Outcomes and Cost of Coronary Artery Bypass Graft Surgery in the United States and Canada

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Background: We sought to determine whether there is a difference in in-hospital outcomes and costs for coronary artery bypass graft surgery (CABG) between the United States and Canada.

Methods: We compared the outcomes and costs of treating 12 017 consecutive patients (4698 US and 7319 Canadian patients) undergoing CABG at 5 US and 4 Canadian hospitals. Participating hospitals used the same cost accounting system to provide patient-level clinical, resource utilization, and cost-of-treatment data (excluding physicians' fees). Canadian costs were converted to US dollars using purchasing power parities.

Results: Compared with Canadian patients, US patients were older (mean±SD age, 68.0±10.4 vs 63.7±9.8 years [$P<.001$]), more likely to be female (27.4% vs 21.8% [$P<.001$]), and discharged from the hospital sooner (mean±SD length of stay, 8.7±0.1 vs 9.5±0.1 days [$P<.001$]). In-hospital costs of treatment were substantially higher in the United States than in Canada (mean±SD cost, $20 673±$241 vs $10 373±$123 [$P<.001$]; median, $16 036 vs $7880). After controlling for demographic and clinical differences, length of stay in Canada was 16.8% longer than in the United States; there was no difference in in-hospital mortality; and the cost in the United States was 82.5% higher than in Canada ($P<.001$).

Conclusions: The in-hospital cost of CABG in the United States is substantially higher than in Canada. This difference is due to higher direct and overhead costs in US hospitals, is not explained by demographic or clinical differences, and does not lead to superior clinical outcomes.

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CARDIOVASCULAR DISEASE IS a leading cause of morbidity and mortality in the United States and Canada and is responsible for more than a third of all deaths in North America.[1] Cardiovascular disease also places a large economic burden of illness on North American society.[1,2] In the United States, cardiovascular disease had an estimated direct cost of $209.3 billion in 2003, including $94.1 billion in in-hospital costs alone.[1] Coronary artery disease, which is responsible for more than half of all cardiovascular disease–related deaths, accounted for more than $60 billion in direct costs in 2003.[1,3,4] Coronary artery bypass graft surgery (CABG) is well established as a leading revascularization procedure in the treatment of coronary artery disease. In 2000, more than 500 000 CABGs were performed in the United States.[1] Despite our substantial knowledge of practice variations (per capita rates of CABG in the United States are at least 3-fold those in Canada), little is known about differences in costs for this procedure between the 2 countries.[5] We therefore examined whether there is a difference in in-hospital costs of CABG between US and Canadian hospitals, and we examined the demographic and clinical drivers of cost in both countries.

METHODS

PATIENT POPULATION

Data were obtained for 12 262 consecutive CABGs from 5 US and 4 Canadian hospitals. Inclusion criteria were defined by procedure codes in the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*).[6] Patients with *ICD-9-CM* codes indicating bypass anastomosis for heart revascularization (36.10-36.19) were identified through the Transition cost accounting system databases (Eclipsys Solutions Corporation, Boca Raton, Fla; hereafter referred to as

the Transition system) of participating hospitals. Patients who also underwent valvular procedures (*ICD-9-CM* codes 35.0-35.3) were excluded at the level of the collaborating centers to generate a homogeneous study population. Additional exclusion criteria included age younger than 21 years and transfer in or out of the hospital before discharge. Of the 12 262 patients whose data were provided by participating hospitals, 118 underwent concurrent procedures such as abdominal aortic aneurysm repair or carotid endarterectomy and were excluded. In addition, 120 patients were discharged alive within 3 days of admission, and 7 patients had total treatment costs of less than $1000. These patients were excluded because they were deemed unlikely to have undergone CABG. Data were therefore analyzed for 12 017 patients who underwent CABG (7319 Canadian and 4698 US patients).

DATA COLLECTION

All data were extracted from the Transition cost accounting system.[7] In this system, detailed patient-level data are extracted from various sources, including the general ledger, medical records, and patient billing departments, and integrated into a single database. Data include demographic and clinical information, resource utilization, and in-hospital costs of treatment for each hospital visit. Demographic and clinical data, extracted from the hospital medical records, include information from the patient's discharge summary such as length of hospital stay (LOS), primary and secondary clinical diagnoses, and principal and secondary procedures. Diagnoses and procedures are defined by *ICD-9-CM* codes.

COSTING METHODS

The methods used by the Transition accounting system to determine cost have been described previously.[8] Briefly, the Transition system uses a 6-step method to assign total unit costs to products and services.[7,9] In the first step of this costing procedure, hospital departments are classified as direct cost centers or overhead cost centers. Direct cost centers are hospital departments that provide direct patient care and may be related to the actual labor of individual employees within the department (eg, salaries and fringe benefits of nurses and technicians) or to materials costs that become part of the patient care process (eg, pharmaceutical products and laboratory tests). Overhead cost centers are departments whose costs are indirectly related to patient care (eg, administration, security, and housekeeping).

