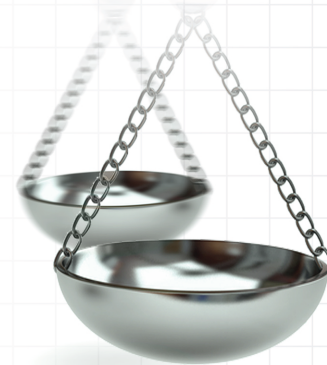




True cost of surgical aortic valve replacement and implications for price setting and diagnosis-related groups: evidence from a tertiary hospital in Eastern China

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Background: Surgical aortic valve replacement (SAVR) has long been the standard treatment for patients with severe aortic stenosis in China, but the costs of SAVR from a hospital perspective in China have not been thoroughly researched. Currently, diagnosis-related groups in China are based on historical expenses that are closely related to the unit charges set by the official pricing department and are frequently inaccurate compared with actual resource consumption. **Materials & methods:** Through a retrospective empirical study on the costs and charges of SAVR cases in a tertiary hospital, this study aimed to compare the costs and charges of service items. We collected clinical information from patients undergoing SAVR (isolated or concomitant procedures) and financial information from the hospital in 2015 and 2016. Top-down full cost accounting and step-allocation were the main methods used in this study. **Result:** This research selected 203 SAVR cases in 2015 and 214 cases in 2016. The median length of hospital stay was 15.92 days (6.07 days pre surgery and 9.57 days post surgery). The average human resource cost of care per day per bed in the cardiovascular surgery department, including doctors and nurses, was US \$62.22 in 2015 and \$66.17 in 2016, but the corresponding charge was no more than \$24. For operation, the cost of isolated SAVR was \$665 in 2015 and \$1015 in 2016, while the charge was \$820. For anesthesiology, the cost of isolated SAVR was \$400 in 2015 and \$526 in 2016, while the average charge was \$192. For examination service items, some costs did not exceed charges. The average total cost of a case was \$19,299 ± 8954, while the average total charge was \$18,923 ± 9194. **Conclusion:** SAVR is associated with significant resource utilization and hospital stay duration. The fees for human resources and services associated with SAVR do not reflect the true costs of SAVR in a Chinese hospital setting. This study may assist in future budget planning and price setting for policy makers in China.

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Over the past several decades, China has undergone a large-scale reform of its healthcare system – a complicated feat with improved health status, universal health coverage in terms of population and better health delivery systems while taking into account rising healthcare costs, inconsistencies in the distribution of healthcare services across China's rural and urban areas [1,2]. China is the most populous country; in 2016, its population was approximately 1.38 billion people (roughly 20% of the world's population), and that number is expected to increase substantially, due to advancements in medical technology and the introduction of previously lacking healthcare resources in

China [3,4]. These developments in healthcare have both improved patient outcomes and contributed to an increased life expectancy (the average life expectancy in China increased from 67.8 years in 1981 to 76.3 years in 2015 [3]), which has resulted in a growing population and a higher proportion of elderly persons in China [4]. In 1980, only 5.1% of Chinese people were aged 65 years and older; by 2012, that percentage increased to 8.7% and by 2016, the percentage of the population aged 65 years and older reached 10.9% [3,4].

With the prolongation of human life and the rapid aging of the Chinese population, it is necessary to reevaluate the impact of major chronic diseases associated with aging, especially within the context of the country's recent strides in healthcare reform [1,5]. This study examined the economic impact of aortic stenosis (AS) in China. AS is a type of valvular heart disease (VHD) in which the aortic valve opening restricts blood flow from the left ventricle to the aorta. A retrospective analysis [5] of patients at a tertiary, or class III, hospital in China who received transthoracic echocardiography from 2010 through 2015 showed that AS was the third most prevalent of other VHDs (class III, or tertiary, hospitals, are large, maximum-care facilities and academic medical centers that often have over 1000 beds. Class I and class II hospitals are smaller, with about 50–100 beds and 100–500 beds, respectively). Researchers found that AS affected 0.28% of the entire study population (392/139,496) and about 18% of those patients with VHD. The study also found the prevalence of severe AS to increase with age, affecting 0.56% of individuals aged 75 years or older [5].

AS carries a significant clinical and economic burden in the USA as well. AS is the most common VHD in western populations and its prevalence is similarly expected to increase as the population ages, with severe AS present in an estimated 3.4% of the population aged 75 years and above in Europe and North America [6–8]. Although the prevalence of AS in China is not as high as in the USA, severe AS affects a large number of elderly people in China. Assuming that 3.9% of the Chinese population were aged 75 years and above in 2016 [3], and if 0.56% of those people had severe AS [5], then severe AS still likely affects an estimated 300,000 elderly patients per year.

