Improved quality and cost-effectiveness of coronary artery bypass grafting in the United States from 1988 to 2005

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Objective: This study was undertaken to assess the impact of increasing patient complexity and health care cost on coronary artery bypass grafting quality and cost-effectiveness in the United States over an 18-year period.

Methods: A retrospective study was carried out utilizing the Nationwide Inpatient Sample to track the characteristics and outcomes of 5,549,700 patients having isolated coronary artery bypass grafting in the United States from 1988 to 2005. Expected mortality, risk-adjusted mortality, and hospital charges were tracked over this period.

Results: The prevalence of congestive heart failure, pulmonary disease, diabetes, and acute myocardial infarction increased significantly over the study period. Expected mortality increased from 2.57% to 3.66%, reflecting the increasing patient comorbidity burden ($P < .0001$). Despite this, coronary artery bypass grafting outcomes improved, leading to a decrease in risk-adjusted mortality from 6.20% to 2.12% ($P < .0001$). Furthermore, when hospital charges were corrected for medical care inflation, hospital charges declined significantly, from $26,210 in 1988 to $19,196 in 2005 (1988 dollars, $P < .0001$).

Conclusions: Coronary artery bypass grafting surgery is being performed on an increasingly complex, high-risk patient population in the United States. Despite this challenge, risk-adjusted operative mortality has progressively declined. Moreover, hospital charges for coronary artery bypass grafting in relation to other medical care services have been reduced. These findings reflect improved quality and cost-effectiveness of coronary artery bypass grafting in the United States. Ongoing efforts directed at quality improvement should address the risks associated with comorbidities that increasingly accompany the diagnosis of coronary artery disease in patients having coronary artery bypass grafting.

Coronary artery bypass grafting (CABG) has been routinely performed for the treatment of obstructive coronary artery disease (CAD) for the past 4 decades.[1-3] Over this period, the patient population having CABG has changed significantly due to advancements in medical therapy and percutaneous techniques. Furthermore, CABG surgery has become recognized as preferred treatment for patients in high-risk subgroups, including those with more extensive CAD and diabetes.[4-6] Although the patient population having CABG has become increasingly complex, cardiovascular surgery has become safer because of advances in surgical techniques and the related disciplines of anesthesia, perfusion, and critical care.[7-12] Changes in the patient population and advances in the perioperative care of patients having CABG have the potential to impact both the clinical and economic outcomes of CABG surgery.

This study was undertaken to assess the impact of these changes on CABG quality and cost-effectiveness in the United States over an 18-year period. A retrospective study was carried out utilizing the Nationwide Inpatient Sample (NIS), a project of the Agency for Healthcare Research and Quality. This database is the largest all-payer inpatient care database publicly available in the United States and allows analysis of national trends in health care utilization, outcomes, and charges. Given the current economic challenges faced by the health care system, studies of treatments that measure quality as well as cost-effectiveness will be important to assess the efficiency of health care delivery.

MATERIALS AND METHODS

Data were selected from the NIS combining the years 1988 to 2005. The NIS is a stratified randomized 20% sample of patient discharge abstracts from nonfederal hospitals.[13] In combining the multiple years of NIS data, the revised statistical weights for comparisons across time were used.

Cases were included in the analysis if they had a recorded CABG procedure, International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedure code 36.1 and all subcodes. Cases were excluded if they had an aortic, mitral, or tricuspid valve replacement (35.21 to 35.24, 35.27, 35.28), excision of aneurysm or other lesion (37.32, 37.33), partial ventriculectomy (37.35), heart revascularization (36.3 and all subcodes), heart transplant (37.5 and all subcodes), thoracic vessel resection (38.45), or endarterectomy of carotid artery or jugular vein (38.12). Patients having these procedures were excluded to yield an isolated CABG population.

