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Effects of Preoperative Risk Stratification on Direct In-hospital Costs for Chinese Patients with Coronary Artery Bypass Graft: A Single Center Analysis

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Summary: The purpose of this study was to analyze the components of inpatient costs for coronary artery bypass graft (CABG) according to preoperative risk stratification and to provide evidence for improvement of diagnosis-related groups (DRGs) payment. All patients (n=458) receiving an isolated CABG between January 2014 and December 2016 in a tertiary referral center, in southwest China, were analyzed. Hospital mortality was predicted by the EuroSCORE Ⅱ for each patient. The patients were subdivided into two groups according to the observed mortality (1.97%, 9/458): a high-risk group (group H, predicted mortality ≥1.97%) and a low-risk group (group L, predicted mortality <1.97%). Clinical outcomes, resource use, in-hospital direct costs, and reimbursement expenses were compared between the two groups. Significant differences existed between group L and group H in postoperative mortality (0.4% *vs.* 3.4%; P=0.02), postoperative complications (10.6% *vs.* 45.7%; P<0.001), postoperative length of hospital stay (17.5±4.9 days *vs.* 18.8±6.5 days, P=0.01), in-hospital costs ($20 256±3096 *vs.* $23 334±6332; P<0.001), and reimbursement expenses ($7775±2627 *vs.* $9639±3917; P<0.001). In general, a higher EuroSCORE Ⅱ was significantly associated with a worse clinical outcome and increased costs. The CABG cost data provide evidence for improvement of DRGs payment.
Key words: coronary artery bypass graft; risk stratification; hospital costs; medical insurance payment

With the increasing prevalence of cardiovascular risk factors and an aging population, the incidence and mortality of coronary heart disease (CHD) in China have increased in recent years. CHD has become the second leading cause of cardiovascular death in China, and CHD incidents and deaths are expected to continue to increase. Inevitably, CHD places an enormous economic burden on patients and societies[1–4]. Coronary artery bypass graft (CABG) is one of the most effective major medical procedures for treating CHD, and the application of CABG in China increased gradually[4]. Thus, insights into data on the hospitalization costs of CABG are essential to reasonably allocate medical resources and control costs; however, detailed analyses of hospitalization expenditures of CABG have been scarcely reported in China.

To control the rising healthcare costs, China is experimenting with the diagnosis-related groups (DRGs) payment system[5]. This payment system aims to set costs and group patients based on diagnostics and characteristics (e.g., age, disease severity and complications) to control medical expenses and improve efficiency[6].

Here, we analyze the components of inpatient costs for CABG according to preoperative risk stratification in order to provide evidence for the improvement of DRGs payment in China.

1 MATERIALS AND METHODS

1.1 Characteristic Data

This study was carried out in the Department of Cardiovascular Surgery, Xinqiao Hospital, a tertiary referral center in the urban area of Chongqing,

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southwestern China. All adult patients undergoing CABG from Jan. 1, 2014 to Dec. 31, 2016 were included. The patients who underwent CABG concomitant with other cardiac surgical procedures were excluded. There were 458 patients with isolated CABG enrolled for analysis. All relevant clinical information and itemized billing data were obtained from the electronic medical record (EMR). The European System for Cardiac Operative Risk Evaluation Ⅱ (EuroScore Ⅱ) for operative mortality was calculated using online algorithms (http://www.euroscore.org/calc.html).

The data included demographic and clinical variables. Postoperative data included the length of hospital stay, in-hospital mortality, postoperative arrhythmia, reoperation, re-intubation, pneumonia, sternal wound infection, leg incision infection, digestive tract hemorrhage, renal insufficiency, prolonged mechanical ventilation and cardiac arrest.

1.2 Cost Data

The medical insurance schemes included the urban employee basic medical insurance (UEBMI), the urban resident's basic medical insurance (URBMI), and the new rural cooperative medical scheme (NRCMS). Because the medical insurance reimbursement services in different administrative areas were not widely available, patients [*n*=189 (41.3%)] from other provinces paid all the medical expenses out-of-pocket first and then applied for reimbursement from their local medical insurance agencies. Thus, we only had the reimbursement data of local patients in Chongqing [*n*=269 (58.7%)].