As the Chinese population ages and the prevalence of AS and VHD increases, so will the healthcare burden of AS, which carries a poor prognosis if left untreated. Surgical aortic valve replacement (SAVR) has long been the standard treatment for patients with severe AS [8,9]. Patients with severe AS who do not have AVR have survival rates as low as 50% at 2 years and 20% at 5 years [10]. The transition from China's previous reimbursement system (a retrospective, fee-for-service [FFS] payment model) to a prospective, diagnosis-related group (DRG)-based, case-mix system as part of China's healthcare reform [2]. Unfortunately, we have little information regarding hospitals' costs/charges for performing SAVR procedures in China, which is a hindrance to the establishment of reasonable DRG payment standards. DRGs have been used effectively in other countries like the USA, the UK, Australia and Germany for quite some time [11], and early pilot studies in China have reported cost and utilization reductions using DRG payments compared with standard, FFS models [12]. However, the Chinese DRG program is still in its infancy and is not yet optimized.

Currently, DRGs in China are based on historical expenses that are closely related to the unit charges set by the official pricing department. This is different from the USA, for example, where established cost-to-charge ratios and the use of relative value units for cost estimation and weight determination are employed to determine the payment standards of DRGs [13]. China's historical, expenses-based DRG payment model is frequently inaccurate compared with actual resource consumption, which ultimately affects the choices made by hospitals and physicians when providing patient care. The current DRG model may also make it difficult for indicated procedures like SAVR to be adopted as widely as possible.

This novel research provides a case study of a tertiary hospital in China comparing the actual cost to the hospital for performing SAVR to the reimbursement 'charge' accepted by the government. This paper evaluates the different hospital resources utilized when performing SAVR to elucidate the cost-to-charge discrepancy that currently exists when a tertiary hospital performs a SAVR procedure. The hope is that this manuscript will provide a framework for other hospitals to generate the evidence needed to promote DRG reform so that more patients with VHD will benefit from lifesaving surgical procedures like SAVR.

Materials & methods

Overview

This study aimed to estimate the total cost of a patient undergoing a SAVR surgery from admission through discharge at a public tertiary hospital in a provincial capital city in Eastern China. First, patient data were collected from the hospital, and the sensitive information of all patients was not included in it. Next, hospital costs and charges were evaluated, and each patient's journey was established. A step-allocation method was then applied to

Table 1. Patient demographics and clinical characteristics of the study population.

Type of costs	Identification and its measurements
1. Personnel costs	Payments that hospital employees (physicians, nurses, etc.) received through the direct or indirect provision of medical services to patients including average effective working time, basic salary, supplemental salary, benefits, bonuses, social security and any additional costs.
2. Consumable medical costs	Costs associated with laboratory materials used for testing blood, oxygen and other testing materials.
3. Drug costs	These costs have been equal to the prices since the implementation of the zero-markup policy [†] on drug sales.
4. Tangible fixed-asset depreciation costs of each department	Calculated by multiplying the value of fixed-assets like buildings, medical device and so on, from each department and the corresponding depreciation rate, then aggregating the depreciated values.
5. Intangible fixed-asset amortization costs	Amortized costs associated with the hospital management system, EMR system, etc.
6. Medical-risk fund cost	Costs that were withdrawn from a clinical department to cope with outstanding debts from patients who did not pay for medical services rendered.
7. Other costs	Consisted of travel costs, postage, incidental office expenses, and utility expenses for maintaining the supplies for normal operation including water, electricity, fuel, equipment maintenance, printing and copying, and other operating costs.

[†]In 2009, China introduced a zero-markup policy designed to make essential medicines affordable and accessible to people and reduce the incentive for clinicians to prescribe and profit from unnecessary drugs.
EMR: Electronic medical record.

estimate the costs of resources used in each department from admission through discharge. Finally, after combing the daily costs per patient associated with SAVR and the time spent in each department, we quantified the cost of each patient during hospitalization for SAVR. Cost data for this study are presented in US dollars. In 2015, \$1 = ¥6.2284 and in 2016, \$1 = ¥6.6423. For this study, investigators used an average conversion rate of \$1 = ¥6.4356.

