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# Comparing Outcomes of Coronary Artery Bypass Grafting Among Large Teaching and Urban Hospitals in China and the United States

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**Background**—Coronary artery disease is prevalent in China, with concomitant increases in the volume of coronary artery bypass grafting (CABG). The present study aims to compare CABG-related outcomes between China and the United States among large teaching and urban hospitals.

**Methods and Results**—Observational analysis of patients aged  $\geq 18$  years, discharged from acute-care, large teaching and urban hospitals in China and the United States after hospitalization for an isolated CABG surgery. Data were obtained from the Chinese Cardiac Surgery Registry in China and the National Inpatient Sample in the United States. Analysis was stratified by 2 periods: 2007, 2008, and 2010; and 2011 to 2013 periods. The primary outcome was in-hospital mortality, and the secondary outcome was length of stay. The sample included 51 408 patients: 32 040 from 77 hospitals in the China-CABG group and 19 368 from 303 hospitals in the US-CABG group. In the 2007 to 2008, 2010 period and for all-age and aged  $\geq 65$  years, the China-CABG group had higher mortality than the US-CABG group (1.91% versus 1.58%,  $P=0.059$ ; and 3.12% versus 2.20%,  $P=0.004$ ) and significantly higher age-, sex-, and comorbidity-adjusted odds of death (odds ratio, 1.58; 95% confidential interval, 1.22–2.04; and odds ratio, 1.73; 95% confidential interval, 1.24–2.40). There were no significant mortality differences in the 2011 to 2013 period. For preoperative, postoperative, and total hospital stay, respectively, the median (interquartile range) length of stay across the entire study period between China-CABG and US-CABG groups were 9 (8) versus 1 (3), 9 (6) versus 6 (3), and 20 (12) versus 7 (5) days (all  $P<0.001$ ). This difference did not change significantly over time.

**Conclusions**—In 2011 to 2013, there was no significant difference in in-hospital mortality among patients who underwent an isolated CABG surgery in large teaching and urban hospitals in China and the United States. The longer length of stay in China may represent an opportunity for improvement. (*Circ Cardiovasc Qual Outcomes*. 2017;10:e003327. DOI: 10.1161/CIRCOUTCOMES.116.003327.)

**Key Words:** comorbidity ■ coronary artery bypass grafting ■ coronary artery disease  
■ hospital mortality ■ length of stay

Cardiovascular disease is a leading cause of death worldwide, and coronary artery bypass grafting (CABG) is among the most common major medical procedures for treating coronary artery diseases (CAD).<sup>1</sup> Several innovations,

such as minimally invasive CABG surgery, off-pump CABG surgery, and antiplatelet therapy have been adopted widely, with the promise of improved clinical outcomes compared with older CABG techniques.<sup>2</sup> Because the United States

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### WHAT IS KNOWN

- The United States healthcare delivery system's recent focus on quality improvement efforts and cost containment has increased attention on reducing procedure complications and the overall length of stay associated with CABG.
- There have been extensive, nationwide efforts to monitor and improve the quality of cardiac surgery care in China.

### WHAT THE STUDY ADDS

- In 2011 to 2013, there was no significant difference in in-hospital mortality among patients who underwent an isolated CABG surgery in China and the United States.
- There is room for improvement in CABG-specific length of hospital stay in Chinese hospitals.
- Improvement is needed to reduce the difference in CABG care between large teaching hospitals and small, often nonteaching hospitals.

healthcare delivery system's recent focus on quality improvement efforts and cost containment has increased attention on reducing procedure complications and the overall length of stay (LOS) associated with CABG,<sup>3</sup> there have been extensive, nationwide efforts to monitor and improve the quality of cardiac surgery care in China.<sup>4</sup>

However, unlike the increasing application of CABG in China over the last decade, a substantial decrease in CABG surgery utilization rates was observed in the United States.<sup>5,6</sup> Until now, there have been no existing studies comparing cardiac surgical outcomes between these 2 countries, and it is unclear how the performance of centers in China benchmark against those in the United States. Databases including National Inpatient Sample (NIS) in the United States and the Chinese Cardiac Surgery Registry (CCSR) are nationwide multicenter and consecutive registries, which have become the cornerstone of clinical quality assessment and improvement.<sup>7,8</sup> Accordingly, a comparison of CABG outcomes between China and the United States can provide insight about the patients referred for operation and the results being produced in countries with different systems.

We used the CCSR data from China and the NIS data from the United States to compare outcomes among large teaching and urban hospitals between the 2 countries for patients aged  $\geq 18$  years who underwent an isolated CABG during the period of January 1, 2007, through December 31, 2013.