In the second step, procedures and services within patient care departments are grouped into discrete intermediate products. These department-specific intermediate products may represent a product or a service or a combination of both. Examples of intermediate products include gauze used in the operating room or physical therapy.

In the third step, each intermediate product's direct costs are estimated. These costs include direct labor and materials costs and are classified as fixed or variable costs, depending on their responsiveness to fluctuations in volume. The sum of a product's fixed and variable costs represents the product's total direct cost. An intermediate product's direct costs are estimated using a weighted procedure method, which assigns to each product a number of relative value units (RVUs). These RVUs are an expression of the relative direct costs of a specific intermediate product relative to other intermediate products within the same department. Once all intermediate products within a given department have been assigned RVUs, the fixed and variable costs of a single RVU can be calculated and an intermediate product's direct cost can be estimated.

In the fourth step, a method for allocating overhead costs to direct cost centers must be determined for each type of overhead cost. For example, square footage is often used as a method to allocate housekeeping costs.

In the fifth step, overhead costs are allocated to direct cost centers using an allocation algorithm. For example, a common overhead cost allocation algorithm is the step-down method, which is a 1-way method. In this method, overhead cost centers are "closed" by allocating their costs to direct cost centers. Once the overhead cost center has been closed, no other cost center can assign costs to it, reducing the number of centers in the allocation procedure. This is repeated until all overhead cost centers are closed.

In the final step of the costing method, the overhead costs, now allocated to direct cost centers, are assigned to department-specific intermediate products using the RVUs previously assigned to each intermediate product. The user is then able to determine the total cost of each intermediate product by summing the product's direct (fixed and variable) and overhead costs.

We examined resource utilization and treatment costs at 3 levels of detail in this study. First, we extracted summary cost data, including total direct, total overhead, and total treatment costs for each patient. The total treatment cost is the sum of direct and overhead costs. Second, we extracted department-level costs, which we grouped into the following 5 categories: laboratory, nursing, pharmacy, surgery, and other miscellaneous departments. Finally, we examined the cost of specific intermediate products (ie, specific products and services) in both countries. One participating US hospital (U5) and 1 Canadian hospital (C3) did not provide intermediate product costs and were excluded from this analysis. Purchasing power parities for 1997 through 2001 were used to convert Canadian dollar costs to US dollar costs.[10] Purchasing power parities from 1997 to 2001 were 1.18, 1.19, 1.19, 1.21, and 1.20, respectively.

STATISTICAL ANALYSES

The statistical analyses consisted of 2 phases. In the descriptive phase, we compared US and Canadian patients. We first examined demographic and clinical characteristics (ie, age, sex, and comorbidities) and admission type. Admission types were defined as elective or nonelective (ie, urgent or emergent) surgery. However, 1 participating US hospital (U4) and 1 Canadian hospital (C1) were unable to provide these data and were excluded from the admission type analysis. We then examined hospital course and in-hospital outcomes, including mortality, procedure use, discharge type, LOS, and costs. Two participating Canadian (C1 and C2) and 1 US hospital (U2) were unable to provide complete procedure use data and were excluded from the procedure analyses. Discharge types were categorized as home care or self-care, or institutional care. Two participating Canadian hospitals (C2 and C4) were unable to provide these data and were thus excluded from discharge type analysis. In addition, to eliminate potential cost differences due to different waiting times and workup costs in the United States and Canada, we also examined post-CABG LOS and patients who underwent CABG on their admission date. Continuous data are presented as the mean ± SD, except for LOS and cost, which are presented as the mean ± SEM. Dichotomous data are presented as percentages. Continuous variables were examined using *t* tests, and dichotomous variables were examined using χ^2 tests. All statistical tests were 2-tailed, and $P \leq .05$ was considered to be statistically significant.

In the analytic phase, we used multivariable linear regression modeling to examine the independent effect of country of treatment on LOS and in-hospital costs. Because of the skewed distributions of LOS and in-hospital costs and the presence of

Table 1. Baseline Clinical Characteristics of 12 017 Patients Who Underwent CABG in Canada and the United States*

Characteristic	Country		*P* Value
	Canada	United States	
No. (%) of patients	7319 (60.9)	4698 (39.1)	<.001
Age, mean ± SD, y	63.7 ± 9.8	68.0 ± 10.4	<.001
Male	78.2	72.6	<.001
Hypertension	44.1	50.2	<.001
Diabetes mellitus	25.5	27.1	.05
Prior myocardial infarction	19.9	14.1	<.001
Lipid metabolism disorder	42.7	31.4	<.001
Preoperative congestive heart failure	7.2	13.9	<.001
Cerebrovascular disease	5.4	6.0	.21
COPD	2.8	9.0	<.001
Previous CABG†	3.8	7.8	<.001
Previous PCI†	0.6	1.3	<.001

Abbreviations: CABG, coronary artery bypass graft surgery; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention.
*Unless otherwise indicated, data are expressed as percentage of patients.
†Two Canadian hospitals (C1 and C4) were unable to provide data regarding previous procedures and were excluded from these analyses.