Data source

Consecutive patients with AS who underwent SAVR (isolated or concomitant procedures) between 1 January 2015 and 31 December 2016, at a tertiary hospital located in a provincial capital in Eastern China were selected for analysis. Concomitant procedures include other valve surgery, electrophysiological surgery, aortic surgery, coronary surgery, etc. Next, investigators collected information on clinical interventions and resource utilization from electronic medical records and the hospital charging system to account for every cost associated with each SAVR operation. All data used to perform this analysis were de-identified, and the study has passed the ethical review. As a retrospective analysis of a de-identified database, the research was exempt from institutional review under 45 CFR 46.101(b)(4) [14].

Cost data identification

Financial information from the hospital in 2015 and 2016 was collected to calculate the full cost of SAVR from the top down. The hospital costs were categorized into seven cost types in Table 1.

Patient utilization from admission through discharge

Patients undergoing SAVR at the hospital in this study typically utilized resources in four main departments of care: in a general, inpatient ward in the cardiology department; in a general, inpatient ward in the cardiovascular surgery department; in the anesthesiology department and in the operating room (OR). Sometimes, patients were sent to the intensive care unit (ICU) or cardiac ICU (CCU) of the cardiology or cardiovascular surgery department as well. Researchers used a step-down cost allocation method to calculate the daily personnel costs, consumable medical costs and any other applicable cost types per patient in each department.

Noncost center & cost center method

Service departments such as administration and housekeeping, are often referred to as noncost centers. These noncost centers must be allocated to revenue-generating departments known as cost centers which cover these costs. The allocation is based on the extent to which each revenue-generating department utilizes these support services.

A step-down method is a standard approach for allocating these costs [15]. Support departments are ranked to accomplish step-down allocation. The ranking is based on the percentage of costs that a support department incurs to maintain other departments. Workload, revenue or effective working time were used to allocate costs to the

Table 2. Patient demographics and clinical characteristics of the study population.

Characteristics, n (%) [†]	Patients (n = 417)	Median (IQR)
Patient demographics		
Sex		
– Male	236 (56.6)	
Age, mean (SD), years	56.2 (11.5)	57 (49.0–64.0)
Age groups (years)		
– <30	13 (3.1)	
– 30–39	14 (3.4)	
– 40–49	80 (19.2)	
– 50–59	141 (33.8)	
– 60–69	124 (29.7)	
– 70–79	42 (10.1)	
– ≥80	3 (0.7)	
Clinical characteristics		
Type of valve		
– Biological	79 (18.9)	
– Mechanical	338 (81.1)	
Type of operation		
– Isolated	80 (19.2)	
– Concomitant	337 (80.8)	
– Length of stay, mean (SD), days	18.8 (12.4)	15.9 (13.1–20.8)
[†] All data are presented as n (%) unless otherwise indicated. IQR: Interquartile range.		

service items used. These allocations were then applied as unit costs for each cost center and allowed the total costs for the service items to be calculated.

Personnel costs were a factor in each department of care and were calculated by allocating the hourly costs of doctors and nurses by professional title, the average effective working time spent with each patient and the number of personnel treating a patient at a given time to each department. Consumable medical service and drug costs were determined by aggregating the number of individual service items received by each patient in a given department multiplied by the cost of each service item. Consumable costs for patients included labor and materialized costs of all examinations, treatments, drugs, blood, and oxygen during a patient's hospital stay. We accounted for the cost of almost all service items, but due to the large number of items, only partial results are presented here.

Researchers estimated the average cost per bed per day in the general, inpatient wards and in the ICU/CCU of the cardiology and cardiovascular surgery departments by totaling allocated personnel costs, nonchargeable materials cost, tangible fixed-asset depreciation costs, medical-risk fund costs and other costs. The cost of the SAVR operation itself was calculated by combining three timed components: all costs associated with running the OR from the time the door was opened to begin the procedure through the time all personnel had left the OR (door-to-door costs), all costs associated with administering anesthesiology based on the duration of anesthesia service and all costs associated with the SAVR procedure itself based on the time that doctors and nurses were in contact with each patient (skin-to-skin costs). Personnel costs in all three time components also considered the number of doctors or nurses tending to the patient in the OR. The average cost per SAVR surgery per patient was therefore estimated by combining all costs associated with the SAVR operation itself, the per bed per day costs associated with each patient in the respective department of care and length of stay.

