Chapter 19: Outcomes after coronary artery bypass graft surgery in Canada: 1992/93 to 2000/01

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BACKGROUND: The authors have previously reported on Canada-wide outcomes of coronary artery bypass graft (CABG) surgery for 1992/93 through 1995/96.
OBJECTIVE: To provide an updated Canada-wide CABG surgery outcome report with outcome data organized by province and by year for 1992/93 through 2000/01.
METHODS: Hospital discharge abstract data were obtained from the Canadian Institute for Health Information and were used to identify all patients who underwent isolated CABG surgery in eight provinces from fiscal year 1992/93 through 2000/01. Crude data from Quebec hospitals were available for calendar years 1998 and 1999. Logistic regression modelling was used to calculate risk-adjusted in-hospital mortality rates by year and province.
RESULTS: Patients undergoing CABG surgery in the later years studied were on average older and had more comorbidities than did patients undergoing this surgery in earlier years. Despite increasing case complexity, risk-adjusted mortality rates decreased significantly from 3.5% (95% CI 3.2% to 3.8%) to 2.0% (95% CI 1.8% to 2.3%). Risk-adjusted mortality rates varied between provinces. Provincial risk-adjusted mortality rates ranged from 2.0% to 3.3%. However, all provinces studied had either persistently low mortality rates (Nova Scotia) or declining mortality rates across years studied, such that all provinces achieved risk-adjusted mortality rates of 2.7% or lower in 2000/01.
CONCLUSIONS: This evaluation of Canadian CABG surgery outcomes demonstrates a pattern of either steadily improving or persistently favourable provincial in-hospital mortality rates after isolated CABG surgery. These favourable provincial outcome trends have been achieved despite an accompanying increase in the average case complexity of patients undergoing CABG in Canada.

Key Words: *Canada; Cardiac procedure; Coronary artery bypass graft surgery; Hospital discharge data; Mortality rates; Patient outcomes*

Résultats des pontages aorto-coronariens par greffe au Canada : de 1992-93 à 2000-01

CONTEXTE : Les auteurs ont publié antérieurement un rapport sur les résultats des pontages aorto-coronariens par greffe (PAC) à l'échelle du Canada pour la période de 1992-93 à 1995-96.
OBJECTIF : Produire un rapport actualisé sur les résultats des PAC à l'échelle du Canada selon une division des données par province et par année pour la période de 1992-93 à 2000-01.
MÉTHODES : On s'est servi des données du registre des hôpitaux obtenues auprès de l'Institut canadien d'information sur la santé pour établir la cohorte des patients ayant subi une intervention isolée de PAC dans huit provinces au cours des exercices de 1992-93 à 2000-01. On a eu accès à des données brutes des hôpitaux du Québec pour les années civiles de 1998 et 1999. On a fait appel à la modélisation de régression logistique pour calculer les taux de mortalité à l'hôpital corrigés en fonction du risque par année et par province.
RÉSULTATS : Les patients qui ont fait l'objet d'un PAC dans les dernières années de la période d'étude étaient en moyenne plus âgés et présentaient davantage de comorbidité que ceux ayant subi la même intervention au début de cette période. Malgré la complexité grandissante des cas, le taux de mortalité corrigé en fonction du risque a considérablement diminué, passant de 3,5 % (IC 95 % : 3,2-3,8 %) à 2 % (IC 95 % : 1,8-2,3 %). Par ailleurs, ce taux variait selon les provinces – allant de 2 à 3,3 %. Cependant, toutes les provinces ayant fait l'objet de l'étude présentaient soit un faible taux de mortalité constant (Nouvelle-Écosse), soit un taux de mortalité allant en décroissant au cours de la période d'étude, si bien que l'ensemble des provinces ont atteint un taux de mortalité corrigé en fonction du risque de 2,7 % ou plus faible en 2000-01.
CONCLUSIONS : Ces résultats des interventions de PAC au Canada révèlent un modèle de diminution du taux de mortalité en hôpital ou de maintien d'un faible taux à la suite d'une intervention isolée de PAC. Ces courbes favorables au niveau provincial ont été atteintes malgré l'augmentation parallèle de la complexité moyenne du cas des patients qui subissent un PAC au Canada.