## Methods

### Study Sample

In 2004, CCSR was started as the first multicenter cardiac surgery registry in mainland China.<sup>8</sup> Until now, it has become the largest and the most representative database in cardiovascular surgery all over the country. The registry includes all patients who underwent CABG or valve surgery at each participating hospital. Participating hospitals received detailed information on data collection requirements and

definitions of variables. Training on data collection was provided to each hospital and was performed by trained clinical nurses or residents. A standardized case report form, containing demographic, preoperative risk factors, operative information, postoperative treatment course, and surgical outcomes, was required to be completed for each hospitalization by participating hospitals. This form was then submitted to the data processing center of the CCSR and entered into the database by 2 data specialists. Two reviewers from the data processing center abstracted a random sample of 5% to 10% of medical records per hospital through on-site auditing at 6-month intervals. The electronic values submitted by the hospitals were compared with the values in the medical records. When a disagreement occurred, a supervisor adjudicated the variable to determine the final value. The China-CABG data were drawn from the CCSR, which includes 102 hospitals for patients undergoing CABG from January 1, 2004, to December 31, 2013, with the exception of 2006 and 2009 in which no data were collected. Most of the participating hospitals are large teaching hospitals located in urban areas (annual cardiac surgical volume  $>100$ ).

The US-CABG data were drawn from the 2007 to 2013 NIS data developed as a part of the Healthcare Cost and Utilization Project and sponsored by the Agency for Healthcare Research and Quality. The NIS is the largest all-payer inpatient care database in the United States. Before 2012, the sampling method was to sample 20% of hospitals and then retain all discharges from each sampled hospital. This national sample represents 20% of annual hospitalizations or  $\approx 8$  million hospitalizations. In 2012, Agency for Healthcare Research and Quality changed the sampling method for NIS.<sup>8</sup> The new method samples 20% of all discharges from all hospitals. To align the 2007 to 2011 NIS data with 2012 and 2013 NIS data, we first randomly selected 20% discharges from the 2007 to 2011 NIS data and then randomly selected 20% of hospitals from the 2012 and 2013 NIS data and appended these 2 subsamples together.

For this study, we restricted data to patients aged  $\geq 18$  years who underwent an isolated CABG, including on-pump or off-pump procedures during January 1, 2007, to December 31, 2013 (except 2009). We defined the isolated CABG by the *International Classification of Diseases* 9th Revision Clinical Modification principal discharge procedure codes 36.10 to 36.17 and 36.19, excluding patients with nonisolated CABG procedure codes (Table I in the [Data Supplement](#)) during the index hospitalization.<sup>9</sup> To facilitate data presentation and analysis, we combined data in 2 measurement periods: 2007–2008, 2010; and 2011 to 2013. We appended the China-CABG data and US-CABG data as one data set and excluded hospitals that had CABG volume  $<25$  in any of these 2 periods.

### Patient Characteristics

Patient characteristics included age, sex, prior CABG or valve surgery, obesity, and prior or current cigarette smoking, and common comorbidities were abstracted from medical records in the China-CABG data, but were identified based on the *International Classification of Diseases* 9th Revision Clinical Modification codes in the US-CABG data. We targeted coexisting medical conditions that are not directly related to the principal diagnosis and are likely to have originated prior to the hospital stay.<sup>10</sup> Obesity was defined as a body mass index  $>27.5$  kg/m<sup>2</sup> in the China-CABG data.<sup>11,12</sup>

### Outcomes

Our primary outcomes included in-hospital mortality, defined as all-cause death during an index CABG hospitalization; total LOS, defined as the difference in dates between discharge and admission; preoperative LOS, defined as the difference in dates between operation and admission; and postoperative LOS, defined as the difference in dates between discharge and operation. If the date of operation was the same as the date of admission, preoperative LOS was counted as 0; if the date of discharge was the same as the date of operation, postoperative LOS was counted as 0. Our second outcome was postoperative 5-day mortality, defined as all-cause death during an index CABG hospitalization within 5 days from the operative date. Because

patients in the China-CABG group had longer LOS than those in the US-CABG group, this outcome allows us to assess in-hospital mortality between 2 groups with equal LOS.

### Statistical Analysis

We combined 2007, 2008, and 2010 as one period and 2011 to 2013 together as another period to compare the outcomes by 2 periods. Mortality was expressed as a percentage and preoperative LOS and postoperative LOS as median (interquartile range) days. All outcomes were compared between the China-CABG and the US-CABG groups. We used the Cochran–Armitage test to determine the statistical significance of the comparisons. We fitted 3 mixed models with a logit link function to assess the difference in in-hospital mortality between the 2 patients groups for each study period separately. Model 1 only included mortality as an outcome without adjusting for patient characteristics, model 2 adjusted for patient age and sex, and model 3 adjusted for patient age, sex, and comorbidities. Each model included a China–US indicator (1 for China and 0 for United States) and reported the odds ratio of this indicator. An odds ratio of >1.0 would represent that compared with the US-CABG group, the China-CABG group had higher in-hospital mortality. To assess differences in mortality between China and the United States by age group, we repeated all models for 2 age categories (18–64 years and ≥65 years) to be able to potentially compare with the US Medicare population.<sup>13</sup> To assess the trends in mortality over time between China and the United States, we fitted a mixed model with an ordinal time variable, corresponding to years 2007 (time=0) to 2013 (time=5), the China–US indicator, and an interaction term of the time and China-US indicator, adjusting for patient age, sex, and comorbidities. We also fitted a mixed model with the time variable, the China–US indicator, and the time and China–US interaction to compare the difference in LOS between the China-CABG and US-CABG groups over time, adjusted for patient characteristics. Because LOS was skewed, we applied a log transformation to normalize its distribution. The estimated coefficient of the China–US indicator represents the percentage change in LOS between China and United States. Because patients were clustered within hospitals, all models were fitted with hospital random intercepts to account for within-hospital and between-hospital variations.