Hospitalization expenses were divided into the following categories: surgical material, medication, therapy, laboratory tests, surgeries, blood products, examinations, anesthesia, nursing, hospital accommodation, and other fees. Given the influence of inflation on health care costs, the costs of hospitalization were adjusted according to China's consumer price index with 2016 as the standard.

1.3 Statistical Analysis

Hospital mortality was predicted by the EuroSCORE Ⅱ[7] for each patient. The patients were subdivided into two groups according to the observed mortality (1.97%, 9/458)[8, 9]: the high-risk group (group H, predicted mortality ≥1.97%) and the low-risk group (group L, predicted mortality <1.97%). The two groups were analyzed for differences related to baseline clinical characteristics, morbimortality, resource use, clinical outcomes, in-hospital direct costs, and reimbursement expenses.

Continuous variables were expressed as the mean±standard deviation or median, and categorical variables were expressed as percentages. Student's *t* tests were used for parametric distributions. Mann-Whitney *U* tests were used to analyze non-parametric distributions. Categorical variables were compared by the Pearson's chi-square test. Analysis was performed with SPSS version 20.0.0 (USA). Statistical significance was set at $P<0.05$. The costs were expressed in US dollars ($), and $1=¥6.6423 RMB (2016).

2 RESULTS

2.1 Patient Characteristics

Patient characteristics are presented in table 1. A total of 458 isolated CABG patients were included in the study. Group L and group H consisted of 226 (49.3%) and 232 (50.7%) patients, respectively. A significant difference in the EuroSCORE Ⅱ was found: 1.2%±0.4% (group L) *vs.* 3.9%±2.7% (group H). Most of the patients were male (81%). There were more female patients in group H than in group L (25.9% *vs.* 11.9%; $P<0.001$). The mean age was 60.4±9.1 years, and the patients in group H were older than those in group L (63.4±8.6 *vs.* 57.4±8.6 years, $P<0.001$). No significant differences in left ventricular function (LVEF), left ventricular end diastolic diameter (LVED), or the number of grafts were found. Comorbidities were more prevalent in group H than in group L.

2.2 Clinical Outcomes

Postoperative clinical outcomes are presented in table 2. There was significant difference in in-hospital mortality between the two groups (0.4% for group L *vs.* 3.4% for group H, $P=0.02$). The proportion of postoperative complications increased with increasing risk (10.6% for group L *vs.* 45.7% for group H, $P<0.001$). Prolonged ventilation was the most common postoperative complication (29%), and the second was pneumonia (12.4%). There was significant difference in incidence of pneumonia between group L and group H (5.8% *vs.* 19%, $P<0.001$), digestive tract hemorrhage (0.9% *vs.* 3.9%, $P=0.036$), and renal insufficiency (0.4% *vs.* 4.3%, $P=0.007$).

2.3 Resource Use and Costs

Resource use and costs are presented in table 3. There was significant difference between group L and group H in the length of hospital stay (25.2±5.9 *vs.* 27.5±8.2 days, $P<0.001$), time in ICU (4.0±1.4 *vs.* 4.5±2.5 days, $P=0.003$), and the postoperative length of hospital stay (17.5±4.9 *vs.* 18.8±6.5 days, $P=0.01$).

There was a significant difference in total costs between group L and group H ($20 256±3096 *vs.* $23 334±6332, respectively, $P<0.001$). For group L, the costs of materials, medication, therapy, laboratory tests, blood products, examinations, accommodations, and nursing were significantly less than those in group H ($P<0.05$). No significant difference was found in the costs of surgery and anesthesia between the two groups ($P>0.05$). The results are shown in table 3.

2.4 Reimbursement

There was significant difference in the reimbursement expenses between group L and group

