailed grouping [3]. Currently, the reform of payment methods in China has entered a new stage, wherein DRG/DIP payment will cover all eligible medical institutions providing inpatient services by the end of 2025 [3]. However, various studies have shown that DRG/DIP for acute hospitalization is not suitable for post-acute care (PAC) [4–7], and the development of a financing and payment system for PAC is lagging in China [8]. Currently, the payment for acute care hospitalization is not separated from the payment for PAC hospitalization in most places in China [9]. The consequence of DRG/DIP payment for PAC was that hospitals began minimizing the length of each patient's hospital stay [5, 10, 11]. PAC typically requires a longer period of hospitalization and has a distinct need for continuity of care, and the current payment method offers no significant effects on containing medical costs or improving PAC quality [6, 12]. The increasing number of older patients with multiple medical conditions who require PAC imposes an almost unbearable burden on the healthcare system in China; so, it is crucial to explore and establish a payment system for PAC in China to meet the rising demand.

As delivered in many countries, PAC typically refers to the medical, nursing, and rehabilitative care provided to maintain or improve the functional status of patients after acute illness or hospitalization [13, 14]. Instead of being a short episode of care for an operation or acute treatment, PAC services are time-consuming to maintain or improve the functional status of patients. It is widely accepted that PAC requires a different classification measure because the clinical issues, modes of care, and resource use of PAC are different from those of acute care [12, 15]. Several case-mix systems of PAC based on functional and other measures have been developed worldwide, among which the Resource Utiliza tion Group Version III (RUG-III) is the most widely used. In China, a wealth of studies ha ve spotlighted the costs of short-term hospitalization in the acute phase of DRG/DIP payment policy [16], but case-mix groups for PAC have not been developed yet [9].

The Patient Driven Payment Model (PDPM), a new case-mix classification model based on per diem resource use developed by the Centers for Medicare & Medicaid Services (CMS) and the Acumen, has been used for the classification of skilled nursing facility patients in the United States of America (USA) since October 1, 2019 [17]. PDPM consists of the following five case-mix adjusted payment components: (1) PT: covers utilization of physical therapy (PT); (2) OT: covers utilization of occupational therapy (OT); (3) SLP: covers utilization of speech-language pathology (SLP) services; (4) nursing: covers utilization of skilled nursing services and social services; and (5) non-therapy ancillary (NTA): covers utilization of NTA services. Each patient is classified into a group corresponding to one of the five case-mix-adjusted components [18]. Additionally, PDPM maintains the existing non-case-mix component to cover the utilization of resources that do not vary with resident characteristics [17].

We report herein a study conducted to assess the validity of PDPM for classifying PAC patients in China. The results can inform payment policy development for PAC in China.

Methods

Sampling

In this study, patients hospitalized from January 1, 2018 to December 31, 2020, from seven hospitals, including three freestanding rehabilitation hospitals and four rehabilitation units of general hospitals, with an interval of at least 90 days since their last acute discharge in Jinhua City, Zhejiang Province of southeast China, were selected. In China, the post-acute intensive rehabilitation stage is set by the medical insurance department for as long as 90 days; so, these patients had usually gone through the intensive rehabilitation stage but still needed to be admitted by medical facilities to receive some medical, rehabilitative, or nursing care. These patients were similar to the patients in skilled nursing facilities in the United States; so, it was hypothesized that PDPM might be a good model for classification. Patients had to meet the following inclusion criteria to be eligible: treated in rehabilitation or geriatric wards, aged ≥18 years, and provided informed consent. The exclusion criteria were as follows: invalid or missing data, an outcome of death, or a length of stay of less than 3 days. Finally, 13,496 PAC patients were included in this study (see Fig. 1).

Data collection

The study was conducted using a method similar to that used to validate and refine RUG-III instruments in other countries. For this study, we collected all indicators/variables required for PDPM grouping, following the method used in the United States. Since China does not have a standardized comprehensive assessment scale for PAC patients, we collected functional assessment data from