To account for the potential imbalances in patient characteristics between the 2 groups, we conducted a second analysis using stabilized inverse probability weighting. Specifically, we weighted each patient by the patient's inverse propensity score of being in the US-CABG group. To obtain the propensity score, we fitted a logistic model with the US-CABG group as an outcome and all patient characteristics included in the above primary mixed models as covariates.<sup>14,15</sup>

To account for potential sampling variation between 2007 to 2011 (except 2009) and 2012 to 2013, because of changes in sampling approach in the NIS data described previously, we conducted a simulation analysis with a nonparametric bootstrap method. Specifically, for the China-CABG data, we randomly selected discharges for each year, with a sample size equal to that year's total discharges but with replacements; for the 2007 to 2011 (except 2009) US-CABG data, we randomly selected 20% of discharges with replacements; for the 2012 to 2013 US-CABG data, we first randomly selected 20% of hospitals with replacements and then obtained all CABG discharges for these hospitals. All selections were stratified by year. We then appended the 3 resampled data sets together and fitted the models to estimate the odds ratio of death for the China-CABG group, referring to the US-CABG group, for each study period and age group. We repeated this process 10 000 times to obtain the distributions of the odds ratios and their 95% confidential intervals. All statistical tests were performed using a 2-sided  $\alpha$  value of 0.05. Analyses were conducted using SAS, Version 9.3 64-bit (SAS Institute, Cary, NC). The Fuwai Hospital institutional review board approved the study and waived the requirement for informed consent. The Fuwai Hospital has a data use agreement with Agency for Healthcare Research and Quality to use the NIS data for this study.

## Results

### Study Sample

The final study sample included 380 hospitals, 77 in China and 303 in the United States. These hospitals included 51 408 patients, 32 040 (62.3%) from China and 19 368 (37.7%) from the United States. Compared with the US-CABG group, patients in China-CABG group were 3 years younger (mean [standard deviation], 61.3 [9.1] versus 64.6 [10.7];  $P<0.001$ ), less likely to be female (22.8% versus 25.8%;  $P<0.001$ ), had higher cigarette use (52.7% versus 19.8%;  $P<0.001$ ), and greater history of acute myocardial infarction or heart failure (34.8% versus 22.9%;  $P<0.001$ ). However, the US-CABG group included more patients with common preexisting conditions, such as hyperlipidemia, atrial fibrillation, diabetes mellitus, hypertension, peripheral vascular disease, and renal failure (Table 1). The mean (SD) annual hospital volumes were 416.1 (1694.4) and 317.8 (217.9) for hospitals in China and in the United States, respectively.

### In-Hospital Mortality

There was no statistically significant difference in the observed all-age in-hospital mortalities between the China-CABG and US-CABG groups for the full study period (1.5% versus 1.5%;  $P=0.880$ ) and the 2011 to 2013 period (1.2% versus 1.3%;  $P=0.458$ ). In the 2007, 2008, and 2010 period, compared with the United States, China did not have significantly higher mortality for all-age patients (1.9% versus 1.6%;  $P=0.06$ ) but did have significantly higher mortality for patients aged ≥65 years (3.1% versus 2.2%;  $P=0.005$ ; Figure 1 and Table 2). However, this difference disappeared in the 2011 to 2013 period (1.23% versus 1.33%,  $P=0.47$ ; 1.68% versus 1.65%,  $P=0.92$ ; Table 2). The mixed model indicated that there was a relationship between country, and mortality changed over time for those aged ≥65 years. The mixed models also show that for patients aged ≥65 years, the odds of death were 1.43 (95% confidential interval, 1.12–1.82), 1.79 (95% confidential interval, 1.38–2.33), and 1.73 (95% confidential interval, 1.24–2.40) times higher for the China-CABG group than for the US-CABG group in the 2007 to 2008, 2010 period from the unadjusted, age- and sex-adjusted, and age-, sex-, and comorbidities-adjusted models, respectively (Figure 2, top). These differences were no longer significant in the 2011 to 2013 period (Figure 2, bottom). The odds of death for the China-CABG group in the 2011 to 2013 period were not significantly different from the those for US-CABG group for all-age, aged 18 to 64 years, and aged ≥65 years (Figure 2, bottom; Table II in the [Data Supplement](#)).