Table 2. In-Hospital Course of 12 017 Patients Who Underwent CABG in Canada and the United States

Variable	Country		*P* Value
	Canada	United States	
No. (%) of patients	7319 (60.9)	4698 (39.1)	<.001
Admission type, %*			
Nonelective	54.1	61.9	<.001
Elective	45.9	35.1	
Unknown	0	3.0	
LOS, d			
Mean ± SEM	9.5 ± 0.1	8.7 ± 0.1	<.001
Median	7.0	7.0	
IQR	6.0-10.0	6.0-9.0	
Postoperative LOS, d			
Mean ± SEM	7.5 ± 0.1	7.0 ± 0.1	<.001
Median	6.0	5.0	
IQR	5.0-8.0	4.0-7.0	
Procedures, %†			
Angiogram	13.0	56.3	<.001
PCI	4.1	3.0	<.001
Pacemaker or balloon pump	6.5	15.2	<.001
Dialysis	0.6	2.1	<.001
Discharge type, %‡			
Home care or self-care	79.5	85.5	<.001
Institutional care	15.4	12.3	
Unknown	5.0	2.2	
Nonfatal cardiac complications, %	19.6	11.6	<.001
Death, %	1.4	2.2	.004

Abbreviations: CABG, coronary artery bypass graft surgery; IQR, interquartile range; LOS, length of stay; PCI, percutaneous coronary intervention.
*One Canadian (C1) and 1 US hospital (U4) were unable to provide data regarding admission type and were excluded from admission type analysis.
†Two Canadian (C1 and C2) and 1 US hospital (U2) were unable to provide complete procedure data and were excluded from the procedure analysis.
‡Two Canadian hospitals (C2 and C4) were unable to provide data regarding discharge type and were excluded from the discharge type analysis.

heteroscedasticity (unequal variance of residuals), the dependent variables for the multivariable analyses were $\log_e$(LOS) and $\log_e$(cost), respectively.[11] An independent variable's exponentiated coefficient in these models therefore represents the multiplicative effect of that independent variable on the outcome variable. Multiple logistic regression was used to examine differences in in-hospital mortality in the 2 countries. Potential confounders were selected for inclusion in the regression model using backward selection for both linear and logistic regression. We also examined potential effect modification between country of treatment and sex and between country and age (as a categorical variable).

RESULTS

PARTICIPATING HOSPITALS

Transition system data were extracted at 5 US and 4 Canadian hospitals for patients who underwent CABG. We examined data for a total of 12 017 consecutive patients (4698 US and 7319 Canadian patients). All participating hospitals used the Transition cost accounting information system. All hospitals offered tertiary care facilities, and all but 1 had a capacity of more than 500 beds. All Canadian hospitals were public teaching hospitals. Most of the US hospitals were public teaching hospitals, with the exception of 2 private institutions and 1 nonprofit corporation.

PATIENT CHARACTERISTICS

The demographic and clinical characteristics of the 12 017 patients are summarized in **Table 1**. A number of baseline demographic and clinical differences existed between the US and Canadian cohorts. Compared with Canadian patients, US patients were older (mean age, 68.0±10.4 vs 63.7±9.8 years [*P*<.001]) and were more likely to be female (27.4% vs 21.8% [*P*<.001]). The US patients also were more likely to have hypertension (50.2% vs 44.1% [*P*<.001]), diabetes mellitus (27.1% vs 25.5% [*P*=.05]), preoperative congestive heart failure (13.9% vs 7.2% [*P*<.001]), and chronic obstructive pulmonary disease (9.0% vs 2.8% [*P*<.001]). Compared with Canadian patients, US patients were also more likely to have had previous cardiac procedures (previous CABG, 7.8% vs 3.8% [*P*<.001]; previous percutaneous coronary intervention, 1.3% vs 0.6% [*P*<.001]). The US patients were also more likely to undergo a nonelective procedure than were Canadian patients (61.9% vs 54.1% [*P*<.001]) (**Table 2**).

