Coronary artery bypass grafting in Canada: national and provincial mortality trends, 1992–1995

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Abstract

Background: Despite a body of research on outcomes of coronary artery bypass grafting (CABG) in Canada, little is known about Canada-wide outcome trends and interregional differences in outcome. The objectives of this study were to examine Canadian trends in rates of in-hospital death after CABG and to compare provincial risk-adjusted death rates.

Methods: Hospital discharge data were obtained from the Canadian Institute for Health Information and were used to identify complete cohorts of patients who underwent CABG in 8 provinces in fiscal years 1992/93 through 1995/96. Data from Quebec hospitals were not available. A logistic regression model was used to calculate risk-adjusted death rates by year, province, and province and year.

Results: A total of 50 357 CABG cases were studied, with an overall death rate of 3.6%. A national trend of decreasing mortality was found, with a risk-adjusted death rate of 3.8% in 1992/93 versus 3.2% in 1995/96 (relative decrease of 17%) ($p < 0.001$ for difference across years). Some provinces (e.g., Alberta, Manitoba and Ontario) achieved overall declines in death rates over the study period, whereas others (e.g., British Columbia and Saskatchewan) did not. The average severity of illness of patients who underwent CABG differed considerably across provinces. Despite risk adjustment for these differences, provincial death rates varied significantly ($p < 0.001$).

Interpretation: Rates of death after CABG in Canada decreased significantly in a relatively short period. Despite this encouraging finding, there were interprovincial differences in severity of illness and risk-adjusted death rates. This finding raises the possibility of unequal access to CABG and variable quality of care for patients undergoing the surgery across Canadian provinces.

Résume

Contexte : Même s'il existe beaucoup de données de recherche sur les résultats du pontage aortocoronarien (PAC) au Canada, on ne connaît pas grand chose des tendances nationales ni des différences interrégionales quant aux résultats. Cette étude visait à examiner les tendances canadiennes des taux de mortalité à l'hôpital après un PAC et à comparer les taux provinciaux de mortalité rajustés en fonction du risque.

Méthodes : On a obtenu, de l'Institut canadien d'information sur la santé, des données sur les congés d'hôpital. Les données ont servi à identifier des cohortes complètes de patients qui ont subi un PAC dans huit provinces au cours des exercices 1992/1993 à 1995/1996. On ne disposait pas de données sur les hôpitaux du Québec. Un modèle de régression logistique a servi à calculer les taux de mortalité rajustés en fonction du risque selon l'année, la province, et selon la province et l'année.

Résultats : On a étudié au total 50 357 cas de PAC qui ont produit un taux global de mortalité de 3,6 %. On a constaté une tendance nationale à une baisse de la mortalité : le taux de mortalité corrigé en fonction du risque s'établissait à 3,8 % en 1992/1993 par rapport à 3,2 % en 1995/1996 (réduction relative de 17 %) ($p < 0,001$ pour la différence au fil des ans). Certaines provinces (p. ex., Alberta,

Evidence

Études

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Manitoba et Ontario) ont enregistré des baisses globales des taux de mortalité pendant la période étudiée, mais d'autres (p. ex., Colombie-Britannique et Saskatchewan) n'en ont pas enregistré. La gravité moyenne de la maladie des patients qui ont subi un PAC était très différente d'une province à l'autre. Même si l'on a corrigé le risque pour tenir compte de ces différences, les taux de mortalité ont varié considérablement selon la province ($p < 0{,}001$).

Interprétation : Les taux de mortalité après un PAC au Canada ont diminué considérablement en relativement peu de temps. En dépit de cette constatation encourageante, on a enregistré des différences interprovinciales au plan de la gravité de la maladie et des taux de mortalité corrigés en fonction du risque. Cette constatation évoque la possibilité d'une inégalité de l'accès au PAC entre les provinces du Canada et de la qualité des soins dispensés aux patients qui subissent cette intervention chirurgicale.