The propensity score analysis, which the model had an area under the receiver operating characteristic of 0.813 and 0.865 for 2007 to 2008, 2010 and 2011 to 2013 periods, respectively, were consistent with the above findings (Figure I in the [Data Supplement](#)). The simulation analysis showed that the difference in sampling approach between 2007 to 2011 and 2012 to 2013 periods for the US-CABG data did not influence the findings substantially (Figure II in the [Data Supplement](#)).

For patients aged 18 to 64 years, there was no statistically significant difference in the observed in-hospital postoperative 5-day mortalities between the China-CABG and US-CABG

**Table 1. Patient Characteristics**

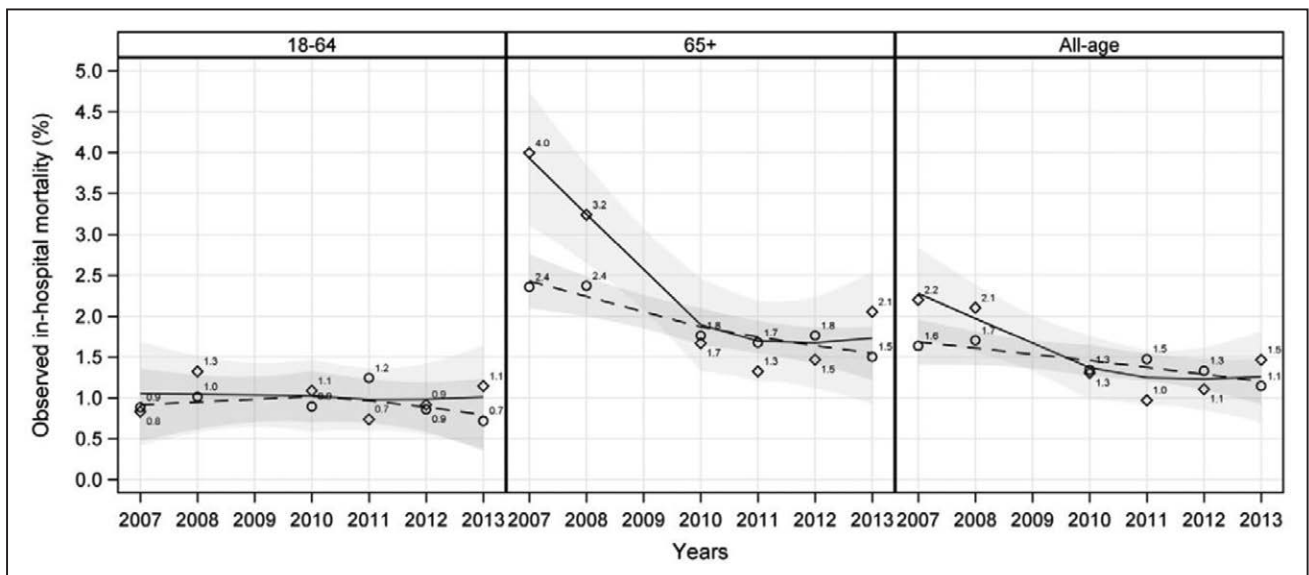
Characteristics	Overall		2007, 2008, and 2010		2011–2013	
	China (n=32 040)	United States (n=19 368)	China (n=12 078)	United States (n=10 501)	China (n=19 962)	United States (n=8867)
<b>Demographics</b>						
Mean age, y, (SD)	61.3 (9.1)	64.6 (10.7)	61.6 (9.2)	64.4 (10.8)	61.1 (8.9)	64.9 (10.4)
Female, n (%)	7296 (22.8)	4991 (26.0)	2632 (21.8)	2744 (26.1)	4664 (23.4)	2247 (25.3)
<b>Cardiovascular conditions and risk factors, n (%)</b>						
Hypertension	18 721 (58.4)	15 185 (78.4)	7808 (64.7)	7973 (75.9)	10 913 (54.7)	7212 (81.3)
Peripheral artery disease	1010 (3.2)	2741 (14.2)	227 (1.9)	1362 (13.0)	783 (3.9)	1379 (15.6)
Prior CABG	387 (1.2)	284 (1.5)	93 (0.8)	144 (1.4)	294 (1.5)	140 (1.6)
Obesity	6624 (20.7)	3996 (20.6)	2248 (18.6)	1837 (17.5)	4376 (21.9)	2159 (24.4)
Smoking	16 896 (52.7)	3843 (19.8)	6100 (50.5)	1985 (18.9)	10 796 (54.1)	1858 (21.0)
Diabetes mellitus	9479 (29.6)	8145 (42.1)	3770 (31.2)	4205 (40.0)	5709 (28.6)	3940 (44.4)
Prior MI or HF	11 139 (34.8)	4431 (22.9)	5078 (42.0)	2271 (21.6)	6061 (30.4)	2160 (24.4)
Renal failure	233 (0.7)	966 (5.0)	137 (1.1)	561 (5.3)	96 (0.5)	405 (4.6)
Hyperlipidemia	13 288 (41.5)	11 525 (59.5)	6958 (57.6)	5547 (52.8)	6330 (31.7)	5978 (67.4)
COPD	379 (1.2)	713 (3.7)	185 (1.5)	376 (3.6)	194 (1.0)	337 (3.8)