The primary end points were in-hospital mortality and total charges. Total charges generally do not include professional fees and noncovered

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CAD = coronary artery disease
ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification
NIS = Nationwide Inpatient Sample

charges. Patient comorbidities were defined based on diagnosis codes present in the discharge abstract as described previously.[14]

Expected and risk-adjusted mortalities were determined from a logistic regression model of in-hospital mortality adjusting for age, sex, comorbidities (congestive heart failure, chronic pulmonary disease, diabetes [complicated or uncomplicated], peripheral vascular disorders, liver disease, renal failure, and cerebral vascular disease [defined as ICD-9-CM diagnosis codes 433 and all subcodes and 437.0]), preoperative conditions (primary diagnosis of myocardial infarction, cardiac catheterization on the same day as CABG, previous CABG [ICD-9-CM code V45.81], and admission status [elective versus nonelective]). Risk-adjustment variables were selected based on available variables that have previously been found to be associated with mortality in CABG and have been used in previous studies using administrative data.[15,16] From this model, a predicted mortality for every patient was determined. From these individual predicted mortalities, the expected mortality for each year was determined and the ratio of observed to expected mortality was multiplied by the overall mortality to give the expected mortality rate for each year.

Charge data were adjusted for inflation using the Consumer Price Index published by the US Department of Labor, Bureau of Labor Statistics. The specific series used were US city average all items (series CUUS0000SA0) and US city average medical care services (series CUUS0000SAM2). The medical care services series includes professional services, hospital and related services, and health insurance. Charge data were normalized to 1988 dollars.

This study was approved by the Institutional Review Board at Oregon Health & Science University. Individual consent was waived.

RESULTS

In total, 1,066,374 cases met the study criteria, representing a national estimate of 5,549,700 isolated CABG cases performed over the 18-year period. Patient demographics, comorbidities, the presence of myocardial infarction as a primary diagnosis, the use of cardiac catheterization on the same day as the CABG procedure, and the in-hospital mortality and total charges are presented in Table 1. The variations of these across time are also shown with the 18-year time period being broken down into 6 3-year groups.

The incidence of all comorbidities increased significantly over the study period. The magnitude of this increase was also notable, with most comorbid conditions at least doubling in frequency over the study period. The incidence of diabetes mellitus increased from 16.66% in the first 3-year group to 33.85% in the most recent 3-year group. The diagnosis of myocardial infarction also increased over the study period, suggesting higher acuity of patients having CABG over time. Previous CABG, in contrast, declined from 3.49% to 1.24% over this same time period. Despite the increases in comorbidities and higher acuity of patients having surgery, observed in-hospital mortality declined progressively from 4.81% to 2.34%.

As shown in Figure 1, expected mortality progressively increased over the 18-year interval from 2.57% to 3.66% (solid line, $P < .0001$). This reflects the increasing prevalence of patient comorbidities known to influence risk at the time of CABG.

Although expected mortality progressively increased over the study period, risk-adjusted mortality decreased over the same time course (Figure 1, dashed line). This change was more substantial than that seen in expected mortality, with reduction in risk-adjusted mortality from 6.20% in 1988 to 2.12% in 2005 ($P < .0001$). The improvement seen in risk-adjusted mortality occurred steadily over the study period, without dramatic step-offs. This improvement continued through the most recent years of the study period. From the year 2000 until 2005, adjusted mortality decreased from 2.32% to 2.12% ($P < .0001$).

Given the increase in patient comorbidities seen in the CABG patient population, there was interest to determine how this may have impacted the economic outcomes of CABG. Hospital charges for CABG admissions were tracked over the study period and are depicted in Figure 2. When corrected for all-item inflation, hospital charges associated with CABG increased from $26,410 in 1988 to $46,734 in 2005 (1988 dollars, solid line, $P < .0001$). Hospital charges were relatively stable over the years 1994 to 1999, but increased from $30,813 in 1999 to $46,734 in 2005.

The cost of health care delivery has generally increased more quickly than the rate of all-item inflation.[17-20] To correct for this accelerated rise in the cost of health care, hospital charges for CABG were adjusted for medical inflation (Figure 2, dashed line). When this was done, hospital charges associated with CABG decreased significantly over the study period, from $26,210 in 1988 to $19,196 in 2005 (1988 dollars, $P < .0001$). The decline in hospital charges adjusted for medical inflation occurred in the years 1988 to 1999. From the year 2000 to 2005, hospital charges actually rose, from $16,800 to $19,196 ($P < .0001$).