Coronary artery bypass grafting (CABG) has been a popular focus of health care outcome researchers,[1–5] presumably because of the procedure's high frequency of use and considerable potential for postoperative complications[6,7] and death.[1] Recent US studies in this area have yielded interesting findings, including repeated demonstration of interhospital[1,2] and interregional[8] differences in rates of adverse outcomes, as well as regional and national trends of decreasing short-term postoperative death rates.[9–12] Both of these findings raise the possibility of variable quality of care across hospitals and regions, and over time.

Despite a body of research on CABG outcomes from Canada,[3,13–18] less is known about interregional differences and outcome trends in this country. In particular, little is known about CABG use and outcomes in provinces other than Ontario, Manitoba and British Columbia, because Canadian studies of CABG have examined data primarily from these provinces.

In this study we used national hospital discharge data to create a more complete profile of CABG outcomes and case-mix in Canada. Our specific objectives were to study trends in mortality after CABG over time and to compare provincial rates of in-hospital death. We developed a logistic regression model to adjust death rates to account for potential differences in patients' severity of illness across years and provinces.

Methods

Data source and identification of cases

We used hospital discharge abstract data for this Canada-wide study of CABG outcomes because a more detailed national database for CABG does not currently exist. Although some reports have shown that better risk adjustment is possible when prospectively collected clinical databases are available,[19–21] Landon and colleagues[22] demonstrated that reasonable risk adjustment is in fact achievable with hospital discharge data.

The data for this study were obtained from the Canadian Institute for Health Information (CIHI), which compiles discharge records of acute care hospital admissions in all Canadian provinces and territories except Quebec. As of 1995, some provinces were recording clinical information in the form of codes of the ninth revision of the International Classification of Diseases, Clinical Modification (ICD-9-CM),[23] whereas others were still using the older ICD-9 codes for diagnoses and the Canadian Classification of Procedures (CCP) codes[24] for procedures. For this study, the CIHI created a uniform database by converting codes from provinces using ICD-9-CM to ICD-9 codes for diagnoses and to CCP codes for procedures. We studied data for fiscal years 1992/93 through 1995/96.

CABG cases were identified by screening all hospital discharges for CCP procedure codes 48.11 through 48.19. We included all cases performed in patients aged 18 years or more. Seven cases were excluded because the patients were discharged from hospitals that recorded only 1 or 2 CABG cases per year. We suspect that these cases represent discharges from smaller hospitals after transfer from a tertiary care facility where the surgery was actually performed.

Combined CABG and valve procedures were retained but were distinguished from isolated CABG cases in our risk-adjustment analysis.

Definitions of study variables

The outcomes of interest were the observed and risk-adjusted rates of in-hospital death. We used logistic regression to adjust death rates for differences across years and provinces in sociodemographic, comorbidity and condition-specific indicators of severity of illness.

The sociodemographic variables studied were age and sex. For comorbidity, we used an ICD-9 coding scheme[25] to identify 17 comorbidity variables that constitute the Charlson comorbidity index.[26] We considered a condition

to be present only when the "diagnosis type" indicator (in CIHI data) was consistent with diagnoses that were present before surgery. We evaluated the comorbidity variables individually for associations with mortality rather than assigning a Charlson comorbidity score to each case, because the weighting of the Charlson index is suboptimal for CABG.[27]

Condition-specific variables included congestive heart failure and recent myocardial infarction. We identified these 2 variables using the ICD-9 coding scheme.[25] The other condition-specific variables were previous CABG (ICD-9 code v45.8), same-admission angioplasty (CCP codes 48.01 through 48.09), combined CABG and valve procedure (CCP codes 47.0 through 47.9), ventricular aneurysm (ICD-9 code 414.1) and urgent (v. elective) admission status (defined dichotomously from the "admission type" field in CIHI data).

