

In-Hospital Cost of Abdominal Aortic Aneurysm Repair in Canada and the United States

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Background: Global health care costs in Canada and the United States have been examined on a macroeconomic level. However, to our knowledge, comparative costs of specific procedures in the 2 countries have not been closely studied.

Methods: To perform a microeconomic comparison of costs of open abdominal aortic aneurysm (AAA) repair, we examined the costs of treating 1057 consecutive patients from 4 Canadian (n=552) and 6 US (n=505) hospitals. Participating hospitals used the same cost accounting system that provided demographic, clinical, and cost data (excluding physician's fees) for each patient. Canadian dollar costs were converted to US dollar costs using purchasing power parities.

Results: Compared with patients who underwent AAA repair in the United States, Canadian patients were signifi-

cantly younger (mean±SD, 70.2±10.5 vs 73.3±8.5 years; $P<.001$) and were less likely to undergo elective repair (48.5% vs 73.3%; $P<.001$). The median length of hospital stay was longer in Canada (9.0 vs 7.0 days; $P<.001$), and mortality rates were similar (12.0% [Canada] vs 9.9% [United States]; $P=.29$). The mean±SEM cost of AAA repair was \$15 852±\$790 in Canada compared with \$23 299±\$1410 in the United States.

Conclusions: The cost of AAA repair is substantially higher in the United States compared with Canada, despite shorter lengths of stay and similar clinical outcomes. The difference in total treatment costs between Canadian and American hospitals was partially attributable to differences in direct costs, but was largely due to differences in overhead costs.

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CANADA AND the United States have adopted different approaches to funding health care. The Canadian system is a socialized medical system and is budgeted in a top-down fashion regulated by the government. The American health care system consists of a mix of privately and publicly financed health insurance. As technological innovations increase the complexity of medicine and demand greater efficiency in health care, the benefits and drawbacks of the 2 systems have come under close scrutiny.¹⁻⁶ Global health care costs in Canada and the United States have been examined on a macroeconomic level. However, to our knowledge, comparative costs of specific procedures in the 2 countries have not been closely studied on a microeconomic level.

Abdominal aortic aneurysms (AAA) are responsible for substantial morbidity and mortality in Canada and the United States and place a large burden on both

health care systems. In Canadian hospitals, AAA is cited as a primary diagnosis in approximately 5000 discharges annually; in American hospitals, AAA is cited in over 50000 discharges annually.⁷ However, these figures represent only a small fraction of the more than 1 million North Americans currently diagnosed with AAA.⁸ Surgical repair of AAA is not only common, it is also expensive. Each procedure in the United States costs an estimated \$25 000; however, this estimate was obtained from charges rather than true cost.⁹ Although length of stay was found to be a major cost driver of AAA repair at one US hospital,¹⁰ in-hospital cost has yet to be evaluated for large numbers of patients. In addition, little is known about the cost of AAA repair in Canada. Given both the scarcity of cost analyses for AAA repair and popular interest in health care cost-effectiveness, we chose to examine AAA repair as a paradigm to compare treatment patterns and costs for a single procedure in Canadian and American hospitals.

PATIENT POPULATION

Data were collected for 1077 consecutive patients (552 patients from 4 Canadian hospitals and 505 patients from 6 American hospitals) who underwent open AAA repair between March 1, 1997, and December 30, 2000. Inclusion criteria were based on procedure codes in the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*. Patients with ICD-9-CM codes 38.34 (resection of vessel by anastomosis, aorta) or 38.44 (resection of vessel with replacement, aorta) were identified using the Transition (Eclipsis, Boca Raton, Fla) cost accounting system databases of participating hospitals. Patients were excluded if they were transferred into or out of the hospital because total costs could not be captured. We further excluded 18 patients who were younger than 21 years. In addition, 2 patients were excluded whose total cost was less than \$1000 (US dollars) because these patients were deemed not likely to have actually undergone AAA repair. Thus, our study cohort comprised 1057 patients undergoing AAA repair.