CCORT investigators are listed in Appendix 1
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Coronary artery bypass graft (CABG) surgery has been frequently studied in health outcome studies because it is a high volume procedure requiring complex surgical and perioperative care, with readily measurable adverse event rates that are occasionally quite high. This interest in CABG surgery outcomes has led to the development of detailed clinical registries in New York state (1), northern New England (2), Pennsylvania (3) and Ontario (4), which have permitted the creation of hospital outcome reports presenting risk-adjusted mortality rates based on detailed clinical data.

In the absence of detailed clinical data on all CABG surgery procedures in Canada, we previously reported on Canada-wide outcomes of CABG surgery for 1992/93 through 1995/96 using discharge abstract data from the Canadian Institute for Health Information (CIHI) (5,6). In a follow-up study (7), we demonstrated that our Ontario findings derived from administrative data closely approximated those derived from analysis of more detailed clinical data compiled by the Cardiac Care Network of Ontario. Reassured by these latter findings, we concluded that, in the absence of detailed clinical registry data, administrative hospital discharge data were useful for generating global CABG surgery outcome reports. The resulting reports derived from administrative data can be verified by more detailed follow-up analyses of clinical factors in individual hospitals or regions where administrative data findings point to a need for more in-depth evaluation.

Our general objective was to update our prior Canada-wide CABG outcome reporting with five more recent years of data because our previously published outcome reports (5,6) extended only to the end of fiscal year 1995/96. This new report focuses on isolated CABG surgery only, while our previous CABG outcome reports included patients undergoing combined CABG and valve procedures.

Our specific objectives were to report on 1) the Canada-wide in-hospital mortality rate for isolated CABG surgery from 1992/93 through 2000/01, 2) risk-adjusted in-hospital mortality rates across provinces for the entire nine year period, and 3) trends in risk-adjusted mortality rates over time for the country as a whole and by province. The resulting analyses will inform Canadians about outcomes associated with the performance of this major invasive cardiac procedure in Canada.

METHODS

Data sources

Hospital discharge abstract data were used for this Canada-wide study of CABG outcomes because a more detailed national database for CABG does not exist. Although some reports have shown that better risk adjustment is possible when prospectively collected clinical databases are available (8-12), work by Landon et al (13) and the authors' prior work described above (7) demonstrate that valid risk adjustment is achievable with hospital discharge data.

The data for this study were obtained from CIHI, which compiles discharge records of acute care hospital admissions in all Canadian provinces and territories. As of 1995, some provinces were recording clinical information in the form of codes from the ninth revision of the *International Classification of Diseases, Clinical Modification* (ICD-9-CM) (14) and others were still using the older ICD-9 codes for diagnoses and the *Canadian Classification of Procedures* (CCP) codes (15) for procedures. For this study, 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. Data were studied for fiscal years 1992/93 through 2000/01 (Quebec data were available only for calendar years 1998 and 1999). Fiscal years began each April 1 and ended the following March 31.

CABG cases were identified by screening all hospital discharges for CCP codes 48.11 through 48.19. All cases of CABG performed in patients 18 years or older were included and cases where a concomitant valve procedure (CCP codes 47.0 through 47.9) was performed (ie, combined CABG and valve surgery) were excluded. All hospitals studied performed over 150 isolated CABG cases per year, with most performing 200 or more procedures annually.

Definitions of variables and statistical analysis

The outcomes of interest were crude and risk-adjusted rates of in-hospital mortality. Logistic regression modelling was used to adjust mortality rates for differences in sociodemographics, comorbidity and condition-specific indicators of average illness severity across the years and provinces. It was important to adjust for average severity of illness on admission in order to assess mortality rates with a 'level playing field' across years and provinces studied (16,17).

The sociodemographic variables studied were age and sex. For comorbidity, an ICD-9 coding scheme was used to identify 17 comorbidity variables that constitute the Charlson comorbidity index (18). A condition was considered present only when the 'diagnosis type' indicator (in the CIHI database) was consistent with diagnoses that were present before the procedure (19). Comorbidity variables were evaluated 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 surgery cases (20).

Data for 1992/93 through 2000/01 were pooled for analysis. Because Quebec reported only crude data for calendar years 1998 and 1999 without information on diagnosis type, data from that province were excluded from the risk adjustment analysis.