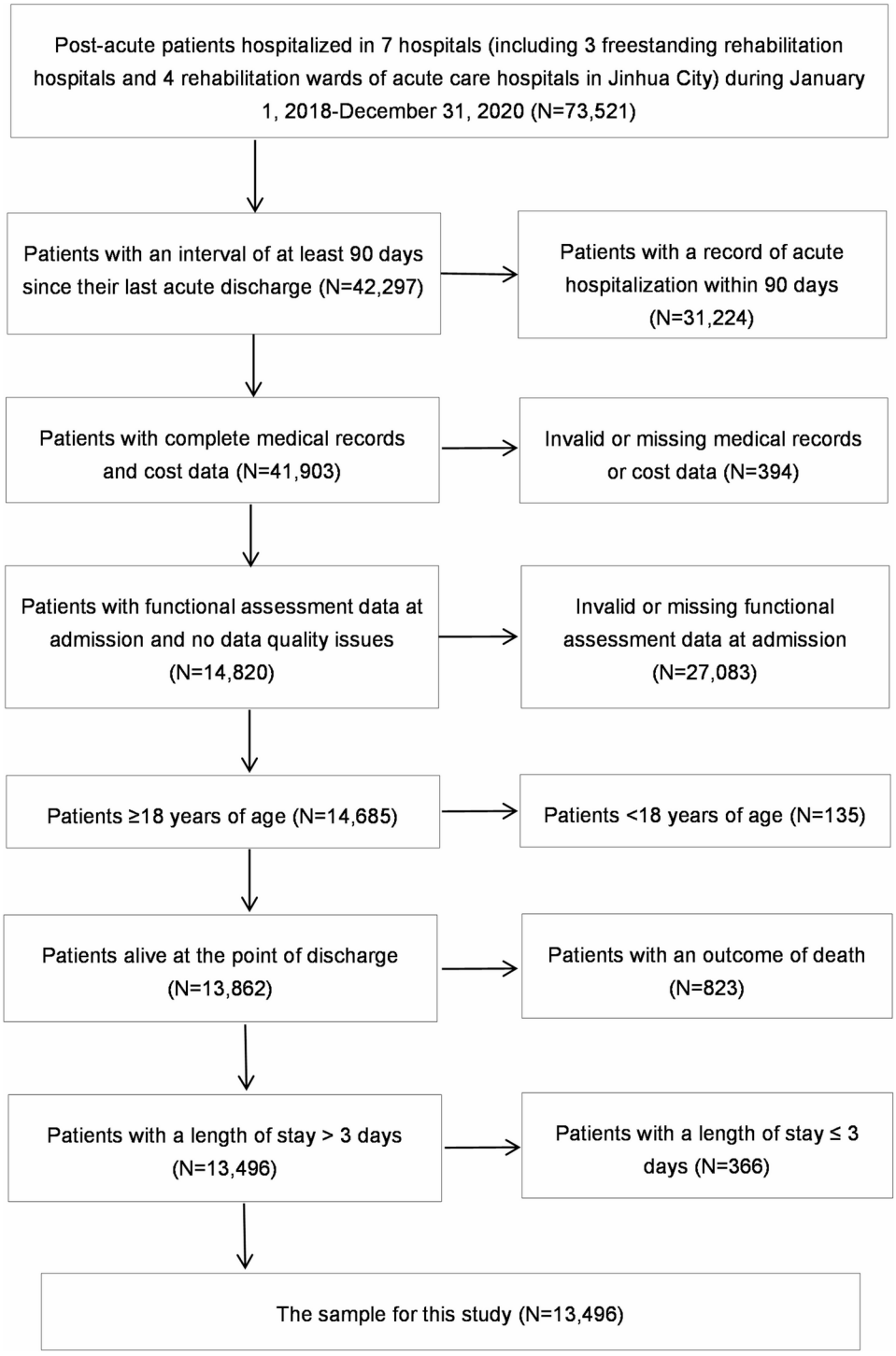

Fig. 1 Patient selection and exclusion process

various assessment scales currently used in clinical practice, as well as indicators from medical records to serve as the variables needed for PDPM grouping, and the group assignment was done by computer. The assessment scales included the Barthel Index (BI), the Mini-Mental State Examination (MMSE), the Gugging Swallowing Screen (GUSS), and the Hamilton Depression Scale (HDS), which were collected at the point of admission by rehabilitation physicians, therapists, or nurses. With the support of the local Healthcare Security Administration, all the medical insurance claim data for these patients were extracted. Permission was obtained from

the Medical Ethics Committee of the Chinese Academy of Medical Sciences & Peking Union Medical College to report the data for research purposes (Protocol Number: X170315009).

Resource use

The resource use of the patients was measured by expenses per day in the hospital. Staff time is typically used to reflect resource use under RUG-III [19]. However, Acumen's PDPM report proposed that staff time only be documented during the 7-day look-back window preceding each assessment. The current data need not capture the exact number of minutes provided each day of a stay [18]. Instead, cost should be considered as a better indicator to reflect differences in the relative resource use across patients [6, 12]. Therefore, in this study, the measure of resource use was based on the medical expenses during inpatient stays, which has been generally used in such studies in China [8, 20]. Expense s were further divided into six categories: (1) PT covers utilization of physical therapy, (2) OT covers utilization of occupational therapy, (3) SLP covers utilization of speech-language pathology services, (4) nursing covers utilization of nursing services, (5) NTA covers utilization of NTA services, such as clinical treatment, medications and drugs, laboratory tests and examination, and medical equipment and materials, and (6) routine includes all other costs, such as room and board. The Consumer Price Index (CPI) of Jinhua City, published by the National Bureau of Statistics of the People's Republic of China from 2018 to 2020, was used to adjust the cost data over the 3-year timespan of this study. In addition, PDPM in the United States requires that payment be made on a per diem basis [18], and also, several studies have concluded that a per diem classification may be suitable for PAC, as the length of stay is not predictable [6, 12, 19]. Thus, the resource use in this study was measured by expenses per day.

Statistical analysis

We conducted a descriptive analysis by calculating the costs on a per diem basis for PAC patients. The statistical performance of the PDPM systems was then measured using R-squared (R^2), the reduction in variance (RIV), the coefficient of variation (CV), and case-mix index (CMI) [21].

First, the explanatory power of the modelling was measured by the percentage of variance in resource use explained by the classification (R^2). R^2 reflects how well the PDPM predicts patient resource use. A higher R^2 value indicates that the groupings effectively explain the variation in resource use, while a lower value suggests weaker explanatory power [18].

In addition, overall performance of the classification was further assessed by the reduction in variance (RIV). RIV is calculated by first determining the total sum of squares (SST), which is the sum of squared deviations of each observation from the overall mean. Then, the error sum of squares (SSE) is calculated by summing the squared deviations of each observation from the mean of its respective group. The difference between SST and SSE gives the regression sum of squares (SSR), and dividing SSR by SST provides the RIV, reflecting the proportion of variance explained by the classification [22]. A high RIV indicates effective grouping, but an excessively high RIV may suggest overfitting or overly segmented groups, leading to impractical classifications for clinical or operational use.

The within-group homogeneity of PDPM can be measured by calculating the coefficient of var- iation (CV), which is defined as the standard deviation of the resource use in each class divided by the arithmetic mean of the observations [21]. A lower CV indicates greater homogeneity, meaning the PDPM effectively groups patients with similar resource needs [23]. For this study, a CV of less than 1 was considered acceptable, as this is conventionally used to signify an appropriate degree of variation in classification models [24].

Lastly, relative resource use was expressed as a case-mix index (CMI), which is a well-known resource consumption adjustment standard [25]. The CMI is calculated by taking the mean cost for all observations within a specific group and then normalizing it to a relative value [26]. This helps determine whether patients in specific groups are consuming more or fewer resources compared to the mean, ensuring appropriate resource allocation across groups.

Given the absence of a universally accepted standard for evaluating PDPM performance (excluding CV), we primarily relied on comparisons with the model evaluation of the PDPM in the United States, along with related international studies, to assess its effectiveness in the Chinese context. Statistical analyses were conducted with IBM SPSS Version 26; the statistical significance level was $p < 0.05$.

Results

For the 13,496 patients, the average cost per day was 526.69 ± 398.337 RMB (78.03 ± 59.013 USD), and the average length of stay was 23.83 ± 25.149 days (Table 1). NTA (53.93%) and PT (26.39%) accounted for larger proportions in the cost composition than OT (0.71%) and SLP (0.57%).