Analysis

Data for 1992/93 through 1995/96 were pooled for analysis. We performed initial bivariate analyses (χ^2 test or Fisher's exact test) to explore associations between death and each of the sociodemographic, comorbidity and condition-specific variables. Variables appearing in at least 30 cases and demonstrating even a weak association ($p < 0.20$) with death were then selected for stepwise entry into a logistic model. Only variables significant at an α level of less than 0.05 were retained in the final model. Two-way interaction terms were assessed and were included in the final model if they were significant at an α level of less than 0.05.

To validate our risk-adjustment model, we computed c and Hosmer–Lemeshow statistics. The c statistic measures a model's discrimination and equals the area under the receiver operating characteristic (ROC) curve.[28] The Hosmer–Lemeshow statistic measures goodness of fit and calibration across deciles of model-predicted risk.[28] We calculated these statistics when we applied the model to our data and when we applied the model to a CABG database from Massachusetts that was used in prior work by one of us (W.A.G.).[12,27]

We used the risk-adjustment model to calculate the predicted probability of in-hospital death for each patient who underwent CABG. We then calculated the average of these predicted probabilities in a given year (or province) to yield an expected death rate (E). The observed death rate (O) was then divided by E to generate an O/E ratio. To calculate the risk-adjusted death rate for a given year (or province), we multiplied the year-specific (or province-specific) O/E ratio by the overall death rate for the 4 years studied.

We tested the statistical significance of differences in adjusted death rates between years and provinces by examining increments in the –2 log likelihood χ^2 statistic when dummy variables for year and province were added to the risk-adjustment model. Confidence intervals around the adjusted death rates were derived by applying "propagation of errors"[29] (based on first-order Taylor series expansions) to provide an approximation to the variance of the adjusted rate based on the joint covariance structure of the basic quantities, O, E and the Canada-wide death rate. The variance and covariances relating to E were based on an asymptotic expansion of E in terms of the error in the variable estimates.

The study was reviewed and approved by the Research Ethics Board at the University of Calgary.

Results

We studied 50 357 CABG cases from 8 provinces (23 hospitals). The numbers of cases from fiscal years 1992/93, 1993/94, 1994/95 and 1995/96 were 11 895, 12 094, 12 956 and 13 412 respectively. The overall death rate for the 4-year period was 3.6%. The mean age of the patients was 63.3 years, and 22.9% of the patients were women. The clinical characteristics of the 50 357 patients are shown in Table 1.

Development of risk-adjustment model

Female sex and increasing age were both associated with higher rates of in-hospital death. A number of comorbidity and condition-specific variables were also associated with higher death rates (Table 1).

On multivariate analysis, the clinical and demographic variables that remained independently associated with death were moderate to severe liver disease (odds ratio [OR] 11.7), metastatic disease (OR 3.7), chronic kidney disease (OR 3.2), combined CABG and valve procedure (OR 2.6), hemiplegia or paraplegia (OR 2.5), recent myocardial infarction (OR 2.3), congestive heart failure (OR 2.2), same-admission angioplasty (OR 2.0), prior CABG (OR 1.9), peripheral vascular disease (OR 1.8), ventricular aneurysm (OR 1.8), cerebrovascular disease (OR 1.5), urgent admission (OR 1.5) and female sex (OR 1.4) (Table 1). In addition, age was an independent predictor of death (OR 1.4 for 10-year age increments). The resulting logistic model had strong discriminatory properties, with a c statistic of 0.759. When 2-way interaction terms were added to the model, the c statistic improved slightly, to 0.765. When applied to the Massachusetts CABG data,[12,27] the model continued to perform well, with a c statistic of 0.756.

The model also performed well on testing for goodness of fit and calibration. A decile-of-risk analysis showed a close match between the observed and expected num-

bers of deaths (Hosmer–Lemeshow goodness of fit χ^2 = 10.3, p = 0.24) and a large (greater than 30-fold) gradient of risk across deciles. (For the Massachusetts data the Hosmer–Lemeshow goodness of fit χ^2 = 7.9, p = 0.45.)