Table 1 Patient characteristics

Characteristics	Overall cohort (*n*= 458)	Group L (*n*=226)	Group H (*n*=232)	*P* value
Age (years)	60.4±9.1	57.4±8.6	63.4±8.6	<0.001
Female (%)	87 (19)	27 (11.9)	60 (25.9)	<0.001
EuroScore II (%)	2.5±2.4 (2.3, 2.8)	1.2±0.4 (1.1, 1.2)	3.9±2.7 (3.5, 4.2)	<0.001
Weight (kg)	66.4±9.9	68.1±10	64.7±9.6	<0.001
LVEF (%)	63.1 (59, 67.5)	63.85 (59.39, 67.83)	63.00 (58, 67)	0.075
LVED (mm)	47.4±5.3	47.4±7.5	47.5±6.2	0.914
History of smoking	253 (55.2)	133 (58.8)	120 (51.7)	0.125
Chronic lung disease	37 (8.1)	13 (5.8)	24 (10.3)	0.071
Hypertension	250 (54.6)	111 (49.1)	139 (59.9)	0.02
Diabetes mellitus	112 (24.5)	35 (15.5)	77 (33.2)	<0.001
Serum creatinine (μmol/L)	80.0 (67, 99.1)	74.6 (64, 89)	90.0 (73.3,109.8)	<0.001
Ccr (mL/min)	79.9±28	91.9±24.6	68.1±26	<0.001
Recent myocardial infarction ≤90 days	66 (14.4)	22 (9.7)	44 (19)	0.005
Unstable angina	402 (87.8)	204 (90.3)	198 (85.3)	0.108
NYHA IV	14 (3.1)	8 (3.5)	6 (2.6)	0.553
III	124 (64)	140 (61.9)	153 (65.9)	0.373
II	116 (25.3)	70 (31)	46(19.8)	0.006
Peripheral artery disease	21 (4.7)	4 (1.8)	17 (7.7)	0.003
Poor mobility	26 (5.8)	9 (4)	17 (7.7)	0.096
Previous cardiac surgery	75 (16.4)	11 (4.9)	64 (27.6)	<0.001
Severe preoperative status	28 (6.1)	1 (0.4)	27 (11.6)	<0.001
IABP	54 (11.8)	18 (8)	36 (15.5)	0.012
Emergency	3 (0.7)	1 (0.4)	2 (0.9)	0.578
Number of grafts	2.7±2.6	2.5±1.2	2.9±3.6	0.091
On-pump	219 (47.8)	114 (50.4)	105 (45.3)	0.267
Off-pump	239 (52.2)	112 (49.6)	127 (54.7)	0.267
Noninvasive ventilation	80 (17.5)	31 (13.7)	49 (21.1)	0.037

Values are the mean±standard deviation (median) or *n* (%).

EuroScore II: European System for Cardiac Operative Risk Evaluation II; LVEF: left ventricular ejection fraction; LVED: left ventricular end diastolic diameter; Ccr: endogenous creatinine clearance rate; NYHA: New York Heart Association; IABP: intra-aortic balloon pump

Table 2 Clinical outcomes

Variable	Overall cohort (*n*= 458)	Group L (*n*=226)	Group H (*n*=232)	*P* value
In-hospital mortality	9 (1.97)	1 (0.4)	8 (3.4)	0.02
Postoperative complications	130 (28.4)	24 (10.6)	106 (45.7)	<0.001
Postoperative arrhythmia	10 (2.2)	4 (1.8)	6 (2.6)	0.550
Reoperations	5 (1.1)	0	5 (2.2)	0.026
Re-intubation	12 (2.6)	5 (2.2)	7 (3)	0.590
Pneumonia	57 (12.4)	13 (5.8)	44 (19)	<0.001
Sternal wound infection	6 (1.3)	0	6 (2.6)	0.015
Leg incision infection	5 (1.1)	0	5 (2.2)	0.026
Digestive tract hemorrhage	11 (2.4)	2 (0.9)	9 (3.9)	0.036
Renal insufficiency	11 (2.4)	1 (0.4)	10 (4.3)	0.007
Cardiac arrest	6 (1.3)	1 (0.4)	5 (2.2)	0.107
Prolonged ventilation time (>24 h)	133 (29)	56 (24.8)	77 (33.2)	0.047

Values are the mean±standard deviation (median) or *n* (%).

H ($7775±2627 *vs.* $9639±3917, *P*<0.001; fig. 1). Upon comparison of the reimbursement expenses for different types of medical insurance schemes within the same risk group, we found that the reimbursement expense of inpatients who joined the URBMI and NRCMS was significantly lower than those who joined the UEBMI. The patients in group H who joined the URBMI and NRCMS had the lowest reimbursement expenses (fig. 2).