More males (54.28%) than females (45.72%) were included in this study, with an average age of 79.84 years for all patients. Patients were classified into a PDPM clinical category based on the primary diagnosis, according to the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD- 10-CM) codes

Table 1 Description of cost and length of stay for post-acute patients in the sample (*N* = 13496)

Variables	Mean	SD	P_{25}	P_{50} (Median)	P_{75}	%
Total Cost of Stay (RMB)	12550.22	16965.625	5122.57	7571.13	13966.55	-
Length of Stay (days)	23.83	25.149	9	15	26	-
Per Diem Cost (RMB per day)	526.69	398.337	379.95	523.64	720.77	100.00%
PT	139.01	159.535	15.76	148.87	248	26.39%
OT	3.72	13.019	0	0	0	0.71%
SLP	3.01	14.961	0	0	0	0.57%
NUR	49.71	50.926	26.13	40.07	61.57	9.44%
NTA	284.06	361.342	125.94	213.74	428.48	53.93%
Routine	47.18	31.965	38	45	55	8.96%

Non-therapy ancillary covers costs for non-therapy ancillary services (e.g., evaluation and drugs). Routine includes all other costs (e.g., room and board)

PT physical therapy, *OT* occupational therapy, *SLP* speech-language pathology, *NUR* nursing, *NTA* non-therapy ancillary

Table 2 The demographic and clinical characteristics of the patients (*N* = 13496)

Variables	*N*	%
Gender		
Male	7325	54.28%
Female	6171	45.72%
Age (in years) 79.84 ± 14.594		
< 65	3191	23.64%
65–74	3064	22.70%
75–84	3056	22.64%
85–94	3451	25.57%
≥ 95	734	5.44%
Clinical Category		
Major Joint Replacement or Spinal Surgery	6	0.04%
Non-Surgical Orthopedic/Musculoskeletal	2555	18.93%
Medical Management	3740	27.71%
Cancer	889	6.59%
Pulmonary	395	2.93%
Cardiovascular & Coagulations	484	3.59%
Acute Infections	26	0.19%
Acute Neurologic	5401	40.02%
Activities of Daily Living		
Independent	6051	44.84%
Moderately Dependent	1297	9.61%
Severely Dependent	4042	29.95%
Totally Dependent	2106	15.60%
Cognitive Impairment	2152	15.95%
Swallowing Disorder	2368	17.55%
Depression	360	2.67%

International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes are mapped to a PDPM clinical category available on the PDPM webpage (https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/SNFPPS/PDPM). The standardized patient assessment data elements (SPADEs) were used to collect data across Chinese post-acute care settings

mapped to a PDPM clinical category available on the PDPM webpage.21 Ultimately, 5,401 (40.02%) patients were classified as acute neurologic, 3,740 (27.71%) as medical management, 2,555 (18.93%) as non-surgical orthopedic/musculoskeletal, 889 (6.59%) as cancer, 484 (3.59%) as cardiovascular & coagulations, 395 (2.93%) as pulmonary, 26 (0.19%) as acute infections, and 6 (0.04%) as major joint replacement or spinal surgery. As for activities of daily living (ADLs), 6,051 (44.84%) were independent, 1,297 (9.61%) were moderately dependent, 4,042 (29.95%) were severely dependent, and 2,106 (15.60%) were completely dependent. Also, 2,152 (15.95%) patients had cognitive impairment, 2,368 (17.55%) patients had a swallowing disorder, and 360 (2.67%) had depressive symptoms. The demographic and clinical characteristics of the sampled patients are presented in Table 2.

Figure 2 shows the flowchart of PT&OT, SLP, nursing, and NTA in PDPM assignment logic in this study. Table 3 shows the PT&OT case-mix classification groups. Patients were first classified into four clinical categories based on the primary diagnosis for the stay (major joint replacement or spinal surgery, other orthopedic, medical management, and non-orthopedic surgery & acute neurologic). Then, patients were sub-divided into 14 groups by the functional score for the PT & OT components [17, 18]. The largest group was "non-orthopedic surgery and acute neurologic with 0–5 PT&OT function score" (3,477 patients or 25.76%). The model explained 11.1% of the variance of the PT&OT average cost. The homogeneity of resource use within each group was measured by the CV value. The CV was less than 0.8 in 10 groups (0.17–0.69), and only four groups had a CV greater than 0.8. Among these 14 groups, the CMI spanned an eight-fold (i.e., 8.91) range from 0.22 (TL) to 1.96 (TN).

For the SLP component, patients were grouped into seven SLP groups based on the presence of acute neurologic condition, SLP-related comorbidity or cognitive impairment (none, any one, any two, all three), and mechanically altered diet or swallowing disorder (neither, either, both) [17, 18]. The mean SLP cost per day was only 3.17 RMB. The fit of the model was not very good, with explained variance of 6.1% for SLP cost. The CMI for individual classes ranged from 0.06 (S1) to 6.17 (S7). Higher CMIs reflected more costs or services provided to patients in that group. Table 4 presents the SLP case-mix classification groups.