Risk-adjusted provincial death rates

The crude death rates, the rates adjusted for age and sex, and the fully adjusted rates (i.e., adjusted for age, sex and all the clinical risk variables identified) by province for the 4-year period are presented in Table 2. The crude death rates varied from 3.0% in Nova Scotia to 4.7% in Alberta, and the fully adjusted death rates varied from 2.4% in Nova Scotia to 4.3% in Alberta ($p < 0.001$ for difference across provinces). The fully adjusted death rates differed from both the crude rates and those adjusted for age and sex. This indicates that death rates are indeed confounded by interprovincial differences in severity of illness.

Fig. 1 shows the expected versus the observed death rates by province for the study period. Nova Scotia had an observed death rate that was considerably lower than expected, whereas Alberta's observed death rate was considerably higher than expected.

The expected death rate for a given province reflects the average severity of illness of patients undergoing CABG in the province. Interestingly, Ontario had the

Table 1: Prevalence of clinical and demographic risk variables and associations with in-hospital death among 50 357 patients who underwent coronary artery bypass grafting (CABG) in 8 Canadian provinces between 1992/93 and 1995/96

Variable	% of patients	Bivariate OR for death (and 95% CI)	Multivariate OR for death (and 95% CI)*
Urgent admission	52.0	2.2 (2.0–2.4)	1.5 (1.4–1.7)
Unstable angina	34.3	1.0 (0.9–1.1)	–
Female sex	22.9	1.8 (1.7–2.0)	1.4 (1.3–1.6)
Diabetes mellitus	16.1	1.1 (1.0–1.3)	–
Recent myocardial infarction	14.1	2.9 (2.6–3.2)	2.3 (2.1–2.6)
CABG + valve procedure	10.0	3.5 (3.1–3.9)	2.6 (2.3–2.9)
Congestive heart failure	7.5	4.3 (3.8–4.8)	2.2 (1.9–2.5)
Chronic pulmonary disease	7.2	1.2 (1.0–1.4)	–
Angioplasty on same admission	5.2	1.7 (1.4–2.0)	2.0 (1.7–2.4)
Peripheral vascular disease	4.2	2.2 (1.9–2.6)	1.8 (1.5–2.2)
Cerebrovascular disease	3.7	2.1 (1.8–2.6)	1.5 (1.3–1.9)
Prior CABG	3.0	1.6 (1.3–2.0)	1.9 (1.5–2.4)
Ventricular aneurysm	1.8	2.2 (1.7–2.8)	1.8 (1.4–2.4)
Diabetes with complications	1.1	1.5 (1.0–2.2)	–
Chronic kidney disease	1.1	4.9 (3.9–6.3)	3.2 (2.4–4.1)
Peptic ulcer disease	0.9	1.6 (1.1–2.5)	–
Neoplasia	0.8	1.2 (0.7–1.9)	–
Rheumatologic disease	0.6	1.5 (0.9–2.4)	–
Hemiplegia or paraplegia	0.4	4.1 (2.7–6.2)	2.5 (1.6–4.0)
Mild liver disease	0.1	3.7 (1.5–9.5)	–
Dementia	0.1	2.0 (0.5–8.4)	–
Metastatic disease	0.1	4.6 (1.8–12.0)	3.7 (1.3–10.6)
Moderate or severe liver disease	0.04	18.0 (7.3–44.0)	11.7 (4.5–30.1)

Note: OR = odds ratio, CI = confidence interval.
*Variables with ORs listed in this column were included in the final risk-adjustment model used to calculate adjusted provincial death rates. Dashes indicate that the variable was not significantly ($p < 0.05$) associated with death on multivariate analysis.