DISCUSSION

This study was undertaken to assess changes in the patient population having CABG in the United States from 1988 to 2005 and how these changes may have impacted clinical and economic outcomes of CABG. The prevalence of patient comorbidities known to impact operative mortality increased over the study period, leading to increased expected mortality. Despite this increase in patient complexity, risk-adjusted mortality decreased substantially. Moreover, hospital charges for CABG in relation to other medical care services have been reduced. These findings reflect improved quality and cost-effectiveness of CABG in the United States.

TABLE 1. Demographics, comorbidities, condition, and outcomes of patients having coronary artery bypass grafting (CABG) in the United States from 1988 to 2005

	All years	1988–1990	1991–1993	1994–1996	1997–1999	2000–2002	2003–2005
n (national estimate)	5,549,700	745,295	905,194	1,029,994	1,055,483	1,022,954	790,780
Demographics							
Age (y)*	65.2 (24.0)	64.6 (24.3)	65.2 (23.8)	65.4 (23.7)	65.6 (24.0)	65.3 (24.1)	65.2 (23.9)
Sex (%)							
Male	71.51	73.71	72.45	71.21	70.13	70.57	71.79
Female	28.49	26.29	27.55	28.79	29.87	29.43	28.21
Comorbidities (%)							
Congestive heart failure	0.68	0.13	0.49	0.76	0.70	0.96	0.93
Chronic pulmonary disease	15.27	8.66	11.60	14.46	16.53	18.60	20.78
Diabetes mellitus	26.30	16.66	20.07	25.11	28.77	31.65	33.85
Peripheral vascular disorders	7.70	4.46	5.11	7.48	8.53	9.34	10.73
Liver disease	0.32	0.10	0.14	0.23	0.30	0.47	0.67
Renal failure	2.83	1.22	1.96	2.30	2.77	3.65	5.05
Cerebral vascular disease	3.11	2.34	3.04	2.97	3.36	3.15	3.74
Preoperative condition (%)							
Primary diagnosis of myocardial infarction	19.24	10.64	16.47	19.78	21.14	22.15	23.54
Cardiac catheterization on the same day as CABG	29.12	18.47	30.28	39.53	33.16	23.64	25.93
Previous CABG	2.67	3.49	2.92	3.19	2.96	2.12	1.24
Nonelective admission	58.47	59.50	63.05	61.75	59.11	53.66	53.96
Outcomes							
Died during hospitalization (%)	3.32	4.64	3.83	3.32	3.08	2.78	2.48
Total charges (dollars)†	43732 (31179–64423)	30191 (22888–41604)	38802 (29539–53769)	39648 (29265–54728)	42244 (31463–58845)	51451 (37540–75553)	70827 (51651–105685)

*Mean (standard deviation); †median (interquartile range). All variables statistically significant at $P < .001$.

The decrease in mortality was progressive over the entire study period and is likely related to multiple incremental advances in surgery practice and the related fields of anesthesiology and critical care as opposed to singular advances. In addition to technical advances, the introduction of quality improvement programs have had a profound effect on cardiac surgery outcomes.[11,21-23] Cardiothoracic surgeons have been leaders in this area and continue to champion voluntary clinical databases for the purpose of both regional and national efforts in quality improvement.

The improvement in risk-adjusted mortality was achieved with decreased hospital charges for CABG after adjustment for medical inflation. The improved safety of CABG is likely to have led to some of this decrease in hospital charges, as avoidance of complications is associated with lower procedural cost.[24,25] In addition, numerous practice pathways were implemented into cardiovascular surgery practice during the study period, leading to improved efficiency and decreased cost.[26] An example of improved safety and efficiency is seen in the reduction in length of stay associated with CABG, which decreased from 11 to 8 days over the study period ($P < 0.0001$, data not shown). A concerning finding of our study is that the recent period from 2000 to 2005 saw increases in hospital charges after adjustment for medical inflation, possibly reflecting the higher cost of care for an increasingly complex patient population.