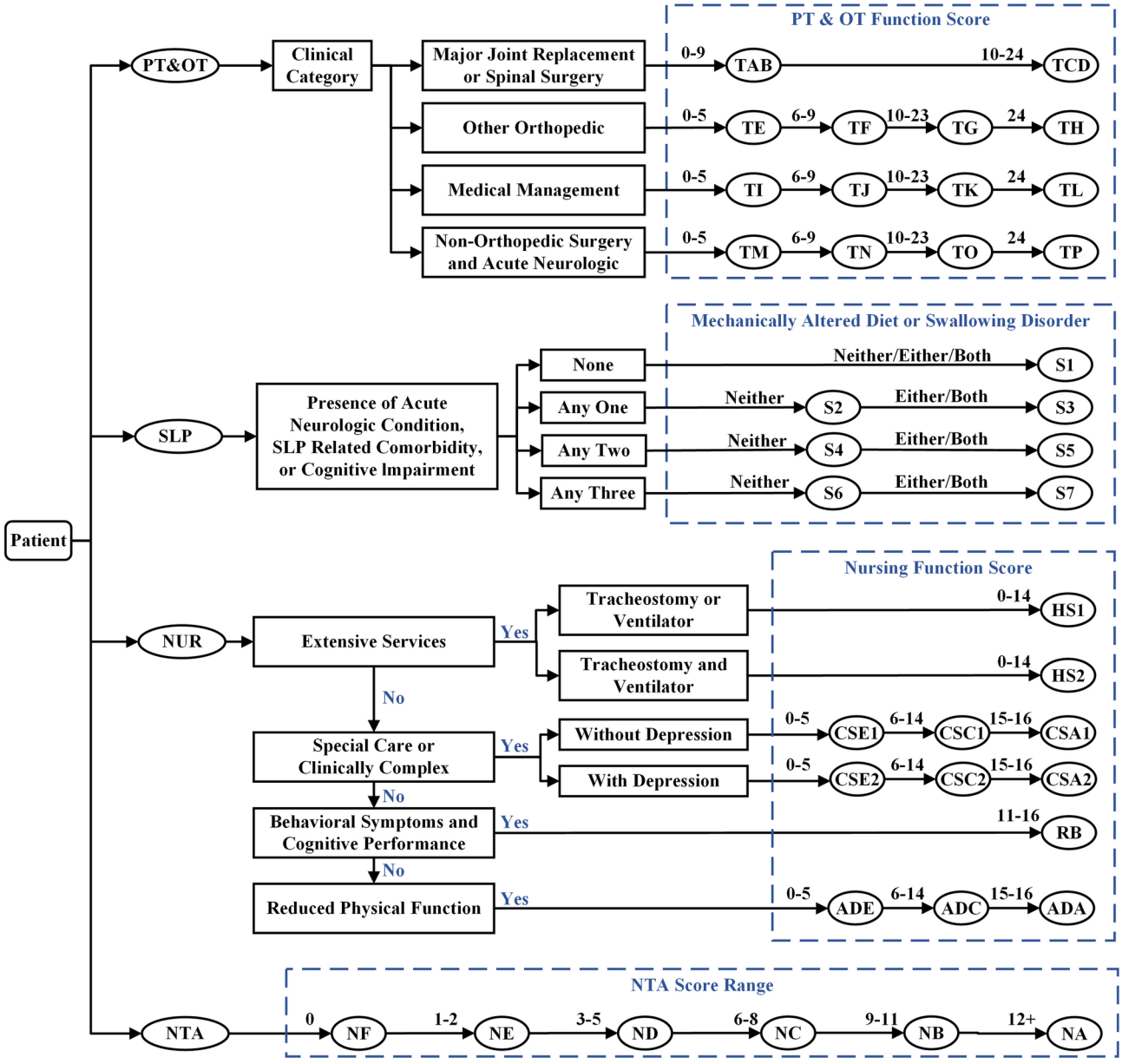

Fig. 2 Flow chart of the PT&OT, SLP, nursing and NTA in PDPM assignment logic. PDPM consists of the four case-mix adjusted payment components: physical therapy and occupational therapy (PT&OT), speech-language pathology (SLP), nursing (NUR), and non-therapy ancillary (NTA). For PT&OT, patients are categorized based on their clinical category (e.g., major joint replacement, other orthopedic, medical management, and non-orthopedic surgery and acute neurologic). Further grouping is determined by the patient's PT&OT function score (0–24), reflecting their functional ability. Based on these criteria, patients are assigned to specific PDPM groups such as TAB, TE, or TH. In SLP, the patient's neurologic condition, SLP-related comorbidities, or cognitive impairments are assessed. They are then evaluated for a mechanically altered diet or swallowing disorder. Patients are placed into SLP groups (S1-S7) based on these conditions. In Nursing (NUR), the first criterion is whether the patient requires extensive services (e.g., tracheostomy or ventilator). If not, the next step evaluates whether they need special care or are clinically complex (e.g., depression). If neither applies, the process moves to whether the patient has behavioral symptoms or reduced physical function. Each patient is assigned a nursing function score (0–16), and based on their needs, they are placed into one of several nursing groups such as HS2, CSE1, or RB. For NTA, patients are assigned an NTA score based on their medical complexity and need for non-therapy services. They are then grouped into one of the NTA categories (NA-NF), with higher scores indicating more complex needs

Table 5 presents the case-mix classification groups for the nursing component. Patients were first split into four nursing categories on the basis of clinical characteristics (extensive services, special care or clinically complex, behavioral symptoms and cognitive performance, reduced physical function) [17, 18]. Each of these four groups was further divided into subgroups on the basis of the presence or absence of depression and nursing function score [17, 18]. A nursing classification with 12 groups was finally produced. As expected, the most

Table 3 PT&OT case-mix classification groups

Clinical Category	PT&OT Function Score	PDPM Original CMG	PDPM CMG in China	*N*	%	Mean	SD	Median	IQR	CV	CMI
Major Joint Replacement or Spinal Surgery	0–9	TA/TB	TAB	3	0.02%	127.40	43.78	121.08	39.77	0.34	0.93
Major Joint Replacement or Spinal Surgery	10–24	TC/TD	TCD	3	0.02%	186.42	32.22	185.92	22.78	0.17	1.37
Other Orthopedic	0–5	TE	TE	322	2.39%	251.05	95.92	225.33	115.79	0.38	1.84
Other Orthopedic	6–9	TF	TF	159	1.18%	187.76	127.65	147.13	221.99	0.68	1.38
Other Orthopedic	10–23	TG	TG	953	7.06%	192.64	132.36	166.17	215.83	0.69	1.41
Other Orthopedic	24	TH	TH	1121	8.31%	178.23	123.55	162.34	193.5	0.69	1.31
Medical Management	0–5	TI	TI	2249	16.66%	67.92	97.43	28.00	140.38	1.43	0.50
Medical Management	6–9	TJ	TJ	574	4.25%	104.03	105.85	59.97	162.57	1.02	0.76
Medical Management	10–23	TK	TK	2061	15.27%	43.67	66.64	3.37	59.17	1.53	0.32
Medical Management	24	TL	TL	650	4.82%	30.52	46.16	2.73	43.23	1.51	0.22
Non-Orthopedic Surgery and Acute Neurologic	0–5	TM	TM	3477	25.76%	254.71	98.89	239.46	136.11	0.39	1.87
Non-Orthopedic Surgery and Acute Neurologic	6–9	TN	TN	564	4.18%	268.10	86.49	245.33	130.83	0.32	1.96
Non-Orthopedic Surgery and Acute Neurologic	10–23	TO	TO	1026	7.60%	240.24	94.49	227.20	124.62	0.39	1.76
Non-Orthopedic Surgery and Acute Neurologic	24	TP	TP	334	2.47%	214.41	133.02	189.64	199.25	0.62	1.57