DATA COLLECTION

All data were extracted from the Transition system at each of the 10 hospitals. The Transition system is a comprehensive database including demographic, clinical, resource utilization, and cost of treatment data for each patient admitted into a hospital.¹¹ Hospitals using the Transition system software integrate detailed patient-level data from various hospital sources into a single database. Demographic and clinical data are extracted from the hospital medical records system. These data include information from the patient's discharge summary such as length of hospital stay, primary and secondary clinical diagnoses (ICD-9-CM codes), and principal and secondary procedures (ICD-9-CM codes). A patient discharged to "home care" receives home nursing, while a patient discharged to "self-care" does not. Resource utilization data are extracted from the specific hospital departments providing services to patients (eg, operating room, pharmacy, and laboratory). Unit costs are then associated with individual products and services used in the treatment of a patient, and the aggregate of these costs represents the patient's total cost of treatment within the hospital.

TRANSITION SYSTEM COSTING METHOD

The Transition system uses a 6-step method to estimate total unit costs of products and services used in in-hospital patient care. In the first step, hospital departments are classified as direct cost centers or overhead cost centers. The system's methodology views hospital departments as direct or overhead cost centers as each department incurs costs that are directly (eg, radiology and operating room) or indirectly (eg, administration and housekeeping) related to the provision of medical services.

In the second step, procedures and services provided in patient care departments are selected and grouped into discrete intermediate products. Intermediate products are department specific and may represent either a product or a service or a combination of products and services used in patient care. Examples of intermediate products include the drugs provided by the pharmacy or nursing care in the intensive care unit.

In the third step, the relative direct costs of each department's intermediate products are estimated. Direct costs include direct labor and direct materials costs. Direct labor and materials costs may be classified as fixed or variable costs depending on their responsiveness to fluctuations in volume.

To estimate an intermediate product's direct costs, the weighted procedure method is used. Using this method, each intermediate product is assigned a number of relative value units, which are an expression of the relative direct costs of one intermediate product to another within a given patient care department.¹² Once relative value units have been assigned to all intermediate products within a department, the fixed and variable direct costs of a single relative value unit can be calculated.

In the fourth step, application rates are identified to allocate overhead costs to direct cost centers. For each type of overhead cost, or cost pool, a base for allocation must first be determined. The total costs of a hospital's housekeeping services, for instance, are typically allocated based on square footage.

In the fifth step, an allocation algorithm is used to allocate overhead costs to direct and overhead cost centers. A common method for allocating overhead costs is the step-down method. In essence, the step-down method is a 1-way or 1-direction allocation method. Once the costs of an overhead cost center have been allocated, it is deemed "closed" (ie, no other cost center can assign costs to it), and there remains one fewer center in the analysis.¹²

In the sixth and final step, the overhead costs that were allocated to patient care departments are assigned to intermediate products within each department. This is done using the relative value units previously assigned to each intermediate product. Once overhead costs have been assigned to individual intermediate products, the user is able to estimate the total unit costs of intermediate products by adding the product's direct costs (fixed and variable) and overhead costs.

We examined direct cost, overhead cost, and total treatment cost for each patient. Canadian dollar costs were converted to US dollar costs using the purchasing power parities for 1997 through 2000.¹³ Year-averaged purchasing power parities from 1997 to 2000 were 1.19, 1.16, 1.17, and 1.18, respectively. Costs for Canadian patients from 2001 were converted using the purchasing power parities from 2000.

STATISTICAL ANALYSIS

To compare the baseline demographic and clinical characteristics of Canadian and US patients, continuous variables were examined using *t* tests, and dichotomous variables were examined using χ^2 tests. Multivariate regression analyses were performed to assess the impact of independent predictors of cost. The Mallows C_p statistic was used in selecting variables for the regression model.¹⁴ Other variable selection procedures such as backward selection and stepwise selection were also used for comparison. Because of the skewed distribution of hospital costs, log_e cost was used as the dependent variable for the regression analysis of in-hospital cost.¹⁵ As a result, the exponential of a regression coefficient is used to determine the percent increase in costs with respect to the corresponding variable. Logistic regression analyses were performed to assess the impact of independent predictors of in-hospital mortality. All statistical tests were 2-tailed, and $P < .05$ was considered statistically significant.