Results

Demographics & clinical characteristics of the study population

Of the 417 consecutive patients with AS who underwent SAVR between 1 January 2015 and 31 December 2016, at a tertiary hospital located in Eastern China, more than half were male (236 [56.6%]) and the overall mean (SD) age was 56.2 (11.5) years. Patient and procedure characteristics are summarized in [Table 2](#). Over half of the patient population was aged 50 years or older, with 141 (33.8%) patients in 50–59 years old group, 124 (29.7%) in the

Table 3. Average hospital personnel cost per h, in US\$[†].

Professional title	Cardiology		Cardiovascular surgery		Anesthesiology [‡]		Operating room [§]	
	2015	2016	2015	2016	2015	2016	2015	2016
Physicians								
– Senior	33.63	39.11	39.26	38.62	39.21	53.90	–	–
– Middle/intermediate	18.44	21.98	20.82	23.19	26.04	29.22	–	–
– Junior	17.73	16.53	15.24	18.18	18.83	23.62	–	–
Nurses								
– Senior	27.77	29.91	26.74	22.23	–	–	25.24	30.29
– Middle/intermediate	16.25	17.81	19.55	16.90	–	–	19.77	25.05
– Junior	11.94	13.33	11.62	10.92	–	–	17.35	20.93

[†]Here, conversions to dollars were made using the average of 2015–2016 where \$1 = ¥6.4356.

[‡]Nurses in this study did not work in the anesthesiology department.

[§]Physicians in this study were not included in the operating room costs; rather, they are accounted for in the cardiovascular surgery department. Separate nurses are required to help with the surgery and run the operating room, which is why nurses are found in both departments but not physicians.

Table 4. Cost-to-charge comparison of some medical service items used to diagnose aortic stenosis, in US\$[†].

Examination item	Cost		Charge
	2015	2016	2015–2016
ECG	5.34	5.62	1.55
X-ray	12.54	12.76	5.44
ECT	173.01	206.04	76.14

[†]Here, conversions to dollars were made using the average of 2015–2016 where \$1 = ¥6.4356.

ECT: Emission-computed tomography.

60–69 years old group and 45 (10.8%) patients aged 70 years and older. More patients received mechanical valves and concomitant procedures (338 [81.1%] and 337 [80.8%] patients, respectively) compared with biological valves and isolated procedures (79 [18.9%] and 80 [9.2%] patients, respectively). The mean (SD) length of stay for any SAVR operation was 18.8 (12.4) days.

Demographics & clinical characteristics of the study population

Table 3 displays the average hospital personnel costs per h for each of the four departments involved with SAVR: cardiology, cardiovascular surgery, anesthesiology and the OR. Senior physicians were the most expensive per h, and junior nurses were the least expensive, highlighting the unsurprising trend that the higher the professional title among doctors or nurses (regardless of department), the higher the cost. Across departments associated with SAVR, however, senior physicians in the cardiovascular surgery department were the most expensive in 2015 (\$39.21), and senior physicians in the anesthesiology department were the most expensive in 2016 (\$53.90). Most costs among physicians increased from 2015 to 2016, except for cardiology junior physicians, cardiovascular surgery senior physicians. Senior physicians in anesthesiology had the largest hourly increase, costing \$14.69 more in 2016 than in 2015. Senior nurses were the most expensive among nurses in the OR and cardiology in 2016. The hourly cost of all levels of nurses in the cardiovascular surgery department decreased from 2015 to 2016. All other nurse wages increased across departments.

Table 4 shows the cost of some of the consumable medical service items used. In some cases, the cost exceeded the charges, such as with ECGs, x-ray and emission computed tomography. Emission computed tomography was the most expensive (\$206.04 in 2016) but only received a reimbursement charge of about \$76.14. The cost of x-ray was about \$12, but the charge was only \$5.44. At the same time, the cost of ECG was about \$5, while the charge was \$1.55. However, other items that charged more than costs.

Table 5 shows the average cost per bed per day of care. In the cardiovascular surgery department, the cost of care was \$62.22 per day in 2015 and \$66.17 per day in 2016. In the cardiology department, this cost was \$65.10 in 2015 and \$68.18 in 2016. These cost for doctors and nurses were around \$45 and 20, respectively. It is important to note that the corresponding charges are far below these costs. For example, the inpatient diagnostic charge is \$2.33 per day for a doctor. For a nurse, the critical care charge is \$0.78 per day, and the special-care charge is

Table 5. Average cost of daily care per bed per day, in US dollars[†].