CABG indicates coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; HF, heart failure; MI, myocardial infarction; and SD, standard deviation.

groups in the 2007 to 2008, 2010 period (0.4% versus 0.7%;  $P=0.063$ ) and the 2011 to 2013 period (0.4% versus 0.6%;  $P=0.094$ ). For patients aged  $\geq 65$  years, no statistically significant difference in 5-day mortality was found between the China-CABG and US-CABG groups in the 2007 to 2008, 2010 period (1.0% versus 1.2%;  $P=0.357$ ). In the 2011 to 2013 period, compared with the United States, China had significantly lower mortality (0.7% versus 1.0%;  $P=0.032$ ). This tendency persisted after adjustment for patient age, sex, and comorbidities (Figure 3).

**LOS and Major Discharge Disposition**

Overall, patients in China had significantly longer LOS than those in the United States. For preoperative, postoperative, and total hospital stay, respectively, the median (interquartile range) LOS across the entire study period between China-CABG and US-CABG groups were 9 (8) versus 1 (3), 9 (6) versus 6 (3), and 20 (12) versus 7 (5) days (all  $P<0.001$ ). These differences did not change significantly between the 2007 to 2008, 2010 and 2011 to 2013 periods (Figure 4 and Table 2). When restricted to those patients who did not survive to



**Figure 1.** Changes in observed in-hospital mortality between China-CABG and US-CABG groups, 2007 to 2013, except 2009 (left, patients aged 18–64 years; middle, patients aged  $\geq 65$  years; and right, all ages). Diamond (China-CABG in-hospital mortality) and circle (US-CABG in-hospital mortality) denote observed values; Curves (solid, China and dash, United States) represent trend over time. The shaded area represents the 95% confidence interval. No data were collected in 2009. CABG indicates coronary artery bypass grafting.

**Table 2. Observed Outcomes**

Outcome	Overall			2007, 2008, and 2010			2011–2013		
	China	United States	P Value	China	United States	P Value	China	United States	P Value
All age	32040	19368		12078	10501		19962	8867	
In-hospital mortality, n (%)	476 (1.5)	284 (1.5)	0.880	231 (1.9)	166 (1.6)	0.0604	245 (1.2)	118 (1.3)	0.458
Preoperative length of stay	9 (8.0)	1 (3.0)	<0.001	9 (9.0)	1 (3.0)	<0.001	8 (7.0)	1 (3.0)	<0.001
Postoperative length of stay	9 (6.0)	6 (3.0)	<0.001	10 (7.0)	6 (3.0)	<0.001	9 (6.0)	6 (2.0)	<0.001
Total length of stay	20 (12.0)	7 (5.0)	<0.001	21 (13.0)	7 (4.0)	<0.001	19 (12)	8 (5.0)	<0.001
Age 18–64 y	19863	9299		7169	5145		12694	4154	
In-hospital mortality, n (%)	201 (1.0)	88 (1.0)	0.657	78 (1.1)	48 (0.9)	0.415	123 (1.0)	40 (1.0)	1.000
Preoperative length of stay	9 (8.0)	1 (3.0)	<0.001	9 (8.0)	1 (3.0)	<0.001	8 (8.0)	1 (3.0)	<0.001
Postoperative length of stay	9 (6.0)	5 (3.0)	<0.001	9 (6.0)	5 (3.0)	<0.001	9 (5.0)	5 (3.0)	<0.001
Total length of stay	19 (12.0)	7 (5.0)	<0.001	20 (12.0)	7 (5.0)	<0.001	18 (11.0)	7 (5.0)	<0.001
Age ≥65 y	12177	10069		4909	5356		7268	4713	
In-hospital mortality, n (%)	275 (2.3)	196 (2.0)	0.112	153 (3.1)	118 (2.2)	0.005	122 (1.7)	78 (1.7)	0.942
Preoperative length of stay	9 (8.0)	1 (3.0)	<0.001	10 (9.0)	1 (3.0)	<0.001	9 (8.0)	1 (3.0)	<0.001
Postoperative length of stay	10 (7.0)	6 (3.0)	<0.001	11 (7.0)	6 (3.0)	<0.001	10 (7.0)	6 (3.0)	<0.001
Total length of stay	21 (13.0)	8 (5.0)	<0.001	22 (14.0)	8 (5.0)	<0.001	20 (12.0)	8 (5.0)	<0.001

In-hospital mortality was reported as number of deaths and rate (%). Length of stay was reported as median (IQR) days. IQR indicates interquartile range.