HOSPITAL COURSE AND OUTCOMES

Significant differences in hospital course were evident for patients in the 2 countries (Table 2). Compared with Canadian patients, US patients underwent more procedures. In particular, use of angiograms (56.3% vs 13.0% [*P*<.001]), pacemakers or intra-aortic balloon pumps (15.2% vs 6.5% [*P*<.001]), and dialysis (2.1% vs 0.6% [*P*<.001]) were significantly higher among US patients. Compared with Canadian patients, US patients under-

Table 3. Independent Predictors of LOS of Patients Undergoing CABG in Canada and the United States*

Variable	Increase in LOS (95% CI), %	*P* Value
Canada	16.8 (14.5 to 19.2)	<.001
Stroke	36.6 (30.8 to 42.7)	<.001
Preoperative CHF	36.5 (32.0 to 41.2)	<.001
Age >85 y	35.2 (19.8 to 52.6)	<.001
Age 75-84 y	27.0 (23.6 to 30.6)	<.001
Nonelective surgery	24.6 (22.3 to 27.0)	<.001
COPD	14.2 (9.0 to 19.6)	<.001
Age 65-74 y	13.4 (11.1 to 15.8)	<.001
Female	8.9 (6.6 to 11.4)	<.001
Diabetes mellitus	6.0 (3.8 to 8.2)	<.001
Year	–1.8 (–2.8 to –0.7)	.001
Previous MI	–2.2 (–4.6 to 0.1)	.06
Hypertension	–5.3 (–7.1 to –3.5)	<.001
Lipid metabolism disorders	–6.6 (–8.5 to –4.7)	<.001

Abbreviations: CABG, coronary artery bypass graft surgery; CHF, congestive heart failure; COPD, chronic obstructive pulomary disease; LOS, length of stay; MI, myocardial infarction.
*One Canadian (C1) and 1 US hospital (U4) did not provide data regarding admission type and were excluded from this analysis.

Table 4. Independent Predictors of Mortality of Patients Undergoing CABG*

Variable	OR (95% CI)	*P* Value
United States	0.92 (0.62-1.35)	.65
Age 75-84 y	3.19 (1.95-5.22)	<.001
Stroke	3.07 (1.84-5.10)	<.001
Age ≥85 y	3.06 (0.68-13.81)	.14
Preoperative CHF	2.99 (1.99-4.51)	<.001
Female	2.00 (1.38-2.91)	<.001
Nonelective surgery	1.93 (1.26-2.97)	.003
Age 65-74 y	1.77 (1.10-2.84)	.02
Year	1.45 (1.16-1.82)	.001
Hypertension	0.66 (0.44-0.97)	.03
Lipid metabolism disorders	0.45 (0.28-0.73)	.001

Abbreviations: CABG, coronary artery bypass graft surgery; CHF, congestive heart failure; CI, confidence interval; OR, odds ratio.
*One Canadian (C1) and 1 US hospital (U4) did not provide data regarding admission type and were excluded from this analysis.

Table 5. In-Hospital Costs of 12 017 Patients Who Underwent CABG in Canada and the United States

Variable	Country		*P* Value
	Canada	United States	
No. (%) of patients	7319 (60.9)	4698 (39.1)	
Total cost, $			
Mean ± SEM	10 373 ± 123	20 673 ± 241	<.001
Median	7880	16 036	
IQR	6488-10 557	13 122-21 409	
Direct cost, $			
Mean ± SEM	7087 ± 87	12 776 ± 149	<.001
Median	5300	10 071	
IQR	4368-7196	7980-13 522	
Overhead cost, $			
Mean ± SEM	3286 ± 37	7896 ± 97	<.001
Median	2580	6188	
IQR	2089-3409	4747-8323	

Abbreviations: CABG, coronary artery bypass graft surgery; IQR, interquartile range.
*All costs are expressed in US dollars.

went fewer percutaneous coronary interventions (3.0 vs 4.1 [$P<.001$]). Canadian patients had significantly longer LOS than US patients (mean LOS, 9.5±0.1 vs 8.7±0.1 days [$P<.001$]). Canadian patients also had a significantly longer postsurgical LOS (7.5±0.1 vs 7.0±0.1 days [$P<.001$]). After controlling for demographic and clinical differences, the Canadian patients' LOS was 16.8% longer than that of US patients ($P<.001$; adjusted $R^2=0.19$) (**Table 3**). Canadian patients also had lower rates of unadjusted in-hospital mortality (1.4% vs 2.2% [$P=.004$]) (Table 2). However, after controlling for demographic and clinical differences, there was no significant difference in mortality between countries (**Table 4**). Compared with Canadian patients, US patients were more likely to be discharged to home care or self-care than to institutional care (85.5% vs 79.5% [$P<.001$]) (Table 2).