Resource/department	Cardiovascular surgery		Cardiology	
	2015	2016	2015	2016
Hospital personnel [‡]	62.22	66.17	65.09	68.19
– Physicians	41.34	47.19	44.17	45.03
– Nurses	20.88	18.98	20.92	23.16
ICU/CCU	404.58	485.65	81.46	80.77
General ward	74.48	88.25	55.31	54.26

[†]Here, conversions to dollars were made using the average of 2015–2016 where \$1 = ¥6.4356.

[‡]We interviewed and observed doctors and nurses at different levels in two departments, and found the average time they spent on each patient's care. Then, according to the unit cost, the average cost of daily care per bed per day is calculated.

CCU: Cardiac ICU; ICU: Intensive care unit.

Table 6. Number of cardiovascular surgeons, anesthesiologists and operating room nurses required per surgical aortic valve replacement.

Professional title	2015	2016	2-year average
Physicians			
Cardiovascular surgery			
– Senior	2.16	1.65	1.91
– Middle/intermediate	1.66	1.39	1.53
– Junior	0.14	0.88	0.51
– Total	3.96	3.92	3.95
Anesthesiology [†]			
– Senior	0.53	0.54	0.53
– Middle/intermediate	0.47	0.46	0.47
– Total	1.00	1.00	1.00
Nurses			
Operating room			
– Senior	0.15	0.26	0.21
– Middle/intermediate	1.34	0.83	1.09
– Junior	0.49	0.87	0.68
– Total	1.98	1.96	1.97

[†]Here is the level of the main anesthesiologist, because the level of assistants is not counted in the system, interviews show that most of the assistants are junior doctors, only in a very few cases will be middle/intermediate doctor.

\$0.62 per day. Additional noteworthy charges are the grade care charge of a tertiary hospital of \$3.11 per day, arteriovenous catheter care charge of \$2.80 per time, sputum suction charge of \$3.88 per time and bed sore nursing charge of \$7.77 per time.

The average cost per bed per day in ICU/CCU or general ward included nonchargeable materials cost, depreciation cost of fixed assets, medical risk fund cost and other costs, except the doctor and nurse charges mentioned above, there are only bed charges for the corresponding cost. The bed charge of ICU/CCU is \$6.22 per day, there are many bed charges of the general ward in cardiovascular surgery or cardiology, but the most expensive is only \$7.77 per day.

Resource occupancy

Table 6 shows the number of surgeons, anesthesiologists, and OR nurses required per SAVR operation and their professional titles. SAVR operations require about four cardiovascular surgeons, two anesthesiologists (one major anesthesiologist and one assistant) and two OR nurses. These numbers remained similar between 2015 and 2016. Table 7 displays the time associated with the SAVR operation, such as the time taken to occupy the OR (door-to-door), the anesthesia time and the operation time (skin-to-skin). Operation times also remained consistent from 2015 to 2016, with the occupation of the OR lasting about 6 h, anesthesia lasting about 5 h and the operation itself taking about 4 h.

Table 7. Average time spent performing surgical aortic valve replacement operations, in h.

Duration, h	2015	2016	2-year average
Occupation of OR [†]			
– Mean (SD)	5.72 (2.15)	5.88 (1.62)	5.8 (1.89)
– Median	5.25	5.50	5.42
Anesthesia [‡]			
– Mean (SD)	5.11 (2.1)	5.26 (1.65)	5.18 (1.88)
– Median	4.67	4.83	4.75
Operation [§]			
– Mean (SD)	4.34 (2.01)	4.55 (1.52)	4.45 (1.78)
– Median	3.92	4.17	4.08

[†] OR time was calculated as the time the OR doors opened through the time the last personnel left the OR (door-to-door).
[‡] The duration of anesthesia was calculated as the time the anesthesiologist entered the OR and was in contact with the patient through the time the anesthesiologist left the OR.
[§] The total operation time was calculated as the total time that the doctors and nurses were actually in contact with the patient during the operation (skin-to-skin).
OR: Operating room.

Table 8. Cost of surgical aortic valve replacement operation and anesthesiology per procedure, in US\$[†].

Treatment items	2015			2016		
	Cost	Charge	Δ [‡]	Cost	Charge	Δ [‡]
SAVR operation	665	820	155	1015	820	-194
Anesthesiology	400	192	-208	526	192	-334
Total	1065	1012	-53	1541	1012	-528

[†] Here, conversions to dollars were made using the average of 2015–2016 where \$1 = ¥6.4356.
[‡] Differences may not appear exact due to rounding.
SAVR: Surgical aortic valve replacement.

Table 9. Total hospital cost-to-charge comparison per surgical aortic valve replacement procedure by year, in US\$[†].