discharge, Chinese patients also had significantly longer LOS than those in the United States. For preoperative, postoperative, and total hospital stay, respectively, the median (interquartile range) LOS among this subset of patients across the entire study period between the China-CABG and US-CABG groups were 10 (13) versus 1 (4), 8 (15) versus 5 (9), and 21 (22) versus 9 (4) days (all  $P < 0.001$ ). Again, these differences did not change significantly between the 2007 to 2008, 2010 and 2011 to 2013 periods (Figure III in the [Data Supplement](#)). All living patients in the China-CABG group were discharged to home. In contrast, in the recent period for the US-CABG group, 43.8% of patients were discharged to home for self-care, and most received postacute services, including on-site home care (36.7%) or postacute care at nursing homes (13.0%).

## Discussion

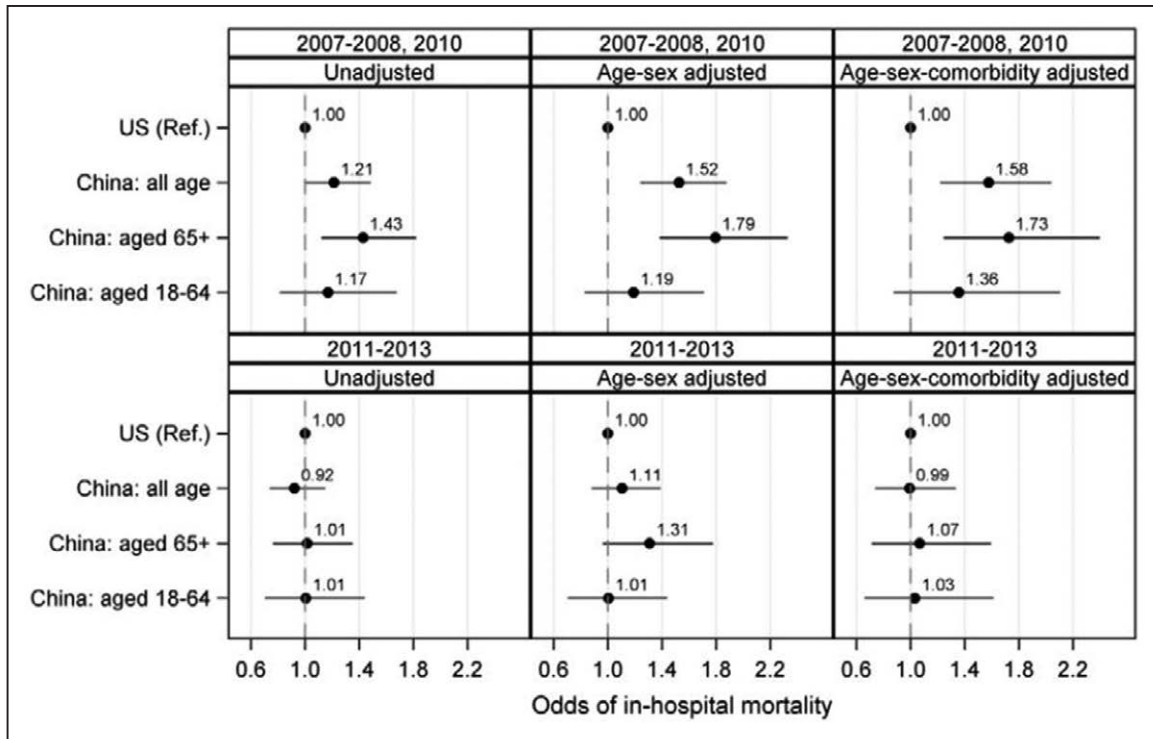
In this study, we found similarities and differences among people undergoing CABG in the United States and Chinese large teaching and urban hospitals. There were some differences in patient profiles, with patients in China being younger and patients in the United States having more common preexisting conditions. Overall, China had statistically significantly higher mortality than the United States for patients aged  $\geq 65$  years in 2007, 2008, and 2010, but this difference was not present in 2011 to 2013. In the 2011 to 2013 period, compared with the United States, China had significantly lower 5-day mortality after the CABG. We also found that CABG patients in China had significantly longer preoperative and postoperative LOS than patients in the United States.

Our findings are consistent with several potential explanations. First, the establishment of national database provides a comprehensive and scientifically rigorous approach for objective assessment of quality and performance measurement. The

CCSR, which was similar to the Society for Thoracic Surgeons in the United States, was established in 2004 to advance CABG-related outcomes in China.<sup>8</sup> The registry, which aims to evaluate surgical outcomes in patients undergoing cardiac surgery, has a committee comprising cardiac surgeons and researchers from universities and major teaching hospitals in China. In 2013, there were 734 hospitals in China offering cardiac surgery services, 209 of which have an annual volume of  $>200$  patients.<sup>16</sup> Studies using CCSR data have shown that mortality and major complications among cardiac surgery in China have decreased over the period that the registry was instituted.<sup>8,16</sup>

Second, China has made remarkable progress in improving population health over recent decades, including increasing healthcare insurance coverage to provide affordable basic healthcare services, improving infrastructure of hospitals and research facilities, strengthening the primary care system, financing public health, and reforming public hospitals.<sup>17–19</sup> These national efforts may directly or indirectly improve health outcomes, including CABG mortality.