3 DISCUSSION

This study showed that the group H presented worse clinical outcomes and required more resources. Thus, the resulting costs were greater in group H than in group L. Patients at high risk (group H) had increased in-hospital mortality (3.4% *vs.* 0.4%), more postoperative complications (45.7% *vs.*10.6%), longer

Table 3 Resource use and cost outcomes (US dollars)

Variable	Overall cohort (*n*= 458)	Group L (*n*=226)	Group H (*n*=232)	*P* value
Length of hospital stay	26.4±7.2 (25.5)	25.2±5.9 (25)	27.5±8.2 (26)	<0.001
Time in ICU	4.3±2.1 (4)	4.0±1.4 (4)	4.5±2.5 (4)	0.003
Postoperative length of hospital stay	18.2±5.8 (17)	17.5±4.9 (17)	18.8±6.5 (17)	0.01
Total costs	23 181±6243 (22 283)	20 256±3096 (20 236)	23 334±6332 (22 345)	<0.001
Materials	9777±3454 (10 380)	9469±3397 (9931)	10 072±3493 (10 591)	0.028
Medication	6120±3212 (5596)	5928±3500 (5517)	6305±2909 (5677)	<0.001
Therapy	1456±984 (1271)	1368±1080 (1224)	1539±877 (1327)	<0.001
Laboratory	1360±574 (1277)	1281±579 (1193)	1436±561 (1366)	0.014
Surgery	1197±279 (1242)	1219±264 (1242)	1176±293 (1154)	0.155
Blood products	921±615 (790)	788±490 (656)	1049±693 (949)	<0.001
Examination	913±413 (832)	890±403 (829)	934±424 (836)	0.008
Accommodation	238±181 (194)	230±157 (191)	246±202 (199)	0.021
Anesthesia	222±46 (217)	218±38 (217)	225±53 (217)	0.188
Nursing care	81±51 (69)	77±56 (67)	85±47 (71)	0.015
Other	89±78 (66)	80±62 (62)	98±90 (70)	0.011

Values are the mean±standard deviation (median) in US dollars for the year 2016.
ICU: intensive care unit

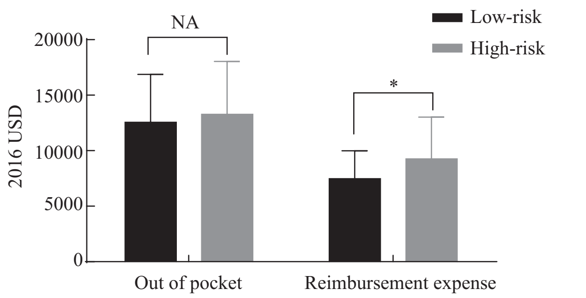

Fig. 1 Comparisons of reimbursement and out of pocket expenses
NA P>0.05; * P<0.05

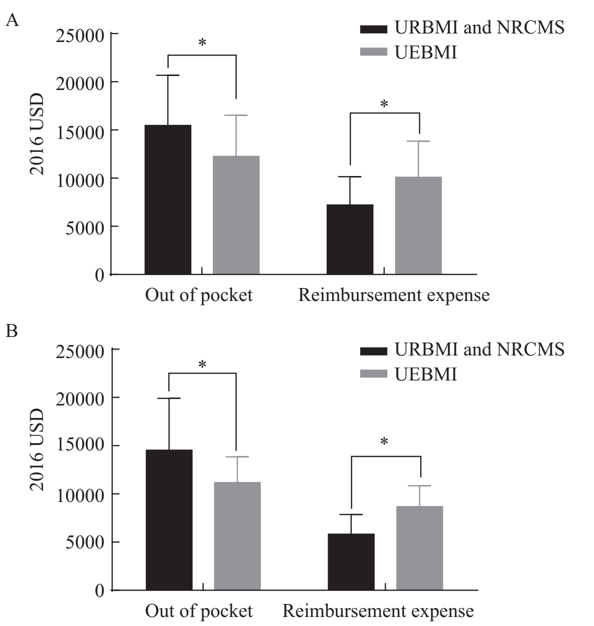

Fig. 2 Comparisons of reimbursement expenses for different types of medical insurance schemes in the same risk group
A: high risk; B: low risk
UEBMI: the urban employee basic medical insurance; URBMI: the urban resident's basic medical insurance; NRCMS: the new rural cooperative medical scheme; * P<0.05

postoperative length of hospital stay (18.8±6.5 *vs.* 17.5±4.9 days), and higher costs ($23 334±6332 *vs.* $20 256±3096). These results were consistent with prior research, which showed that a direct relationship existed between high risk patients and increased morbimortality and costs[10].