PT physical therapy, *OT* occupational therapy, *SD* standard deviation, *IQR* interquartile range, *CV* coefficient of variation, *CMI* case mix index

populated categories were special care or clinically complex (9,619 patients or 71.27%) and reduced physical function (3,487 patients or 25.84%), while the extensive services (333 patients or 2.47%) and behavioral symptoms and cognitive performance (57 patients or 0.42%) categories included fewer patients. The R^2 was as high as 0.14, reflecting a better grouping performance. Low CV (less than 0.8; range: 0.09–0.66) indicated slight variation and better homogeneity within each group. The CMI spanned a 10-fold (i.e., 10.73) range from 0.59 (ADA) to 6.33 (HS2).

NTA covers costs for NTA services (e.g., medical tests, drugs, and consumable materials). NTA classification is based on the presence of certain comorbidities or use of certain extensive services [17, 18]. Patients were divided into six groups by NTA score range according to the grouping principles and definitions of the original PDPM. The mean NTA cost per day was as high as 221.74 RMB. The six-group model explained 10.6% of the variance of NTA per diem cost. The CV was less than 0.8 in six groups (0.38–0.64), achieving good homogeneity within each group. The CMI for individual classes ranged from 0.72 (NF) to 2.91 (NA). Higher CMIs reflected more NTA costs or services provided to patients in that group. Table 6 presents the NTA case-mix classification groups.

Discussion

Our study was the first to validate the PDPM as a case-mix classification for PAC patients in China. Under PDPM, the costs are divided into six components, five of which are case-mix adjusted components (PT, OT, SLP, nursing, and NTA), and one of which is a non-case-mix component (routine). The grouping results from our data were basically consistent with those from the United States, which pioneered the implementation and validation of the PDPM, as well as with findings from other similar studies. In addition, the PDPM model demonstrated strong performance in terms of the CV, indicating effective grouping of patients with similar resource needs. Therefore, the PDPM case-mix classification system can be considered an appropriate model for classifying the resource use of PAC patients in China.

In our study, the composition of costs, especially regarding the percentages of NTA and rehabilitative costs, was significantly different from that in the United States. The NTA in our study accounted for 53.93% of the total cost, compared to 17.53% in the United States [22, 27]. This major deviation is worth discussing. In China, the prices of clinical procedures, including rehabilitative services and nursing care, are relatively low, whereas the prices of medical materials, drugs, and examinations (for example, computed tomography (CT) and magnetic resonance imaging (MRI)) are relatively high [28], which has incentivized hospitals and physicians to increase

Table 4 SLP case-mix classification groups

Presence of Acute Neurologic Condition, SLP Related Comorbidity, or Cognitive Impairment	Mechanically Altered Diet or Swallowing Disorder	PDPM Original CMG	PDPM CMG in China	*N*	%	Mean	SD	Median	IQR	CV	CMI
None	Neither/Either/Both	SA/SB/SC	S1	6178	45.78%	0.20	2.76	0.00	0.00	13.80	0.06
Any one	Neither	SD	S2	2645	19.60%	1.13	9.39	0.00	0.00	8.31	0.36
Any one	Either/Both	SE/SF	S3	591	4.38%	5.97	28.87	0.00	0.00	4.84	1.88
Any two	Neither	SG	S4	2109	15.63%	2.14	9.72	0.00	0.00	4.54	0.68
Any two	Either/Both	SH/SI	S5	801	5.94%	16.50	32.51	0.00	22.00	1.97	5.21
All three	Neither	SJ	S6	473	3.50%	4.13	14.24	0.00	0.00	3.45	1.30
All three	Either/Both	SK/SL	S7	699	5.18%	19.56	32.90	0.00	22.22	1.68	6.17

SLP speech-language pathology, *SD* standard deviation, *IQR* interquartile range, *CV* coefficient of variation, *CMI* case mix index

profits by prescribing examinations and drugs, even in PAC settings. In recent years, some reforms have been implemented in China to reduce these incentives, such as the zero mark-up policy for drugs, monitoring the proportion of drug sale revenue in hospitals, and promoting mutual recognition of medical test results across various hospitals. However, the challenges of increasing medical expenditure and the heavy reliance on drug sales and expensive medical examinations have not been adequately dealt with; nor has the profit-driven behavior of hospitals been sufficiently reversed [28]. Therefore, the prices of medical services should be adjusted to honor the value of medical skills including medical rehabilitation; and incentive measures and regulations should be established to reduce unnecessary use of high-cost medical examinations and consumables and to further correct the profit-driven behavior of hospitals and health workers.

In China, the average per diem cost of PT is 20.59 USD (26.39%), OT is 0.55 USD (0.70%), and SLP is 0.45 USD (0.58%); in the United States, the average per diem cost of PT is 75.30 USD (15.90%), OT is 69.16 USD (14.60%), and SLP is 31.07 USD (6.56%) [27]. China has made substantial progress in strengthening its rehabilitation capacity, but the shortage of rehabilitation doctors and therapists, the limited medical insurance coverage for rehabilitative services, and the improper payment system for rehabilitation in China have led to the lagging development of rehabilitation [29]. To cope with the rapidly aging demographic, China should promote and establish a systematic plan for the development of rehabilitation medicine.

Acumen found a strong correlation of 0.67 between PT and OT costs per day [18]. Acumen also looked at trends in PT and OT costs per day across a wide range of resident characteristics and found that they followed similar trends [18]. Acumen then regressed a range of patient characteristics on PT and OT costs per day separately and found that the coefficients in both models followed similar patterns (90% of coefficients had the same sign across the two models) [18]. Given these three reasons, the PDPM could address PT and OT services through a single component. However, during technical expert panels, various professional organizations and other stakeholders stated that PT and OT services should be addressed via separate components, given the different aims of the two therapy disciplines [18]. In our study, the average per diem cost of PT (139.01 RMB/20.59 USD) is much greater than that of OT (3.72 RMB/0.55 USD). Because of the strong correlation between the dependent variables used for both components and the similarity in predictors, we used the same case-mix classification model for both components. In addition, due to the small sample size in the major joint replacement or spinal surgery, the four groups were combined into two groups. The R^2 value in this study ($R^2 = 0.111$) was better than that in Acumen's PDPM Technical Report (PT: $R^2 = 0.067$, OT: $R^2 = 0.040$) [18]. More than 71% of groups had a good homogeneity of resource use, expressed as the CV. The trends of CMI among different groups in our study were nearly consistent with those in Acumen's PDPM Technical Report [18].