Table 2: Crude and risk-adjusted rates of death after CABG by province

Province	Crude death rate (and 95% CI), %	Death rate adjusted for age and sex (and 95% CI), %	Fully adjusted death rate (and 95% CI), %
British Columbia	3.7 (3.3–4.2)	3.5 (3.1–3.9)	3.1 (2.7–3.4)
Alberta	4.7 (4.2–5.4)	4.7 (4.2–5.2)	4.3 (3.9–4.8)
Saskatchewan	4.0 (3.2–4.9)	3.6 (2.9–4.3)	3.7 (3.0–4.4)
Manitoba	4.1 (3.3–4.9)	3.7 (3.1–4.4)	3.4 (2.7–4.0)
Ontario	3.3 (3.1–3.5)	3.5 (3.3–3.7)	3.9 (3.7–4.1)
New Brunswick	3.1 (2.4–4.0)	3.1 (2.2–3.9)	3.1 (2.2–3.9)
Nova Scotia	3.0 (2.4–3.6)	2.7 (2.1–3.3)	2.4 (1.8–2.9)
Newfoundland	4.4 (3.4–5.7)	4.8 (3.7–5.8)	3.9 (3.0–4.8)

lowest average severity of illness (expected death rate of only 3.0%), whereas Manitoba, British Columbia and especially Nova Scotia (expected death rate of 4.5%) had higher average severity of illness.

National and provincial mortality trends

The risk-adjustment model was also used to study Canada-wide trends in adjusted rates of death after CABG (Fig. 2). Despite a slight increase in the national death rate over the study period, there was an overall decline in the death rate adjusted for risk, from 3.8% in 1992/93 to 3.2% in 1995/96 (relative decrease of 17%) ($p < 0.001$ for the difference across years). This decline occurred despite an apparent increase in average case severity (expected death rate 3.4% in 1992/93 v. 3.8% in 1995/96). The clinical risk variables whose prevalence increased significantly ($p < 0.05$) between 1992/93 and 1995/96 were urgent admission (51.9% v. 53.6%), congestive heart failure (6.5% v. 8.3%), recent myocardial infarction (13.1% v. 15.4%), previous CABG (2.1% v. 5.2%) and combined CABG and valve procedure (9.0% v. 10.5%). Mean age also increased slightly during the study period (62.7 v. 63.7 years) ($p < 0.001$).

Trends over time in adjusted death rates were not uniform across provinces (Fig. 2). Some provinces (e.g., Alberta, Manitoba and Ontario) achieved overall declines in death rates between 1992/93 and 1995/96, whereas others (e.g., British Columbia and Saskatchewan) did not.

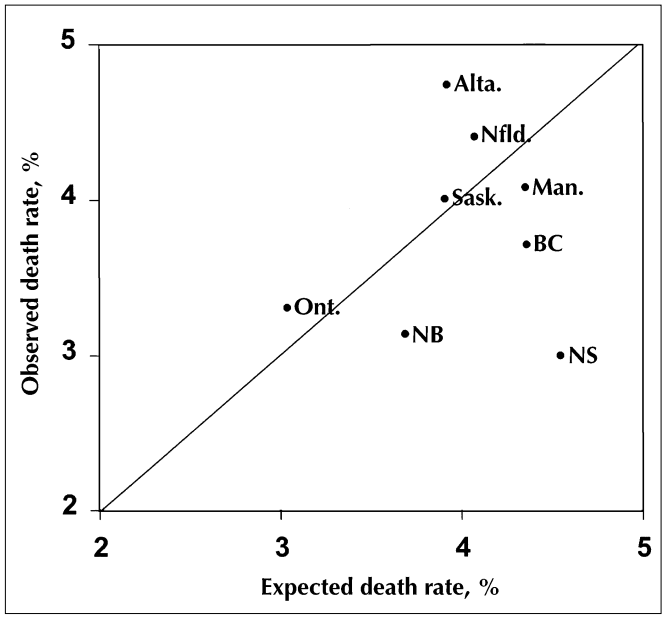

Fig. 1: Plot of observed against expected rates of death after coronary artery bypass grafting (CABG) for the 8 Canadian provinces studied, 1992/93 through 1995/96. Diagonal line indicates points at which the observed and expected rates are the same. Provinces falling above this line had higher than expected mortality, whereas those below the line had lower than expected mortality.