RESULTS

BASELINE CHARACTERISTICS AND HOSPITAL COURSE

There were several demographic and clinical differences between patients who underwent AAA repair in Canada ($n=552$) and the United States ($n=505$) (**Table 1**). Age (mean \pm SD) was lower in Canada (70.2 ± 10.5 vs 73.3 ± 8.5 years; $P < .001$), and Canadians were twice as likely as

Table 1. Demographic and Clinical Characteristics of Canadian and US Patients Undergoing AAA Repair*

Characteristic	Canada (n = 552)	United States (n = 505)	P Value
Age, mean ± SD, y	70.2 ± 10.5	73.3 ± 8.5	<.001
Male sex	79.2	76.6	.32
Diabetes mellitus	7.8	8.5	.74
Prior myocardial infarction	13.9	8.4	.01
Hypertension	46.9	47.0	.12
Admission type†			
Nonelective	50.9	24.0	<.001
Elective	48.3	73.3	<.001
LOS, median (IQR), d	9.0 (5.0-13.0)	7.0 (4.5-9.5)	<.001
Discharge type‡			
Self-care	90.3	66.3	<.001
Home care	0.5	16.0	<.001
Institutional care	8.0	16.8	<.001
Other	1.1	0.9	.50

Abbreviations: AAA, abdominal aortic aneurysm; IQR, intraquartile range; LOS, length of stay.

*Data are percentage of patients unless otherwise indicated.

†One center in Canada and one in the United States did not provide data regarding admission type and were excluded.

‡Two centers in Canada did not provide data regarding discharge type and were excluded.

Americans to undergo nonelective AAA repair. There was no significant difference in sex between the 2 cohorts, and the prevalence of diabetes and hypertension were similar. Canadian patients had a higher prevalence of prior myocardial infarction, and they also had a longer median length of hospital stay (9.0 [intraquartile range, 5.0-13.0] days vs 7.0 [intraquartile range, 4.5-9.5] days). More than 90% of Canadians were discharged to self-care vs less than two thirds of US patients.

Elective mortality rates were similar in Canada and the United States (5.2% vs 5.5%, respectively). However, nonelective mortality rates were lower in Canada (16.9% vs 26.0%). Overall mortality rates following AAA repair were not significantly different in Canada and the United States (12.0% vs 9.9%; $P = .29$). Rates of nonfatal cardiac complications were also not significantly different (5.6% vs 4.7%, respectively; $P = .58$). After controlling for age and urgency of surgery, there was no significant difference in mortality rates between Canada and the United States. When baseline clinical characteristics were added to the model (only histories of diabetes mellitus [$P = .004$] and hypertension [$P = .001$] were significant), there was still no difference in mortality rates between Canada and the United States (treatment in United States: odds ratio, 0.95; $P = .82$).

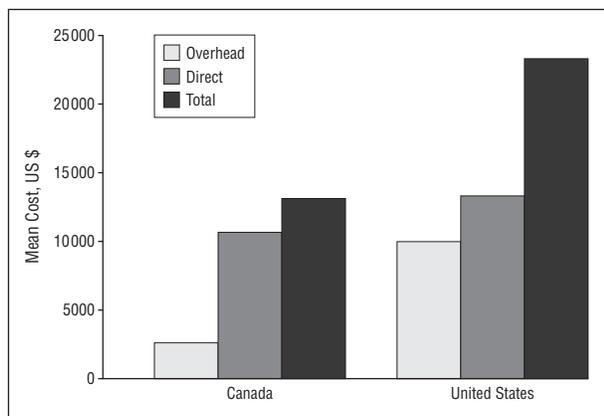


Figure 1. Mean overhead, direct, and total costs of abdominal aortic aneurysm repair in Canada and the United States.