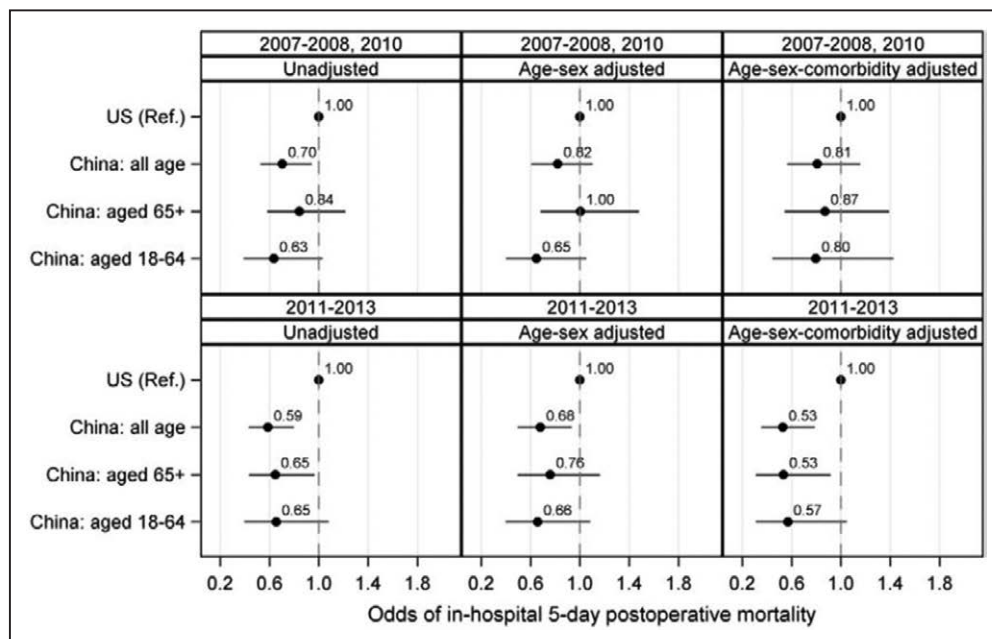
Third, quality of care and outcome measurements have become the key foci of recent healthcare improvements in China, with knowledge and standards being codified, shared, and used to guide practice.<sup>20</sup> International healthcare conferences and further education overseas provide opportunities for Chinese surgeons to learn novel cardiovascular disease-related treatments, as well as outcome research topics from experts worldwide.<sup>21</sup> Moreover, hospitals in China have much higher CABG volumes than hospitals in the United States. As a result Chinese surgeons may benefit more from the volume–outcome relationship in cardiac surgery than their peers in the United States.<sup>22,23</sup> Such efforts and circumstances could have contributed to the recent improvement in CABG mortality in China.



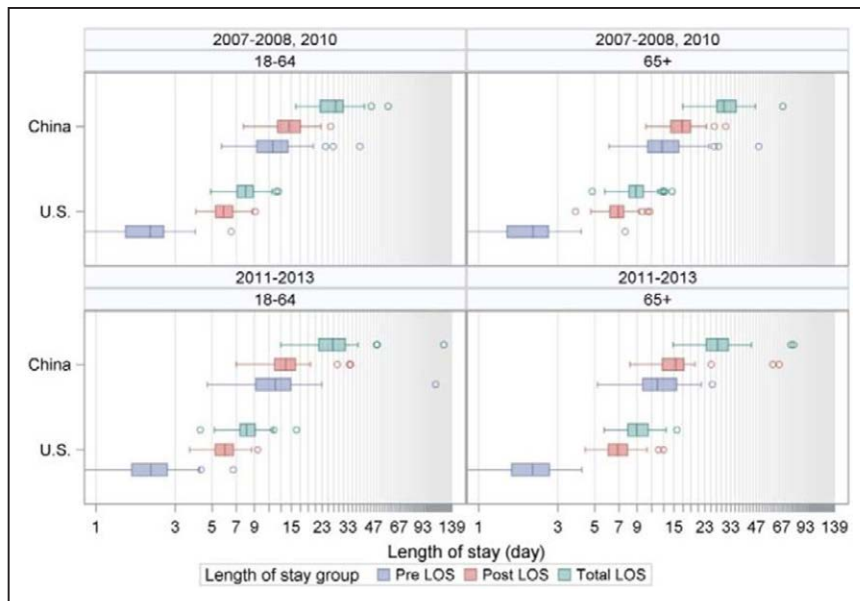
**Figure 2.** Frost plots of odds ratio of dying for patients in the China-CABG group versus patients in the US-CABG group. CABG indicates coronary artery bypass grafting.