Because the average per diem cost of SLP was only 0.45 USD (3.01 RMB) in this study, the 12 groups were combined into seven groups. Although the within-group homogeneity results were not very good, the trends of CMI for the groups were almost similar with those in Acumen's PDPM Technical Report [18]. Compared with the R^2 value in Acumen's PDPM Technical Report ($R^2 = 0.140$), the seven-group model only explained 6.1% of the variance of SLP per diem cost. This may be because the cost of SLP was much lower due to the lagging development of SLP in China. In China, one of the profit-driven behaviors of hospitals and health workers is to use pare nteral feeding or tube f eeding for patients with swallowing disorders, rather than performing SLP [9]. Moreover, the effect of SLP is usually not very prominent and the potential for improvement is small [30]. These factors may be responsible for the underdevelopment of SLP in China. However, as a result of the rising life expectancy and rapidly aging population in China, there will be a steep increase in the need for SLP rehabilitation. Thus, it

Table 5 Nursing case-mix classification groups

Nursing Category	RUG-IV CMG	PDPM Original CMG	PDPM CMG in China	Clinical Conditions	Depression	Nursing Function Score	*N*	%	Mean	SD	Median	IQR	CV	CMI
Extensive Services	ES3	ES3	HS2	Tracheostomy & Ventilator	-	0–14	58	0.43%	324.38	49.63	331.26	67.46	0.15	6.33
	ES2	ES2	HS1	Tracheostomy or Ventilator	-	0–14	275	2.04%	257.14	57.65	267.81	90.69	0.22	5.02
Special Care or Clinically Complex	HE2/HD2/LE2/LD2/CE2/CD2	HDE2/LDE2/CDE2	CSE2	Serious medical conditions (e.g. comatose, septicemia, respiratory therapy, radiation therapy, dialysis) or conditions requiring complex medical care (e.g. pneumonia, surgical wounds, burns)	Yes	0–5	187	1.39%	96.76	34.01	100.10	64.86	0.35	1.89
	HE1/HD1/LE1/LD1/CE1/CD1	HDE1/LDE1/CDE1	CSE1		No	0–5	4976	36.87%	82.95	39.91	57.80	66.51	0.48	1.62
	HC2/HB2/LC2/LB2/CC2/CB2	HBC2/LBC2/CBC2	CSC2		Yes	6–14	129	0.96%	76.51	48.83	45.20	60.08	0.64	1.49
	HC1/HB1/LC1/LB1/CC1/CB1	HBC1/LBC1/CBC1	CSC1		No	6–14	3119	23.11%	57.77	30.72	44.87	36.64	0.53	1.13
	CA2	CA2	CSA2		Yes	15–16	44	0.33%	45.18	6.21	44.89	9.38	0.14	0.88
	CA1	CA1	CSA1		No	15–16	1164	8.62%	42.21	28.02	35.96	35.07	0.66	0.82
Behavioral Symptoms and Cognitive Performance	BB2/BA2/BB1/BA1	BAB2/BAB1	RB	Behavioral or cognitive symptoms	-	11–16	57	0.42%	38.71	3.53	40.00	3.99	0.09	0.76
Reduced Physical Function	PE2/PD2/PE1/PD1	PDE2/PDE1	ADE	Assistance with daily living and general supervision	-	0–5	1099	8.14%	34.70	12.10	31.94	19.28	0.35	0.68
	PC2/PB2/PC1/PB1	PBC2/PBC1	ADC		-	6–14	1247	9.24%	31.79	10.26	31.64	14.90	0.32	0.62
	PA2/PA1	PA2/PA1	ADA		-	15–16	1141	8.45%	30.33	9.33	27.44	12.04	0.31	0.59

ES1 groups (Infection Isolation) in RUG-IV and PDPM Original CMG were not included

SD standard deviation, *IQR* interquartile range, *CV* coefficient of variation, *CMI* case mix index

Table 6 NTA case-mix classification groups

NTA Score Range	PDPM Original CMG	PDPM CMG in China	*N*	%	Mean	SD	Median	IQR	CV	CMI
12+	NA	NA	306	2.27%	644.72	245.10	601.58	344.33	0.38	2.91
9–11	NB	NB	471	3.49%	436.37	214.07	378.29	299.10	0.49	1.97
6–8	NC	NC	2017	14.95%	418.28	254.22	341.22	345.25	0.61	1.89
3–5	ND	ND	2611	19.35%	319.82	201.69	256.00	243.06	0.63	1.44
1–2	NE	NE	2837	21.02%	182.14	91.96	164.72	103.81	0.50	0.82
0	NF	NF	5254	38.93%	160.36	102.84	133.37	115.29	0.64	0.72

NTA non-therapy ancillary, *SD* standard deviation, *IQR* interquartile range, *CV* coefficient of variation, *CMI* case mix index

is essential to identify a better payment method for rehabilitation in China.

The statistical performance of the nursing classification was favorable, with 12 groups and an RIV of 0.29. A recent overview of international validation studies of the RUG-III case-mix system in eight countries and regions revealed an RIV value of 0.14–0.67 (22–53 groups) [19], compared to which our results are also acceptable. The CMIs estimated from our data, which quantified the resource consumption for each of the nursing groups, were almost similar with t hose calculated for the United States [17]. The CV also achieved better homogeneity within each nursing group. It is worth noting that the nursing assistant, providing daily living care for the patient, is not yet an integrated part of the comprehensive nursing care system in China, neither within the hospital nor within the healthcare payment system [31, 32]. However, in most developed countries, multiple payment systems have been established, wherein non-clinical nursing care is covered by either the private health insurance system like in the United States [33, 34] or by the public health insurance system with government subsidy like in Europe, Australia, and Japan [35–37]. Along with the aging population, decreasing family size, and rising living standards, patients' needs and expectations for a high quality of life and a high quality of clinical and non-clinical nursing care have been increasing quickly [38]. It is necessary to place non-clinical nursing care under the management of the hospital and ensure that it is covered by the basic health insurance system under legitimated supervision in China.