This study utilized the NIS to track trends in CABG practice in the United States. Advantages of this database include its national scope, the relatively long period for which data

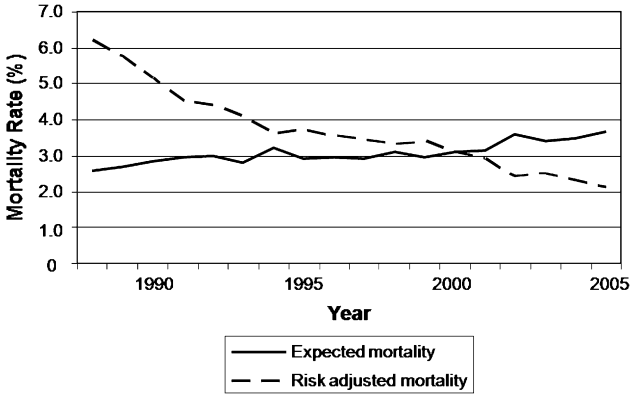

FIGURE 1. Expected and risk adjusted mortality of coronary artery bypass grafting *(CABG)* in the United States from 1988 to 2005.

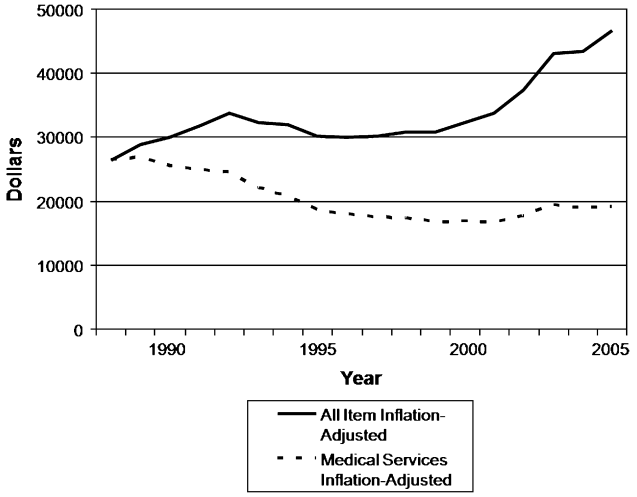

FIGURE 2. Hospital charges for coronary artery bypass grafting *(CABG)* in the United States from 1988 to 2005. Expressed in 1988 dollars.

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are available, and the availability of charge information on all patients, regardless of payer. The NIS is not a clinical database, and its data fields were not designed to risk model CABG outcomes. Inpatient stay data are derived from information typically available from discharge abstracts. The NIS is therefore subject to coding errors and changes in reporting patterns that may have occurred over time.

To test the accuracy for prediction of the logistic risk model, a c-index was calculated and found to be 0.71, which was reassuring.[15] This value, which is a traditional approach to assess model performance, fell in the same range as that reported for risk models using clinical databases, including the Society of Thoracic Surgeons National Adult Cardiac Surgery Database.

Another weakness of the study was that although the charge data are useful to track trends in CABG resource utilization, they do not provide an assessment of the cost–utility relationship associated with CABG, as charge data lack an estimate of CABG benefit such as quality-adjusted life-years. Furthermore, hospital charges only reflect part of the total cost of CABG to the health care system and do not account for the total cost of recovery, including inpatient rehabilitation.

Despite these limitations, this study does demonstrate the increasing complexity of the patient population having CABG in the United States. The continuous pursuit of increased safety and efficiency in cardiovascular surgery has led to improved clinical outcomes and greater cost-effectiveness. Ongoing efforts directed at quality improvement should address the risks associated with the comorbidities that increasingly accompany the diagnosis of coronary artery disease in our patients. Cost containment will continue to be a challenge as the CABG population continues to become more complex.

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