Several reasons might contribute to higher hospitalization costs in group H. First, patients in group H had more comorbidities and needed extra care and precautions, resulting in higher costs. Raza *et al*[11] found that costs for patients with diabetes mellitus undergoing CABG were 9% greater. LaPar *et al* reported that optimizing renal function preoperatively should improve patient quality and reduce costs by approximately 6% ($1250) per 10 mL/min improvement in creatinine clearance[12]. Another study showed that effective perioperative blood pressure (BP) control reduced hospitalization costs by 7%, compared with less effective BP control in patients[13]. Second, the quality of primary health care was not well characterized, especially in southwest China. Under diagnosis was pervasive, and treatment was rare[14]. Therefore, the potential medical costs were likely to be higher. Third, more postoperative complications in group H increased costs. Mehaffey and colleagues[15] in 2017 reported that each additional major complication would result in an exponential increase in cost. Previous studies found that sternal wound infection was costly ($19 000), and prolonged ventilation had the highest cumulative cost[16] .

While there was a difference between the two groups in reimbursement expenses, the difference was only $1929. We found that many patients had health needs that could not be met, especially for patients in group H who participated in the URBMI and NRCMS.

In 2017, the per capita disposable income for a Chinese resident was $3910 and the median was

$3373. The disposable income was even lower in southwest China. Thus, the huge healthcare expenses associated with CABG could be catastrophic for patients and their families given that the costs exceed an annual expenditure of 40%[17]. For low-income groups, although health insurance could provide some financial protection, the out-of-pocket payment was still unaffordable. Many patients made medical decisions based on cost or ability to pay, rather than their health needs. Thus, policies need to be changed to provide more financial support for low-income groups requiring CABG. The average in-hospital cost of CABG estimated in our research was slightly lower than Brazilian study's results of $7992.6, with a reimbursement of $3450.7 (48.7%)[18]. Another study showed that the mean hospitalization cost of CABG was $38 848 in the United States[19].

Since new medical reforms have taken effect, China has established nearly nationwide health insurance coverage for its people[20]. In our study, all of the patients participated in health insurance schemes. According to the local policies, the inpatient reimbursement rates were 85% to 90% in the UEBMI, and 40% to 45% in the URBMI and NRCMS insurance schemes; however, in our survey, the actual inpatient reimbursement rates (28.9%–31.8% in URBMI and NRCMS, and 43.8%–45.1% in UEBMI) were significantly lower than the policy standards. The main reasons underlying these discrepancies included the deductibles and annual caps, as well as limited drug and treatment in the insurance catalogues[14]. In China, most people only rely on the basic medical insurance. The underdevelopment of subsidiary medical insurance was another insufficiency in China's medical insurance system.

China's investment in health care has increased since the new medical reforms have taken effect. The proportion of government health expenditures rose from 28.7% in 2010 to 30.1% in 2017. The proportion of personal pay health expenditures dropped from 35.3% to 28.8%, and the burden of disease has been reduced; however, in this study, the inpatient self-payment rate was 60.5%. Because China's current medical insurance system is less oriented to chronic diseases, insurance coverage of most chronic diseases is not well established, and thus, basic medical insurance cannot meet the associated health needs.

The current data, combined with a high burden of CABG, represented a large impact on the health care budget. The budgetary impact of CABG is expected to continue to increase. To control the unsustainable rise in healthcare costs, China is experimenting with the DRGs payment system. Designers of health care payment models should consider risk stratification of patients to meet the health needs of patients. Without reform, patients may find it difficult to get treatment since the providers (hospitals) treating them will not be able to afford their care.

This study had some limitations. First, because it was a single-center study, there may be potential patient bias. Patients' trust in primary health-care institutions is low, even though the reimbursement rate is generally higher than that of tier-3 hospitals, and most patients in China are still willing to seek medical service in a tier-3 hospital for their excellent health resources. Second, we did not know the reimbursement rate in the local region for a large number of subjects, and the sample size may have influenced some analyses.

To be concluded, a higher EuroSCORE Ⅱ was significantly associated with higher postoperative mortality, complications, postoperative length of hospital stay, and in-hospital costs. Designers of health care payment models should consider risk stratification of patients to meet the health needs of patients.

Conflict of Interest Statement

The authors declare that there is no conflict of interest with any financial organization or corporation or individual that can inappropriately influence this work.

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