To develop an updated logistic regression model for risk adjustment, the authors used the main-effect variables and interaction terms identified in prior published work on CABG surgery outcomes in Canada between 1992/93 and 1995/96 (5,6), and calculated new updated beta coefficients for the full data set evaluated in this study, with data extending from 1992/93 through 2000/01. The main-effect variables predicting mortality in this risk adjustment model were age, female sex, urgent admission, peripheral vascular disease, cerebrovascular disease, hemiplegia, chronic renal disease, metastatic cancer, congestive heart failure, recent myocardial infarction, prior CABG, same day admission percutaneous coronary intervention and ventricular aneurysm (5,6). The full logistic regression model used for risk adjustment in this study (ie, main-effect variables and interaction terms with corresponding beta coefficients) is presented in Appendix 2.

To assess the performance of this updated risk adjustment model, the authors calculated the c statistic (a measure of model discrimination that equals the area under the receiver operating characteristic curve [17]) and found it to be 0.754 – a result indicating strong model discrimination.

The updated risk adjustment model was used to calculate the predicted probability of in-hospital mortality for each patient who underwent CABG. The average of the predicted probabilities among cases in a given year (or province) was calculated to yield an expected rate (E). The observed (ie, crude) mortality rate (O) was divided by E to generate an O/E ratio. To calculate the risk

TABLE 1
Prevalence (%) of clinical and demographic risk variables by year in Canada, 1992/93 to 2000/01

Variables	1992/93 to 2000/01	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Volume (n)	116,540	10,827	10,854	11,632	12,009	13,222	14,202	14,304	14,656	14,834
Mean ± SD age (years)	63.4	62.2	62.5	63.0	63.2	63.5	63.6	63.9	64.1	64.1
	±9.9	±9.6	±9.8	±9.8	±9.9	±9.8	±9.91	±9.9	±9.9	±10.0
Age over 65 (%)	50.0	45.3	46.8	48.8	49.3	50.5	51.2	52.0	51.9	52.0
Female (%)	22.3	22.0	21.6	22.4	22.2	23.2	22.5	22.6	22.2	22.1
Urgent admission (%)	53.4	51.7	49.6	52.6	53.9	54.9	52.5	51.2	59.3	53.7
Diabetes (%)	19.9	16.7	17.0	15.7	16.5	18.2	20.1	22.4	24.0	25.0
Neoplasia (%)	0.9	0.8	0.8	0.9	0.8	0.8	0.9	1.1	1.0	1.1
Rheumatological disease (%)	0.6	0.7	0.5	0.6	0.5	0.6	0.7	0.8	0.6	0.7
Peptic ulcer disease (%)	0.8	0.9	1.0	0.7	0.8	0.9	1.0	0.8	0.7	0.9
Hypertension (%)	35.2	31.5	29.9	27.2	29.3	32.5	34.0	38.4	43.1	45.8
Unstable angina (%)	40.1	32.1	36.5	38.7	39.6	42.5	40.7	42.0	43.2	42.6
Percutaneous coronary intervention (%)	3.0	6.5	6.3	5.7	3.9	3.6	3.0	0.1	0.1	0.1
Mild liver disease (%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Moderate or severe liver disease (%)	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.1	0.03	0.03
Dementia (%)	0.04	0.05	0.04	0.03	0.1	0.03	0.1	0.03	0.03	0.05
Metastatic disease (%)	0.1	0.05	0.05	0.1	0.04	0.1	0.1	0.1	0.1	0.1
Hemiplegia (%)	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.2	0.2	0.2
Chronic renal failure (%)	1.3	0.9	0.9	0.9	1.1	1.4	1.3	1.7	1.9	1.5
Ventricular aneurysm (%)	1.4	2.0	1.9	1.6	1.6	1.4	1.3	1.2	1.2	0.8
Diabetes with complications (%)	1.6	1.2	1.2	1.0	1.3	1.8	1.8	1.75	1.6	2.2
Peripheral vascular disease (%)	4.0	4.3	3.6	3.7	3.4	4.0	4.3	4.0	4.0	4.3
Cerebrovascular disease (%)	4.2	3.5	3.5	3.6	3.8	4.4	4.3	4.6	4.7	5.0
Prior CABG (%)	5.2	2.1	2.3	2.2	5.5	6.1	5.9	6.6	6.9	7.6
Congestive heart failure (%)	7.1	5.2	5.7	5.8	6.8	8.0	6.6	8.0	7.6	9.1
COPD (%)	7.2	7.6	6.6	7.1	7.0	6.8	7.0	7.2	7.6	7.7
Recent myocardial infarction (%)	16.1	13.5	13.5	14.7	15.8	16.1	15.8	16.4	18.2	19.5
Old myocardial infarction (%)	20.3	23.1	23.2	19.2	18.6	20.7	21.0	20.0	20.0	18.3
Mortality (%)	2.5	3.1	3.1	2.9	2.6	2.7	2.3	2.4	2.1	2.1