Our study shows that there is room for improvement in CABG-specific length of hospital stay in Chinese hospitals. Currently, China has a CABG LOS that is an average of 13 days longer than that of the United States. Postacute care that aims to shorten LOS, including nursing homes, home health, rehabilitation, and long-term care, plays a key role in the entire episode of patient care in the United States.<sup>24-26</sup> In contrast, there are many fewer nursing homes per capita in

China compared with the United States. In 2013, only 4.3 million nursing home beds were available for nearly 125 million elderly, accommodating only 3.5% of China’s elderly population.<sup>27</sup> It may be that expanding this capacity in China can shorten LOS and improve outcomes—but it could also increase costs and time away from home. There will be a need to study best approaches to optimize postacute care and reduce time in the hospital, which would shorten patient’s hospital stay and



**Figure 3.** Frost plots of odds ratio of dying within 5 days after CABG for patients in the China-CABG group versus patients in the US-CABG group. CABG indicates coronary artery bypass grafting.



**Figure 4.** Distributions of total (Total LOS), preoperative (Pre LOS), and postoperative (Post LOS) length of stays for patients undergoing CABG by age groups and by China and United States. CABG indicates coronary artery bypass grafting; and LOS, length of stay.

improve the current Chinese healthcare system. Moreover, implementation of fast-track protocols and clinical pathways may also help enable earlier extubation and mobilization of patients, streamline care, and reduce postoperative hospital stays in China.<sup>28</sup> The outcomes of LOS might be affected by the effects of insurance coverage, including the insurance ownership, insurance type, and the reimbursement ratio. The insurance system in China is as complex as that in the United States, and it includes Medical Insurance for Urban Residents, Rural Cooperative Medical Systems, State-funded Public Medical System, and commercial health insurance. Considering the great variance in the health insurance type between China and the United States, we think more studies need to be conducted to gain deeper insights into the effects of insurance coverage on cardiac surgery outcomes in these 2 countries.

Another improvement needed is to reduce the difference in CABG care between large teaching hospitals and small, often nonteaching hospitals. Our findings were based on large teaching and urban hospitals that usually have more resources, but healthcare quality is advancing unevenly between urban and rural areas and among different regions in China.<sup>27</sup> The majority of health providers are underqualified, especially in rural areas.<sup>29,30</sup> Several measures have been taken to improve competencies for rural health professionals throughout the country, such as in-service training for Township Health Center health professionals, partnerships between urban hospitals and Township Health Centers, and job-transfer training for general practitioners.<sup>25</sup> Furthermore, a new health management information system and performance-based management of health staff may enhance oversight.<sup>30</sup>

Cardiothoracic surgical leadership in the United States challenged the surgical community to achieve an operative mortality rate of 1.0% for the performance of isolated CABG. A recent study indicates that achieving this goal would be feasible in only 60% of CABG patients, without making further improvements in processes of care.<sup>31</sup> However, the possibility of achieving this aspiration in China remains unknown because of the increasing number of high-risk patients being referred for CABG.

Our study has several limitations. First, that the sources from which patient comorbidities were obtained differed between China and the United States. Such difference between clinically abstracted and administrative information is an ongoing challenge. To address this challenge, we also provided age- and sex-adjusted results that showed there was no substantial difference in mortality in recent years between China and the United States. Second, limited by the NIS data, we were not able to compare the in-hospital major complication rate, an important outcome for patients who underwent a CABG surgery, between China and the United States. Nevertheless, Safaie et al<sup>32</sup> reported that based on a sample of 500 randomly selected patients aged  $\geq 70$  years who underwent a CABG surgery in the United States from 2004 to 2011, the post-CABG complication rates were 1.6%, 0.8%, 2.4%, 2.8%, and 2.4% for stroke, deep vein thrombosis, acute myocardial infarction, repeat surgery, and bleeding, respectively. By restricting our sample to the same period as the study of Safaie et al<sup>32</sup> for all patients aged  $\geq 70$  years from the CCSR data, the complication rates were found to be 0.69% for stroke, 0.74% for acute myocardial infarction, 3.60% for reoperation for bleeding, 0.51% for reintubation, and 3.92% for renal failure. Third, restricted by our data source, we were not able to use a fixed period of follow-up for mortality, such as 30-day mortality. Finally, we only included  $\approx 15\%$  of all hospitals rendering services in the field of cardiac surgery in China in the study. Because these hospitals are all large and urban hospitals and they are the elite hospitals in China, our findings are not representative of China's overall CABG care.

## Conclusions

However, there was no statistically significant difference in the in-hospital CABG mortality during the period of 2011 to 2013 between Chinese and American large teaching and urban hospitals. But there is significant room for improvement in reducing CABG-related LOS in China. A better postacute care system for its hospitalized patients, especially for patients who have undergone an isolated CABG surgery, is warranted.

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