Year	Total SAVR cost	Total SAVR charge	Δ [‡]
2015			
– Mean (SD)	18,498 (7032)	18,510 (7857)	12
– Median	17,610	16,788	-822
2016			
– Mean (SD)	20,060 (10,416)	19,314 (10,307)	-745
– Median	17,625	16,995	-630
2-year average			
– Mean (SD)	19,299 (8954)	18,923 (9194)	-377
– Median	17,610	16,823	-786

[†] Here, conversions to dollars were made using the average of 2015–2016 where \$1 = ¥6.4356.
[‡] Differences may not appear exact due to rounding.
SAVR: Surgical aortic valve replacement.

Comparisons of costs & charges

Table 8 compares the actual hospital costs for performing a SAVR operation to the charges received from government reimbursement per SAVR operation for 2015 and 2016. The mean (SD) cost of isolated SAVR only was \$665 (\$155) in 2015 and \$1015 (\$274) in 2016, while the charge was \$820. For anesthesiology, the average cost was \$400 (\$154) in 2015 and \$526 (\$114) in 2016, while the average charge was \$192. The reimbursement charges were sufficient to cover the costs of the SAVR operation alone in 2015; however, they were not enough to cover the costs of anesthesiology. In 2016, the total cost of the SAVR operation in addition to anesthesiology was \$1541 per procedure; however, reimbursement charges only covered \$1012, leaving a difference of about \$528.

We estimated the expenditures of each patient during hospitalization by totaling the costs of each item or service used from admission to discharge including the costs of interventions in each department, the length of stay, and the number and level of health technicians required for treatment. As shown in **Table 9**, the mean (SD) total cost

of a SAVR case from admission through discharge was \$19,299 (\$8954), while the average total reimbursement charges were \$18,923 (\$9194), leaving an average deficit of about \$377 and a median deficit of \$786.

Discussion

This retrospective case study of a tertiary hospital in Eastern China found that the overall charges associated with a SAVR operation insufficiently covered the aggregate costs paid by the hospital for tests, labs, doctors, nurses and the SAVR operation itself. Investigators calculated that the actual hospital costs per SAVR operation from admission through discharge were higher than charges by an average mean deficit of \$377 and an average median deficit of \$786 over the 2 years. Additionally, the cost discrepancies worsened from 2015 to 2016 in most cases. The charge of the isolated SAVR operation combined with the anesthesiology was only \$53 less than the actual costs in 2015; however, in 2016, the costs of the SAVR operation and the anesthesiology separately increased while the charges for each decreased, leading to a significantly larger deficit of about \$528 in 2016. These increasingly large cost-to-charge discrepancies are likely symptomatic of the rising cost of healthcare combined with several issues that plague China's current healthcare system including slow hospital reform, unintended effects of the zero-markup drug policy and the current DRG system.

Healthcare expenditures have been growing substantially in China, and they continue to increase worldwide [16]. Annual costs associated with healthcare in China increased from about ¥984 billion in 2006 to ¥4635 billion in 2016 (approximately \$150 and 700 billion, respectively, using the conversion \$1 = ¥6.4356) [3]. In the USA, total costs related to cardiovascular disease alone are projected to increase from \$318 billion in 2015 to \$749 billion in 2035, most significantly for patients aged 65 years and older [17]. Hospitals and reimbursement systems will need to adapt to accommodate rising healthcare costs as new technologies develop and the elderly population grows. However, while the Chinese government has made important advances in healthcare reform, public hospitals have been slow to change, and the current system is marked by extreme variations in healthcare allocation and inconsistent reimbursement for drugs and medical procedures [1].

Inconsistent drug reimbursement across Chinese public hospitals has been a longstanding problem; some drugs are fully reimbursable in one city but are out-of-pocket expenses in another [1]. Furthermore, in the past, healthcare providers in China were able to both prescribe and sell prescriptions, turning drugs into revenue for public hospitals, which incentivized clinicians to take advantage of patients by recommending and prescribing unnecessary, expensive medications and treatments [18]. In 2007, pharmaceuticals accounted for 43% of expenditures per inpatient hospitalization and 51% per outpatient visit, so medications were responsible for about half of total health spending in China [19].