IN-HOSPITAL COSTS

The costs of treatment of patients undergoing CABG in the United States and Canada differed substantially (**Table 5**). Unadjusted mean in-hospital cost in the United States ($20 672 ± $241) was approximately 2-fold the mean cost in Canada ($10 373 ± $123). Median treatment costs were also substantially different ($16 036 vs $7880). After controlling for age, sex, and baseline clinical differences, multivariate analysis confirmed a strong association between country and total treatment cost (**Table 6**). Compared with treatment in Canada, treatment in the United States was associated with an 82.5% higher total cost ($P<.001$; adjusted $R^2=0.39$). When a composite end point of nonfatal cardiac complications and mortality was included in a second model, treatment cost in the United States was 87.7% higher than in Canada ($P<.001$; adjusted $R^2=0.41$). Finally, after adjusting for demographic and clinical characteristics and in-hospital procedures (angiogram, percutaneous coronary intervention, dialysis, and pacemaker or balloon pump), treatment in the United States was associated with a 74.8% increase in cost compared with treatment in Canada ($P<.001$; adjusted $R^2=0.53$).

Substantially more US patients had their preoperative workup, including coronary angiogram, during the CABG admission. To ensure that the cost differences between Canada and the United States were not the result of Canadian waiting lists, the in-hospital costs of patients who underwent CABG on their admission date were also examined. Among these patients, mean in-hospital costs among US patients (n=1321) were still significantly higher than those among Canadian patients (n=1517) ($19 156 ± $424 vs $8059 ± $158 [$P<.001$]).

When total costs were broken down into direct and overhead cost components, US costs were higher for both components (Table 5). A greater proportion of total cost was ascribed to overhead cost components in the United

Table 6. Independent Predictors of Cost Among Patients Undergoing CABG in Canada and the United States*

Variable	Increase in Cost (95% CI), %	*P* Value
Model 1†		
United States	82.5 (78.8 to 86.3)	<.001
Preoperative CHF	44.0 (39.2 to 48.9)	<.001
Stroke	31.2 (25.6 to 37.0)	<.001
Age ≥85 y	19.6 (6.0 to 34.9)	.003
Age 75-84 y	16.6 (13.4 to 19.8)	<.001
Nonelective Surgery	16.0 (13.8 to 18.1)	<.001
COPD	11.5 (6.4 to 16.8)	<.001
Age 65-74 y	8.9 (6.7 to 11.2)	<.001
Female	6.5 (4.2 to 8.9)	<.001
Diabetes mellitus	6.3 (4.1 to 8.6)	<.001
Year	4.0 (2.8 to 5.1)	<.001
Previous MI	−3.2 (−5.5 to −0.9)	.06
Hypertension	−4.7 (−6.5 to −2.8)	<.001
Lipid metabolism disorders	−4.7 (−6.5 to −2.8)	<.001
Model 2‡		
United States	87.7 (83.9 to 91.6)	<.001
Preoperative CHF	40.3 (35.7 to 45.0)	<.001
Stroke	29.1 (23.7 to 34.8)	<.001
Cardiac complications or death	25.0 (22.0 to 28.2)	<.001
Age >85 y	18.3 (5.1 to 33.3)	.005
Nonelective surgery	14.9 (12.8 to 17.0)	<.001
Age 65-74 y	14.1 (11.1 to 17.3)	<.001
Age 75-84 y	14.1 (11.1 to 17.3)	<.001
COPD	11.2 (6.2 to 16.4)	<.001
Diabetes mellitus	6.6 (4.5 to 8.9)	<.001
Female	6.5 (4.3 to 8.9)	<.001
Year	3.4 (2.3 to 4.6)	<.001
Previous MI	−2.7 (−5.0 to −0.4)	.02
Lipid metabolism disorders	−4.3 (−6.1 to −2.4)	<.001
Hypertension	−4.4 (−6.2 to −2.6)	<.001
Model 3§‖		
United States	74.8 (69.9 to 79.7)	<.001
Dialysis	90.7 (71.9 to 111.4)	<.001
Balloon pump or pacemaker	54.4 (48.8 to 60.2)	<.001
Angiogram	42.5 (38.7 to 46.5)	<.001
Preoperative CHF	28.4 (23.8 to 33.2)	<.001
Stroke	25.9 (20.3 to 31.7)	<.001
Age 75-84 y	17.5 (14.1 to 21.0)	<.001
COPD	14.1 (8.4 to 20.1)	<.001
Age >85 y	12.0 (−1.4 to 27.2)	.07
Age 65-74 y	9.1 (6.8 to 11.4)	<.001
PCI	7.6 (2.4 to 13.1)	.003
Female	5.3 (3.0 to 7.8)	<.001
Diabetes mellitus	5.2 (2.9 to 7.5)	<.001
Year	3.4 (2.2 to 4.6)	<.001
Nonelective surgery	3.2 (1.1 to 5.3)	.003
Hypertension	−4.8 (−6.7 to −2.9)	<.001
Lipid metabolism disorders	−7.0 (−8.8 to −5.1)	<.001

Abbreviations: CABG, coronary artery bypass graft surgery; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; PCI, percutaneous coronary intervention.