Our results showed that the NTA classification achieved a variance explanation of about 10.6%, almost similar with that of the United States ($R^2 = 0.116$). The CV and CMI also showed favorable performance in six NTA groups. It is worth discussing that the NTA incorporated an adjustment factor based on days of a stay. Acumen indicates that NTA costs are high for the first 3 days of a stay due to the examinations performed upon admission [18]. Based on this observation, Acumen bins the first 3 days of the stay for NTA payment and calculates the average per diem costs for this flat period. In a previous study, the estimated per diem NTA costs declined from 150 USD during days 1–3 to 45 USD during days 4–100. Then, the adjustment factor was set to 3.00 for days 1–3. Following the 3-day flat period, the adjustment factor was set to 1.00, reflecting the 70% decline in per diem costs after the flat period and relatively constant per diem costs thereafter [18]. Our results were almost the same. The estimated per diem NTA costs in our study declined from 513.31 RMB (77.13 USD) during days 1–3 to 173.97 RMB (26.14 USD) during days 4–100. Thus, the adjustment factor was set to 3.00 for days 1–3 and to 3.00 for days 4–100, because for most stays, the majority of the stay falls within this range. To obtain a robust estimate of the cost of a specific day in a stay, it is necessary to set an adjustment factor for the NTA component.

Our study has several limitations. First, since the PAC service system has not been established in China and the development of rehabilitation is lagging, the expenses of rehabilitation programs, including PT, OT, and SLP, are relatively low, which significantly affects the results of the grouping model. When China's rehabilitation development improves, it will be necessary to re-examine the validity of PDPM in China. Moreover, as this research is based on skilled nursing facility patients in seven facilities in Jinhua City, the validation of PDPM as a case-mix system should be further tested on a more representative sample of patients before generalizing the results to the entire country. In addition, since China does not use a standardized comprehensive assessment scale such as MDS or CARE in PAC settings, we collected the functional assessment data and medical record data to establish the database needed for PDPM grouping. Therefore, it is still necessary to validate the PDPM classification system using a standardized comprehensive assessment scale in China. Lastly, a recent study points out that R^2 tends to overestimate the proportion of variation explained by models [39]. This overestimation should be considered when interpreting the explanatory power of the PDPM in this study. However, given that the R^2 values reported in Acumen's report of the PDPM implemented in the United States are similar to those found in our study, we believe that the PDPM remains applicable in China despite this limitation.

Conclusions

Our study was the first to validate the PDPM as a case-mix classification for PAC patients in China. Under the adapted version of PDPM, each patient was classified into a group corresponding to one of the four case-mix adjusted components: PT&OT, SLP, nursing, and NTA. Each component utilizes different criteria as the basis for patient classification. The results of this study provide evidence of the feasibility of using PDPM classification in China's PAC setting, which will be useful to facilitate the development of an appropriate payment method for PAC patients in China. However, future studies are needed to validate the PDPM classification system in China using a standardized comprehensive assessment scale.

Acknowledgements
This work was supported by the Jinhua Healthcare Security Administration, Zhejiang, China. The authors wish to thank facilitators, doctors, nurses, computer programmers, research assistants, and all patients who participated in the present study.

Authors' contributions
All authors were involved in the study design. YX, MZ and LH processed, analyzed and interpreted the data, drafted the article and made necessary revisions. MZ contributed to the data management and the primary analyses. LH and NS made a significant contribution on acquisition of data, revised the manuscript critically for important intellectual content. All authors agreed with the final version of the manuscript and agreed to take responsibility and be accountable for the contents of the article.

Funding
This work was supported by the Medical and Health Innovative Engineering Program of Chinese Academy of Medical Sciences (2021-I2M-1-046). The funding agencies were not involved in the study design, data analysis, and manuscript preparation.

Data availability
The data that support the findings of this study are available from Jinhua Healthcare Security Administration but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Jinhua Healthcare Security Administration.

Declarations

Ethics approval and consent to participate
The facilities gathered the data routinely in clinical practice according to the requirement of the local Healthcare Administration, and all data were processed without any personal identities being disclosed. Informed consent was obtained from all subjects. Ethics approval of the study has been obtained from the Medical Ethics Committee of the Chinese Academy of Medical Sciences & Peking Union Medical College to report the data for research purposes (Protocol Number: X170315009). This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication
Consent for publication was obtained from all the authors. In this study, patient consent is not applicable.

Competing interests
The authors declare no competing interests.

Received: 28 September 2023 / Accepted: 15 April 2025
Published online: 10 May 2025