In 2009, China implemented a national essential drug list and the zero-markup policy in an attempt to discourage clinicians from superfluously prescribing overpriced drugs and medical services to patients [18]. The zero-markup policy mandates that: medications on the essential drug lists must be stocked and accessible; medications not on the lists must not be sold (to help maintain quality); and providers can no longer profit from these essential drugs, which are now available at wholesale prices [18]. Government subsidies were increased for public hospitals under the policy to compensate for the loss of income previously generated from prescription drug sales [1,18]. However, not all cities have carried out this policy; and, while drug revenue has decreased, inpatient care has doubled, which suggests that hospitals may still be overprescribing or even treating fake patients to cross-subsidize funds for doctors and nurses and correct other deficits in revenue created by the policy [1,18]. In the context of our study, the high costs of SAVR at the hospital may be inflated due to these unintentional consequences of the zero-markup policy.

The cost-to-charge discrepancies observed in this study may also be attributed to current reforms in the medical payment system in China. Currently, government financing (proportionally allocated based on hospital beds per year) only accounts for about 10% of the income for most Chinese public hospitals. A retrospective, FFS payment system (with a disease-specific cap per admission) is largely responsible for the remaining 90% of funding for public hospitals in China [2]. Unfortunately, the retrospective FFS system also incentivizes healthcare professionals to overdiagnose, overtreat and overprescribe to boost their income, further increasing healthcare costs in the country [2].

A major part of China's healthcare reform has been transitioning from the retrospective FFS system to prospective, DRG-based, case-mix system that also includes scaled payments and capitation [2,20]. Early evaluations of DRGs have been shown to help control costs, improve quality of care and increase efficiency.

In 2011, Beijing implemented pilot studies at six tertiary hospitals to test the effectiveness of the DRG model over the FFS model. Preliminary results were encouraging, showing a reduction in average hospital stays and 2-week

rehospitalization rates for DRG pilot hospitals (7 days and 6.5%, respectively) compared with tertiary hospital averages (10 days and 7.4%, respectively) [1]. A difference-in-difference study by Jian *et al.* also reported reductions at pilot hospitals using DRG payments compared with standard, FFS models [12]. They found that DRGs reduced health expenditures by ¥1251 (6.2%) and out-of-pocket payments per admission by ¥647 (10.5%) compared with FFS. The Jian *et al.* study did not find a difference between average length of stay and only a 1.4% reduction in readmission rates; however, about 35% of potential DRG cases were not reimbursed that way because elderly patients with more comorbidities were still being processed using FFS. Ironically, older patients with more complex conditions are the very people who might benefit most from a more inclusive and efficient DRG system.

However, the use of medical payment systems varies significantly between provinces, and often reimbursements employ a combination of payment types including FFS [20]. Additionally, the current DRG system is very simplified; has not been implemented fully; is based on historical, hospitalization-expenditures data; and charges based on a patient's primary diagnosis but does not take into account key patient characteristics like age, sex, severity and comorbidities [20]. The payment standards of DRGs should be based on cost, as in the USA, not expenditure.

In more developed countries, diseases like moderate-to-severe VHD carry a large clinical and economic burden among elderly populations, especially since the prevalence of VHD increases with age, affecting 4–9% of people aged 65–74 years and 12–13% of people aged 75 years and older [6,7,9,17]. However, DRG systems in those countries incorporate baseline patient characteristics like age, sex and chronic comorbidities when setting costs and grouping patients, which is not the case with the simplified DRG system in China [20]. Prices are distorted further because China's new DRG system sets costs based on historical, expenses-based FFS data. As observed in this study, the total cost of a SAVR hospitalization was much greater than the total charges of a SAVR hospitalization, and insufficient compensation may incentivize hospitals to not perform SAVR, despite recommendations [8,9].

With the launch and application of Transcatheter AVR (TAVR), a new technology for the treatment of AS, in China, TAVR is bound to replace part of SAVR, and it might also face problems that SAVR encounter when it is involved in DRGs. TAVR is a kind of valve placement through blood vessels with the help of catheters. It does not need surgical thoracotomy or remove the diseased valve. However, in China, the valve of TAVR is very costly, and it challenged its adoption and utilization. At present, some studies in Japan, the USA and The Netherlands have shown that TAVR is more cost-effective than SAVR in high perioperative risk groups [21–23]. However, there is no published health economics research on TAVR versus SAVR based on Chinese data. Therefore, similar studies are needed to provide more evidence in the future.

The discrepancies between hospital costs and charges associated with SAVR that were observed in this study may be a result of several factors including rising healthcare costs worldwide, unintended effects of healthcare reforms like the zero-markup policy and a simplified DRG system. These findings illuminate the need for improvement in the current Chinese healthcare system, especially since DRGs are based on outdated hospital expenditures. SAVR is just one example; however, and further hospital cost-allocation studies may offer policy makers in China important evidence necessary for planning future budgets, setting prices and determining resource allocation, all of which will become increasingly important as the country's population ages and grows.