*One Canadian (C1) and 1 US hospital (U4) did not provide data regarding admission type and were excluded from these models.

†Predictors include country of treatment and baseline demographic and clinical characteristics.

‡Predictors include country of treatment, baseline demographic and clinical characteristics, and postoperative complications.

§Predictors include country of treatment, baseline demographic and clinical characteristics, and in-hospital procedure use.

‖Two Canadian (C1 and C2) and 1 US hospital (U2) were unable to provide complete procedure data and were excluded from this model.

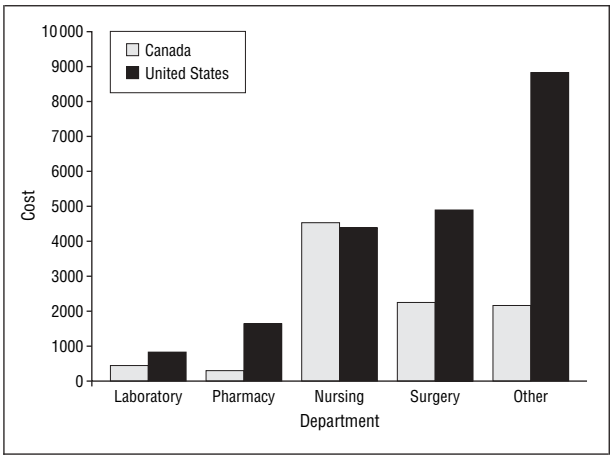

Figure 1. Mean department-level costs of 12 017 patients undergoing coronary artery bypass graft surgery (CABG) in Canada and the United States. All costs are expressed in US dollars. Other departments include ambulatory care, anesthesiology, blood bank, cardiology, central processing, chaplaincy, diabetic clinic, dialysis, dietary services, emergency, endocrinology, eye clinic, fiberoptics, gastrointestinal services, intensive care unit, intravenous resources, mammography, medical supplies unit, mental health services, neurology, occupational therapy, oncology, physical therapy, radiation oncology, radiology, recovery, rehabilitation, respiratory therapy, and speech therapy.

States compared with Canada (38.2% vs 31.7%), whereas the United States had lower direct cost components (61.8% vs 68.3%). Overall, the $10 300 mean difference in total treatment costs between Canadian and US hospitals was almost equally attributable to differences in direct and overhead costs (55.2% and 44.8%, respectively).

In addition to breaking down total cost into direct and overhead cost components, total cost was also analyzed by department (**Figure 1**). Compared with Canadian hospitals, US hospitals had substantially higher mean costs in surgery ($4905 ± $58 vs $2274 ± $31 [*P*<.001]), pharmacy ($1653 ± $41 vs $308 ± $15 [*P*<.001]), laboratory ($826 ± $13 vs $458 ± $12 [*P*<.001]), and other miscellaneous ($8838 ± $153 vs $2176 ± $104 [*P*<.001]) departments. Despite a significantly shorter LOS among US patients, there was no significant difference in nursing costs. However, in Canada, nursing accounted for approximately 44% of the total treatment costs, while only 21% of total cost in the United States was attributed to nursing. This finding was at least partially due to the longer LOS in Canada.

The costs of specific intermediate products in Canada and the United States were also examined (**Table 7**). Compared with intermediate products in Canadian hospitals, most intermediate products in the United States were associated with higher costs. The costs of diagnostic tests, laboratory tests, and medications were all higher at US hospitals. The cost of 1 hour of operating room time and the daily cost of a bed on a surgical ward (predominantly nursing costs) were also higher in the United States. The daily cost of a bed in an intensive care unit (also predominantly nursing costs) was similar in the 2 countries.

In both countries, urgency of surgery was a strong determinant of in-hospital cost (**Figure 2**). In the United States, patients undergoing nonelective CABG had unadjusted mean costs that were 31% higher than those of patients undergoing elective procedures ($21 643 ± $367

vs $16 566 ± $400 [$P<.001$]). In Canada, nonelective surgery was associated with a 16.4% increase in mean in-hospital costs ($11 183 ± $196 vs $9606 ± $172 [$P<.001$]). After adjusting for demographic and clinical differences, patients who underwent nonelective CABG had 16% higher costs in both countries.