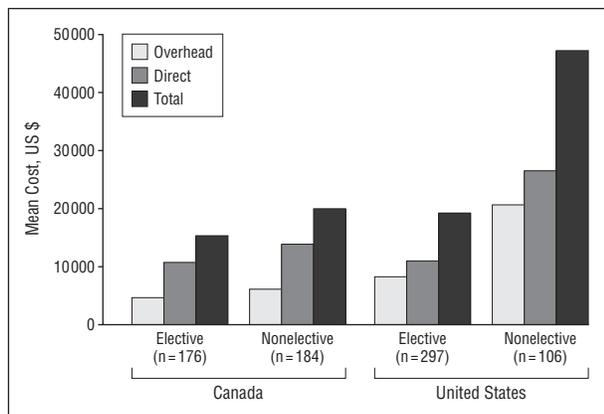


Figure 2. Mean overhead, direct, and total costs of abdominal aortic aneurysm repair in Canada and the United States by admission type. One center in Canada and one in the United States did not provide data regarding admission type and were excluded from this figure.

IN-HOSPITAL COSTS

Costs of open AAA repair in Canada and the United States differed markedly. Unadjusted in-hospital cost (mean ± SEM) per patient in Canada (\$15852 ± \$790) was 68% of the cost per patient in the United States (\$23299 ± \$1410) (**Figure 1**). Median treatment costs were also substantially different (\$9415 vs \$13276, respectively).

Canadian costs were lower than American costs for both direct and overhead cost components (\$6939 vs \$8186 for median direct costs; \$1708 vs \$5246 for median overhead costs). A greater percentage of total mean cost was ascribed to direct cost components in Canada compared with the United States (71.5% vs 57.2%). In contrast, overhead cost components made up a greater proportion of US total cost (42.8% vs 28.6%). Overall, the \$7447 mean difference in total treatment costs between Canadian and American hospitals was partially attributable to differences in direct costs, but was largely due to differences in overhead costs.

In both countries, costs associated with nonelective surgery (ie, urgent or emergent surgery) were higher than costs for elective surgery (**Figure 2**). Urgency of surgery played a much larger role in determining cost in the United States than in Canada. In the United States, 24% of patients underwent nonelective surgery. These patients accounted for 51% of all costs. In Canada, 51% of patients underwent nonelective surgery. However, these patients accounted for only 57% of all costs. For both elective and nonelective surgery, costs for American patients were persistently greater than those for Canadian patients. After controlling for baseline patient differences and clinical outcomes, multivariate regression analysis demonstrated a persistent and strong association between country and total cost of treatment (**Table 2**). Cost

of treatment in the United States was 55% higher than in Canada ($P < .001$).

COMMENT

Our study was designed to compare in-hospital costs among patients undergoing open AAA repair in Canada and the United States. We found that in-hospital costs were substantially higher in the United States despite shorter lengths of stay and similar clinical outcomes. This differential reflects higher direct and overhead costs in the United States. However, although treatment costs are lower in Canada, Canadian hospitals may be less efficient at streamlining services, resulting in significantly longer hospital stays. These results suggest that Canada and the United States may each benefit by looking to the other for cost-reducing strategies.

Few studies have previously examined between-country cost differences for specific procedures. These types of studies are of critical importance because they not only help policymakers to better evaluate hospital resource allocation and treatment patterns, but they also have broad implications for the debate over public vs private funding for health care. The recent introduction of cost accounting systems into a number of Canadian hospitals provides a unique data source for cost analyses of specific hospital procedures such as AAA repair. Because cost accounting systems are used widely in American hospitals, between-hospital and between-country cost comparisons can now be performed.

Excluding physician's fees, the difference in mean treatment costs for AAA repair in Canada and the United States was over \$7000. Notwithstanding this large difference in cost between the 2 countries, overall postoperative mortality rates were comparable between the 2 countries. Both direct and overhead costs contributed to the cost differential to varying degrees: direct costs were 1.3 times greater in American compared with Canadian hospitals, while overhead costs were 4.1 times greater. Thus, higher costs in the United States are related to both higher costs for the same resources as well as increased overhead costs associated with the multipayer system.