References

1. Teppo K, Airaksinen KEJ, Halminen O, et al. Rural-urban and geographical differences in prognosis of atrial fibrillation in Finland: a nationwide cohort study. Scand J Public Health. 2024;52(7):785–92.
2. Fetter RB, Shin Y, Freeman JL, Averill RF, Thompson JD. Case mix definition by diagnosis-related groups. Med Care. 1980;18(2 Suppl):iii–1.
3. Notice of the National Healthcare Security Administration on the issuance. of a three-year Action Plan for DRG/DIP Payment Reform. http://www.gov.cn/zhengce/zhengceku/2021-11/28/content_5653858.html. Accessed 10 Sept 2024.
4. Stineman MG. Case-mix measurement in medical rehabilitation. Arch Phys Med Rehabil. 1995;76(12):1163–70.
5. Zhang L, Sun L. Impacts of Diagnosis-Related groups payment on the health-care providers' behavior in China: a cross-sectional study among physicians. Risk Manage Healthc Policy. 2021;14:2263–76.
6. Eagar K, Cromwell D, Kennedy C, Lee L. Classifying sub-acute and non-acute patients: results of the new South Wales casemix area network study. Aust Health Rev. 1997;20(2):26–42.
7. Khiaocharoen O, Pannarunothai S, Zungsontiporn C. Cost of acute and sub-acute care for stroke patients. J Med Assoc Thai. 2012;95(10):1266–77.
8. Z C. Analysis of the influence of paid by diagnosis-related groups on acute cerebral infarction [in Chinese]. Chi Med Rec. 2019;20(4):43–5.
9. Jia L, Qian S, Xiping S, et al. Exploratory research on patient care charging scheme model for patients with nervous system diseases based on RUG [in Chinese]. Nur J Chi PLA. 2020;37(4):55–8.
10. Liu R, Shi J, Yang B, Jin C, Sun P, Wu L, Yu D, Xiong L, Wang Z. Charting a path forward: policy analysis of China's evolved DRG-based hospital payment system. Int Health. 2017;9(5):317–24.
11. Laine J. RUG-III for exploring the association between staffing levels and cost-efficiency in nursing facility care in Finland. Health Care Manage Rev. 2006;31(1):73–7.
12. Khiaocharoen O, Pannarunothai S, Zungsontiporn C, Riewpaiboon W. Casemix classification payment for sub-acute and non-acute inpatient care, Thailand. J Med Assoc Thail. 2010;93(7):849–59.
13. Eilertsen TB, Kramer AM, Schlenker RE, Hrincevich CA. Application of functional independence measure-function related groups and resource utilization groups-version III systems across post acute settings. Med Care. 1998;36(5):695–705.
14. Sala S, Soontornpipit P. Design and development of data model for Thai sub acute and non acute patients. Appl Mech Mater. 2015;781:579–82.
15. Fries BE, Schneider DP, Foley WJ, Gavazzi M, Burke R, Cornelius E. Refining a case-mix measure for nursing homes: resource utilization groups (RUG-III). Med Care. 1994;32(7):668–85.
16. Jinxuan Z, Qiuping M. Meta-analysis of nursing stroke survivors in convalescence in China in recent ten years [in Chinese]. Chi Clini Nur. 2019;11(5):449–51.
17. Services CfMM. Medicare program; prospective payment system and consolidated billing for Skilled Nursing Facilities (SNF) proposed rule for FY 2019, SNF value-based purchasing program, and SNF quality reporting program. 2019.
18. Acumen. Skilled nursing facilities patient-driven payment model technical report. 2018.
19. Turcotte LA, Poss J, Fries B, Hirdes JP. An overview of international staff time measurement validation studies of the RUG-III case-mix system. Health Serv Insights. 2019;12:1–11.
20. Yan S, Ya L, Hua ZW. Analysis of variance and multiple linear regression on the structure and influential factors of rehabilitation hospitalization costs of stroke patients [in Chinese]. Jiangsu Healthc Admin. 2020;31(5):617–21.
21. Palmer G, Reid B. Evaluation of the performance of diagnosis-related groups and similar casemix systems: methodological issues. Health Serv Manage Res. 2001;14(2):71–81.
22. Medarevic AP. Describing Serbian hospital activity using Australian refined diagnosis related groups: a case study in Vojvodina Province. Slovenian J Public Health. 2020;59(1):18–26.
23. Jian W-Y, Lu M, Cui T, Hu M. Evaluating performance of local case-mix system by international comparison: a case study in Beijing, China. Int J Health Plann Manag. 2011;26(4):471–81.
24. Camilleri C, Jofre-Bonet M, Serra-Sastre V. The suitability of a DRG casemix system in the Maltese hospital setting. Health Policy. 2018;122(11):1183–9.
25. Yang C-M, Reinke W. Feasibility and validity of international classification of diseases based case mix indices. BMC Health Serv Res. 2006;6(1):125.

26. Stewart SL, Celebre A, Head MJ, James ML, Martin L, Fries BE. A case-mix system for children and youth with developmental disabilities. Health Serv Insights. 2020;13:1178632920977899.
27. Services TCfMM. Prospective payment system and consolidated billing for skilled nursing facilities; updates to the quality reporting program and value-based purchasing program for federal fiscal year 2023. 2022.
28. Liu X, Xu J, Yuan B, Ma X, Fang H, Meng Q. Containing medical expenditure: lessons from reform of Beijing public hospitals. BMJ. 2019;365:l2369.
29. Report on stroke prevention andtreatment in China Writing G. Brief report on stroke prevention and treatment in China, 2019 [in Chinese]. Chi J Cerebrovasc Dis. 2020;17(5):272–81.
30. Peng LN, Lu WH, Liang CK, Chou MY, Chung CP, Tsai SL, Chen ZJ, Hsiao FY, Chen LK. Functional outcomes, subsequent healthcare utilization, and mortality of stroke postacute care patients in Taiwan: a nationwide propensity score-matched study. J Am Med Direct Assoc. 2017;18(11):990.e997-990.e912.
31. He MQ, Yao Y. Discussion on dual management mode of nursing workers under the background of combination of medical care and nursing care [In Chinese]. Chin Remedies Clin. 2019;19(18):3227–8.
32. Yu LP, Zeng LH, Guo Y. Application effect of dual management mode of hospital nursing department and housekeeping company in nursing care management [in Chinese]. Chin J Rural Med Pharm. 2019;26(8):85–6.
33. Cimarolli VR, Burack O, Poole-Dayan G, Liu I, Samaroo SP, Bondy M. An evaluation of a geriatric substance abuse recovery program in post-acute care of a skilled nursing facility. Educ Gerontol. 2018;44(1):28–39.
34. Dawson WD, Cutler J. Addressing long-term services and supports reform via medicare. yes, medicare, that post-acute care program. J Aging Soc Policy. 2020;32(2):108–24.
35. Kudo Y, Kido S, Shahzad MT, Yoshimura E, Shibuya A, Aizawa Y. Work motivation for Japanese nursing assistants in small- to medium-sized hospitals. Tohoku J Exp Med. 2011;225(4):293–300.
36. Cong PL, Cao HL. Analysis on the promotion of professional title and salary standard of Australian registered nurses [in Chinese]. J Nurses Train. 2017;32(24):2301–3.
37. Wang Y, Jia TY, Yuan HY. International comparison of the nursing assistants industry [in Chinese]. Chin Hosp. 2016;20(11):76–8.
38. Fan HL, Du EQ, Zhou WP. The practice and experience of standardized management of nurses in tertiary hospitals [in Chinese]. J Tradi Chin Med Manage. 2020;28(1):235–6.
39. Gao J. R-Squared (R2)– How much variation is explained? Res Methods Med Health Sci. 2023;5(4):104–9.

Publisher's Note