COMMENT

The purpose of this study was to examine in-hospital outcomes and the differences in and determinants of costs of CABG in the United States and Canada. We found important differences in in-hospital LOS between US and Canadian hospitals. After controlling for patient-level differences, treatment in Canada was associated with a 17% longer LOS. We also found important differences in in-hospital costs between US and Canadian hospitals. Median total in-hospital costs were $16 036 in the United States and $7880 in Canada, representing a 2-fold difference. Mean costs were $20 673 ± $241 and $10 373 ± $123, respectively. After controlling for patient baseline differences and clinical outcomes, treatment in the United States was associated with an 82.5% increase in total cost. Differences in direct costs of treatment accounted for 55.2% of the difference in total costs, whereas differences in indirect costs accounted for 44.8% of the difference in total costs.

Our results suggest that higher costs in the United States are not only due to higher overhead costs but to higher direct costs as well. Costs in the United States were higher for all departments except nursing, where despite a significantly shorter LOS in the United States, costs were similar to Canadian nursing costs. The similar nursing cost indicates that the salary of US nurses is higher that of Canadian nurses. Our examination of the costs of specific intermediate products revealed higher costs in the United States for products and services. Increased US treatment costs are also partially explained by increased resource utilization compared with treatment at Canadian hospitals. For example, after adjusting for differences in procedure use, the increase in cost associated with treatment in the United States was reduced from 82% to 75%. Although some of the remaining difference may be partially explained by residual confounding due to other procedures and other resource utilization, our results indicate that the increase in cost is due to higher costs of products and services and increased procedure use. The potential to reduce costs therefore exists, especially given the similar in-hospital outcomes between the 2 countries.

Canadian hospitals may also benefit by examining treatment practices at US centers. In particular, if Canadian hospitals were able to lower their LOS to US levels while maintaining the same standard of care, Canadian hospitals would be able to further reduce their costs. Canadian patients had substantially lower costs despite having longer LOS and fewer patients undergoing CABG during an acute coronary syndrome admission in which there are substantial costs associated with the preoperative workup. Most of the increase in LOS among patients undergoing CABG in Canada is due to preoperative LOS. Reducing the preoperative LOS among Canadian patients undergoing CABG has the potential to further lower in-hospital costs in Canada.

Table 7. Median Costs of Specific Intermediate Products at Canadian and US Hospitals*

Product	Country, Mean Cost, $†	
	Canada	United States
Diagnostic test		
Blood gas	7.22	21.61
CBC profile	4.89	8.47
Chest x-ray (2 views)	25.45	46.93
CT of head	47.12	70.60
Left heart catheterization	306.86	511.70
Medication costs		
Amlodipine, 5 mg	1.56	3.17
Aspirin, 325 mg	0.97	1.56
Ciprofloxacin, 250 mg	2.58	8.29
Digoxin, 0.25 mg	2.65	2.18
Warfarin, 5 mg	0.75	1.69
Service costs		
Intensive care unit bed (1 d)	1123.95	1121.81
Operating room time (1 h)	313.76	397.05
Surgical bed (1 d)	360.10	561.53

Abbreviations: CBC, complete blood cell count; CT, computed tomography.
*One US hospital (U5) and 1 Canadian hospital (C3) did not provide intermediate product costs and were excluded from this analysis.
†All costs are expressed in US dollars.

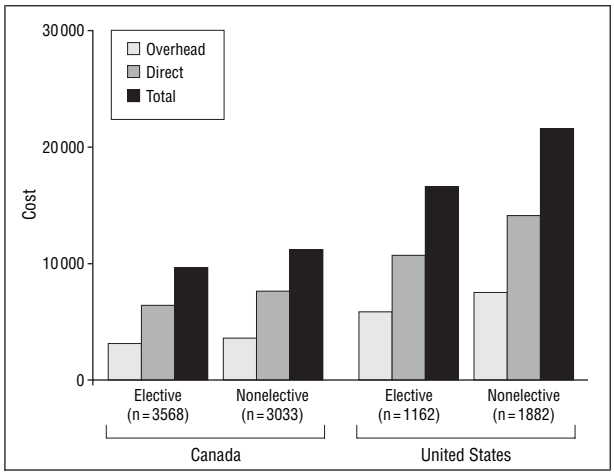

Figure 2. Mean overhead, direct, and total in-hospital costs of 9645 patients undergoing coronary artery bypass graft surgery in Canada and the United States by admission type. All costs are expressed in US dollars. One center in Canada and 1 in the United States did not provide data regarding admission type and were excluded from this figure.