Interpretation

We found a national trend of decreasing rates of in-hospital death after CABG between 1992/93 and 1995/96. Despite the national trend, however, some provinces did not have declining death rates across the years studied. We also found significant differences across provinces in overall adjusted death rates and considerable differences in average severity of illness, as measured by our risk-adjustment model.

The national trend of decreasing mortality is encouraging and is similar to trends reported recently from the United States.[9–12] It is difficult to make direct comparisons between the 2 countries regarding the magnitude of the declines, because patient populations and time periods differ across studies. However, our finding of a relative decline in the risk-adjusted death rate of 17% over the

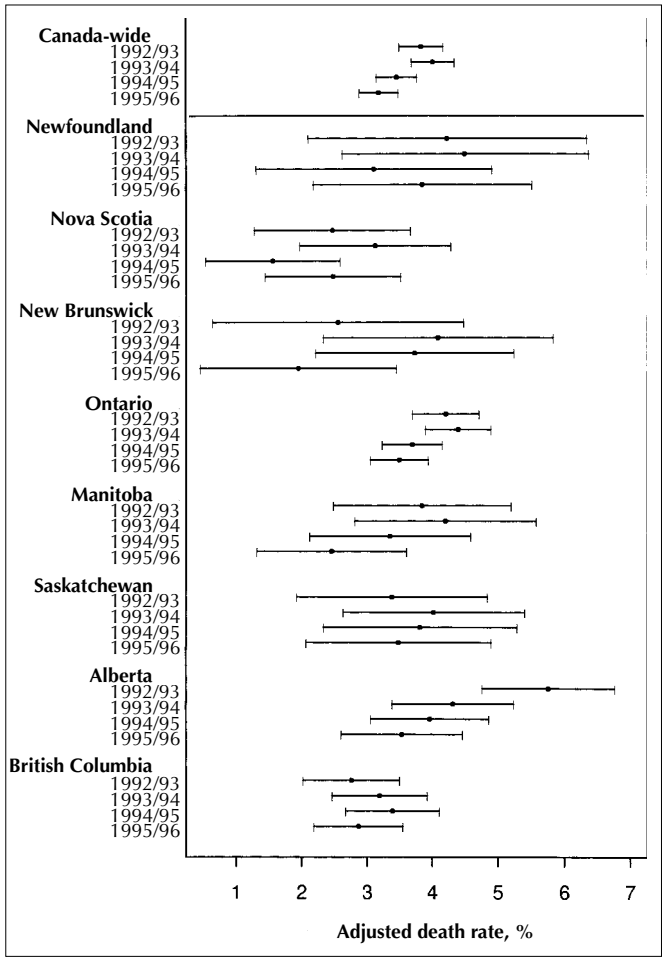

Fig. 2: Trends in risk-adjusted rates of death after CABG, 1992/93 through 1995/96, for the country (top panel) and by province (bottom panel). (Bars represent 95% confidence intervals.)

study period is similar to the decline of 18% reported by Peterson and associates[9] for CABG performed in US Medicare beneficiaries. Individual states, such as New York[10] and Massachusetts,[12] have reported decreases in death rates of over 40%, but our results show that similar decreases occurred in selected provinces (e.g., 39% in Alberta and 36% in Manitoba). These findings suggest that the magnitude and pattern of declines in death rates may be similar in the 2 countries.

There has been considerable speculation about the factors that are causing these decreases.[10–12] Possible explanations include improved methods of cardiac anesthesia and cardioplegia,[9,30] increasing use of internal mammary artery grafts,[30] advances in the medical treatment of heart disease[31–33] and increased emphasis on quality improvement.[34] The last possibility is of particular interest in the United States, because some states have adopted quality "report cards" as a way of tracking mortality by provider and hospital.[10,11,35] Many investigators feel that these report cards are leading to improved outcomes.[10,11]