An explanation for the elevated direct costs may simply be higher prices of supplies and labor in the United States. The strikingly higher overhead costs of AAA repair at American hospitals most likely reflects increased administrative expenses associated with a multipayer insurance system. Complying with the requirements of many insurers, determining patient eligibility, and direct patient billing all contribute to high accounting costs.¹ Universal insurance, on the other hand, simplifies the administrative structure and reduces hospital overhead costs. It has been reported that Canadians spend less per capita to administer universal comprehensive coverage than Americans spend to administer Medicare and Medicaid alone.¹

Nonelective AAA repair was more costly than elective repair in both Canada and the United States. Interestingly, total costs in Canada were lower than in the United States despite the substantially higher rates of nonelective surgery. The greater prevalence of nonelective AAA repairs in Canada may be due to the longer waiting lists in Canada, which may lead to more patients being

Table 2. Determinants of Total In-Hospital Cost for Patients Undergoing AAA Repair in Canada and the United States

Characteristic*	Increase in Cost, %†	P Value
United States	55	<.001
Nonfatal cardiac complication or death	40	<.001
Nonelective surgery	36	<.001
Age ≥ 75 y	19	.001
Female sex	16	.03

Abbreviation: AAA, abdominal aortic aneurysm.

*The Mallows C_p statistic was used in selecting variables for the model.¹⁴

†The logarithmic transformation was applied to the total cost.¹⁵

admitted for urgent or emergent procedures. It may also be the result of elective Canadian patients with aneurysms 5 cm or greater in diameter being coded as urgent by their physicians and admitted through the emergency department to bypass waiting lists. The observation that nonelective mortality rates were significantly lower for Canadian patients compared with American patients could reflect this possibility. However, this discrepancy may also be an artifact due to a small sample size, variation in the coding of admission types (ie, emergent status based on rupture vs acute presentation without rupture), or certain hospitals treating more high-risk patients than others.

PREVIOUS STUDIES

To our knowledge, no studies have previously examined the cost of AAA repair in Canada. Several cost studies have been published on this subject in the United States, though most involved small numbers of patients at single centers. Among these studies, there are considerable differences in factors influencing overall cost, including different method for calculating cost, variability among hospital characteristics, and different patient population characteristics (eg, elective vs emergent surgery). Nevertheless, our results are largely consistent with those of previous studies. Reported costs of AAA repair in the United States range from \$20 000 to \$30 000.^{9-10,16-21}

LIMITATIONS

Several potential limitations of our study deserve mention. First, physician fees are not available from the Transition system and are therefore excluded from our cost analysis. Nonetheless, since physician fees are generally higher in the United States, their inclusion would only widen the cost difference reported in this study.

Second, we were not able to capture out-of-hospital clinical or cost data (either prehospitalization or posthospitalization) for AAA repair. However, because a greater proportion of US patients were discharged to institutional care or home care, inclusion of out-of-hospital costs would likely amplify the difference in cost between Canada and the United States.

Finally, while most hospitals using the Transition system classify surgical procedures as being either non-

elective or elective, how these admission types are defined and coded may differ from hospital to hospital. The greater proportion of nonelective surgical procedures in Canada may be due to differences in coding patterns between the 2 countries, with elective Canadian patients being coded as urgent to bypass waiting lists.

CONCLUSIONS

Abdominal aortic aneurysm repair is a costly procedure that is commonly performed in both Canada and the United States. The cost of open AAA repair is substantially higher in the United States despite shorter lengths of stay and similar clinical outcomes. This differential primarily reflects higher resource and administrative costs in the United States. However, although treatment costs are lower in Canada, Canadian hospitals may be less efficient at streamlining services, resulting in significantly longer hospital stays. With the growing consciousness in North America concerning cost-effectiveness in health care provision, Canada and the United States may each benefit by looking to the other for cost-reducing strategies.

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