PREVIOUS STUDIES

A substantial body of literature has compared health care costs between Canada and the United States. Most of this literature has focused on national expenditures, particularly administrative costs.[12-14] For example, Woolhandler et al[12,13] have produced a number of reports examining administrative costs in Canada and the United States. They found that, in 1999, per capita health care administration costs were $1059 in the United States, compared with $307

in Canada. These health care administration costs have important implications for in-hospital costs. In our study examining the in-hospital cost of patients undergoing CABG, approximately 45% of the increase in cost in the United States was due to higher overhead costs. This increase is largely due to higher administrative costs, which is consistent with the current findings in the literature.

To date, few studies[8,15] have compared the costs of treatment of different diagnoses and procedures in Canada and the United States. To our knowledge, no previous studies have compared the costs of CABG in Canada and the United States. However, a number of studies[16-21] have investigated the cost of CABG in the United States. The US National Center of Health Statistics has estimated treatment costs to be approximately $25 000, including physician fees.[16] In other studies, Cowper et al[17] reported a mean cost (excluding physician fees) of $15 713, whereas Magovern et al[18] reported mean ± SD estimated hospital costs of $15 600 ± $3100. In a study by Weintraub et al,[19] the mean in-hospital cost was $25 057 among randomized patients who underwent CABG and $29 120 among registry patients who underwent CABG. In a study examining the impact of complications on cost, Mauldin et al[20] reported an overall mean cost of $19 094. In a retrospective database review, Kurki et al[21] found a mean total hospital cost of $28 408 (median, $21 644). Most recently, Reynolds et al[22] reported a mean cost of $20 574 (2000 US dollars). The average per-patient cost for CABG in our study was $20 673 ± $241 in the United States, excluding physician fees, which is similar to findings in earlier studies.

Recently, much attention has been focused on the disparity in the cost of medications in Canada and the United States.[23-25] Although much of the evidence to date is anecdotal, a small number of studies have examined these costs. For example, the Patented Medicine Prices Review Board, which determines the price for drugs that are under patent in Canada, reported that patented prescription drugs were approximately 67% more expensive in the United States when compared with Canadian prices.[23] Our study found that medication costs were substantially higher in the United States than in Canada, with the differential in cost reaching as high as 321% for ciprofloxacin (250 mg). This is a difference in in-hospital cost; an examination of hospital charge would reveal a greater difference between Canadian and US medications.

The incidence of post-CABG mortality in our patient cohort was 1.7%, which corresponds well with that of previous studies.[26-28] Ghali et al[26] reported a death rate of 3.6% among Canadian patients whereas, in another study, Ferguson et al[27] reported an in-hospital mortality rate ranging from approximately 3.0% to 3.8%. Although our mortality rate varies with that of the 5.6% reported by Rosen et al,[28] this discrepancy may result from differences in patient characteristics and severity of illness.

LIMITATIONS

Several potential limitations of our study should be noted. First, physician fees were not included in our study because they are not captured by the Transition system. However, physician fees for CABG are significantly higher in the United States than in Canada, and including these data in our analysis would only contribute to increasing the divergence in cost between the 2 countries.[29]

Second, our cost analyses captured only in-hospital costs until the time of discharge. Postdischarge resource utilization, readmissions, and follow-up costs after discharge were not captured. However, previous studies have demonstrated that the cost of the initial hospitalization represents approximately 85% of the overall costs within 8 years of undergoing CABG.[17]

Third, in cases where a patient was admitted for an acute coronary syndrome and was discharged pending CABG, the initial cost of diagnosis and treatment would not have been included in the in-hospital cost we examined. Costs for diagnostic and therapeutic procedures and admission to coronary care or intensive care units constitute significant costs. Canadian patients are more likely than US patients to have been discharged to await outpatient CABG. Although this could lead to an underestimation of the cost of CABG in Canada, when we examined patients who underwent CABG on the same day as admission, we consistently found that the US patients had substantially higher costs than Canadian patients.

Finally, although data from the Transition system are reliable and national guidelines for cost accounting exist in the US and Canada, it is important to recognize that differences in costing practices still exist between hospitals. These differences are generally found in the following 2 areas: (1) the selection and costing of intermediate products and (2) the allocation of direct and overhead costs. Although these differences may influence direct costs vs overhead costs, department-level costs, or costs of specific intermediate products, they are not likely to affect the total in-hospital costs, the primary outcome of our study.

CONCLUSIONS

Coronary artery bypass graft surgery requires substantial resources in Canada and the United States. However, patients undergoing CABG at US hospitals incur approximately twice as much cost compared with those at Canadian hospitals, with little difference in clinical outcome and despite shorter average LOS. The difference in total in-hospital costs is almost equally attributable to differences in direct and overhead costs between the Canadian and US hospitals. This cost differential primarily reflects higher resource prices for products and labor and higher overhead costs in the United States resulting from a nonsocialized medical system. However, US hospitals also appear to streamline services better to reduce LOS, a strategy Canadian hospitals might emulate to further reduce treatment costs.

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