Among Canadian provinces, Ontario has adopted a confidential report card system,[36] which may be contributing to the (modest) decrease in death rates seen in that province. Alberta has a provincial CABG database that has been used to track mortality since 1991. Perhaps not coincidentally, Alberta is also one of the provinces that has seen declining death rates. Although the temporal association between outcome reporting and declining mortality suggests that outcome reports may, in fact, be beneficial, this association is not necessarily causal. Further study is needed to determine the true effect of regional outcome reporting on rates of death after CABG.[12,34]

Our finding of differing adjusted death rates across provinces raises the possibility of variable quality of care. By adjusting death rates, we created a level playing field for the comparison of outcomes. The adjusted rates that we present reflect those that would be seen if the provinces were caring for patient populations with similar average severity of illness. Our results suggest that Alberta, Ontario and Newfoundland had higher risk-adjusted death rates than the other provinces for the years studied.

Further studies evaluating processes of care across provinces are required to determine whether these differences in fact reflect quality of care. For example, a study could examine factors such as the perioperative use of β-blockers or acetylsalicylic acid (drugs that clinical studies suggest are beneficial in the treatment of coronary artery disease.[37,38]) A finding of variable use of these medications across provinces would constitute a process difference that might be influencing outcomes. Similarly, studies could focus on intensive care units and early postoperative care; process variables such as duration of postoperative intubation and use of the intraaortic balloon pump may be affecting patient outcomes.

Our results also suggest that average severity of illness varies considerably across provinces. Possible explanations for this finding include differences in underlying population characteristics, variation in CABG referral practices, unequal access to cardiac care services and variable coding of clinical diagnoses used to characterize severity of illness. The first possibility is unlikely to explain fully the large difference in expected mortality across provinces. The second possibility, however, may be an important contributor. It is indeed conceivable that clinicians in some provinces (e.g., Ontario, with its apparently low average severity of illness) may have a lower threshold for referring cardiac patients for CABG than do clinicians in other provinces (e.g., Nova Scotia and Manitoba, with their relatively high average severity of illness). Further work evaluating clinical decision-making for cohorts of patients with ischemic heart disease is needed to determine whether "triage" to one of medical therapy, CABG or angioplasty differs across regions. The third possibility, unequal access to cardiac care, may also be a factor. For example, the relatively low case severity in Ontario may be due to ease of access to the relatively large number of hospitals (9) performing CABG in that province; in contrast, in Nova Scotia only 1 hospital performs CABG for a large geographic area. Provincial health care planners need to consider these questions of access to ensure that all patients have adequate access to revascularization services.

The fourth possibility, variable coding of diagnoses across provinces, highlights a study limitation. We used administrative data to study mortality associated with CABG because there is no existing Canada-wide clinical database for CABG. Although more complete adjustment of death rates is possible when prospectively collected clinical data are available (e.g., left ventricular ejection fraction),[19–21] Landon and colleagues[22] recently demonstrated that risk-adjusted hospital-specific death rates associated with CABG derived from administrative data are similar to those derived from more detailed clinical databases. We are certainly reassured by the strong performance of our risk-adjustment model on validation testing. However, such models may fail to capture certain aspects of severity of illness. Therefore, adjusted mortality estimates should always be interpreted cautiously and considered to be merely possible indicators of quality of care that need to be corroborated by focused studies evaluating processes of care.

A second limitation of our study is the lack of data from Quebec. Unfortunately, Quebec hospitals do not submit their administrative hospital discharge data to the CIHI.

A national clinical database for CABG would certainly

be a valuable resource for cardiac outcome research in Canada. Until such a database becomes available, however, large outcome studies such as ours must rely on existing administrative data. Our results encouragingly suggest a trend of decreasing rates of death after CABG between 1992/93 and 1995/96, but our findings of interprovincial differences in adjusted death rates and severity of illness raise important questions about variable access to care, clinical decision-making and quality of care. Given the many possible interpretations of our results, more interprovincial collaboration in cardiac outcome studies is required if we are to understand better the factors that affect access to and outcomes of CABG in Canada.

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