Limitations of the study

This study should be interpreted with caution for several reasons. For one, the Chinese healthcare system is in transition, which may affect cost and charging reports. The government adjusted the price of some medical service items in 2014, so this study selected data after 2014 to help prevent the comparison of data from different reform benchmarks; however, some remnant errors may have been unavoidable. Additionally, hospital data are inherently subject to coding errors, but in China, certain policies may trigger the under- or over-reporting of clinical conditions. Retrospective analyses are also subject to confounding variables and inherent biases.

The availability of hospital information systems data also restricted the sampling period to 2 years (2015 and 2016), so a smaller sample size may have exaggerated or hidden some results. This study did not deduct government subsidies properly, if considered, the cost may be reduced to some extent. This was a case study from a tertiary hospital in a first-tier city in China. China has an immense population with significant variations in economic and health status across provinces. Furthermore, public hospitals currently use a mixed system of DRGs, FFS, capitation and scaled payments; therefore, the results presented here cannot be generalized and may not be replicable in a class II or class I hospital in smaller-tier cities. At last, this study only researched hospital charges and costs during hospitalization and did not follow-up with patients after admission due to lack of data.

Despite these limitations, this is, to our knowledge, the first study to highlight cost-to-charge discrepancies for SAVR in a Chinese hospital setting. Findings like these provide important evidence that reflects the true costs of SAVR and offer methodologies that may be used to understand hospital data associated with other life-saving procedures. As healthcare in China continues to reform, we hope that our research acts as first step in establishing a realistic reimbursement system for Chinese hospitals.

Conclusion

The total charges for hospital personnel and services associated with SAVR do not reflect the true costs of SAVR in a tertiary hospital setting in a first-tier city in China. In the future, the Chinese government may need to adjust the charges of medical service items to reflect current costs, increase the charges of personnel-related items, appropriately reduce the charges of some examination items and accelerate the reversal of inappropriate cross-subsidizing by amending healthcare reform policies.

More studies are needed across different hospital settings to further establish the need for improvement in Chinese public hospitals. This research hopes to assist future budget planning, pricing and resource allocation for policy makers in China when evaluating hospital financial systems, calculating the actual cost of medical service items and diseases, and setting updated costs for DRG-based payment standards.

Summary points

- This study examines the economic discrepancies that exist in the Chinese hospital reimbursement system for patients with aortic stenosis (AS) who undergo a surgical aortic valve replacement (SAVR) and the implications for this growing patient population if not addressed.
- AS is a type of valvular heart disease in which the aortic valve opening restricts blood flow from the left ventricle through the aorta and as such, patients with severe AS who do not have AVR have survival rates as low as 50% at 2 years and 20% at 5 years.
- SAVR has long been the standard treatment for patients with severe AS. However, the hospital economics of SAVR in China are not fully understood.
- Understanding the economics is important as China transitions its reimbursement system from a retrospective, fee-for-service payment model to a prospective, diagnosis-related group-based, case-mix system.
- This novel research provides a case study of a tertiary hospital in China comparing the actual cost to the hospital for performing SAVR to the reimbursement 'charge' accepted by the government.
- Investigators collected information on clinical interventions and resource utilization from electronic medical records and the hospital charging system to account for the costs associated with SAVR operations.
- Findings suggest that the overall charges associated with a SAVR operation insufficiently cover the aggregate costs paid by the hospital for tests, labs, doctors, nurses and the SAVR operation itself.
- This manuscript highlights the inadequacies of the current reimbursement system in China and serves as a framework to understand and generate the economic evidence for consideration in China's diagnosis-related group reform to allow for more patients with valvular heart disease to benefit from lifesaving surgical SAVR procedures.

Author contributions

X Qin, Y He, W Wang, Y Shao and Y Chen contributed to methodology determination for the research. Y Chen and J Wang developed the research goals and aims. X Qin, M Kong and A Dong contributed to investigation. X Qin, Y He, Q Zhu, J Fan and M Kong contributed to data curation. X Qin and Y Shao contributed to formal analysis. Y Shao and Z Huang participated in validation. X Qin and X Liu contributed to writing – original draft preparation. X Qin and Y Chen undertook the writing – review and editing. Y Chen obtained funding and carried out project management. J Wang provided resources. Y Chen and J Wang supervised the research. All authors read and approved the final manuscript.

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Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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