CABG Coronary artery bypass grafting; COPD Coronary obstructive pulmonary disease. Data source: Canadian Institute for Health Information, hospital discharge data

adjusted mortality rate for a given year (or province), the year-specific (or province-specific) O/E ratio was multiplied by the overall mortality rate for the nine years studied. For outcome reporting by province, patients were assigned to the province where the procedure was performed.

The statistical significance of differences in adjusted mortality rates between years and provinces was calculated 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.

RESULTS

A total of 116,540 CABG surgery cases performed in 23 hospitals across eight provinces, excluding Quebec, were studied. No procedures were performed in Prince Edward Island or the three territories because patients from those regions were referred to surrounding provinces for treatment. The number of patients undergoing CABG surgery per year increased markedly from 10,827 in 1992/93 to 14,834 in 2000/01 (Table 1). The proportion of CABG surgery patients over the age of 65 increased from 45.3% in 1992/93 to 52.0% in 2000/01. The data suggest that an increasing number of patients with acute coronary syndromes (either unstable angina or a recent myocardial infarction) proceed to have CABG surgery, because the proportion with these variables present increased between 1992/93 and 2000/01. The prevalence of diabetes and prior CABG also increased. Despite notable increases in age and apparent severity of illness, crude mortality rates decreased considerably from 3.1% in 1992/93 to 2.1% in 2000/01 ($P<0.001$).

In-hospital mortality rates by province

Crude and expected mortality rates for the overall nine-year study period are presented by province in Table 2. Crude mortality rates varied from 2.1% in New Brunswick to 3.4% in Alberta, and expected mortality rates varied from 2.2% in Ontario to 3.3% in Nova Scotia. The apparent difference between crude and expected rates indicates that mortality rates are confounded by interprovincial differences in average severity of illness. The risk adjusted mortality rates in the last column of Table 2 varied significantly ($P<0.001$), ranging from a low of 2.0% in both Nova Scotia and Manitoba to a high of 3.3% in Newfoundland. The same risk adjusted rates are presented in graph form in Figure 1, with accompanying 95% CI for each province.

Figure 2 shows a plot of crude versus expected mortality rate by province for the entire study period. The diagonal line on the figure represents equivalence of crude and expected in-hospital mortality rates. Among the eight provinces studied, British Columbia, Manitoba, Nova Scotia and New Brunswick fell

TABLE 2
Crude and risk-adjusted in-hospital mortality rate per 100 patients by province in Canada, 1992/93 to 2000/01

				In-hospital mortality		
Province	Volume	Crude deaths	Expected deaths	Crude rate	Expected rate	Risk-adjusted (95% CI)
Canada	116,540	2974	2974	2.6	2.6	2.6 (2.5 to 2.7)
Newfoundland	3277	104	82	3.2	2.5	3.3 (2.8 to 3.9)
Nova Scotia	7085	185	235	2.6	3.3	2.0 (1.7 to 2.4)
New Brunswick	3855	80	92	2.1	2.4	2.3 (1.7 to 2.8)
Ontario	62,105	1477	1389	2.4	2.2	2.8 (2.6 to 2.9)
Manitoba	6376	155	198	2.4	3.1	2.0 (1.7 to 2.4)
Saskatchewan	4952	143	128	2.9	2.6	2.9 (2.5 to 3.3)
Alberta	12,214	416	374	3.4	3.1	2.9 (2.6 to 3.1)
British Columbia	16,676	414	476	2.5	2.9	2.3 (2.0 to 2.5)

Data source: Canadian Institute for Health Information, hospital discharge data

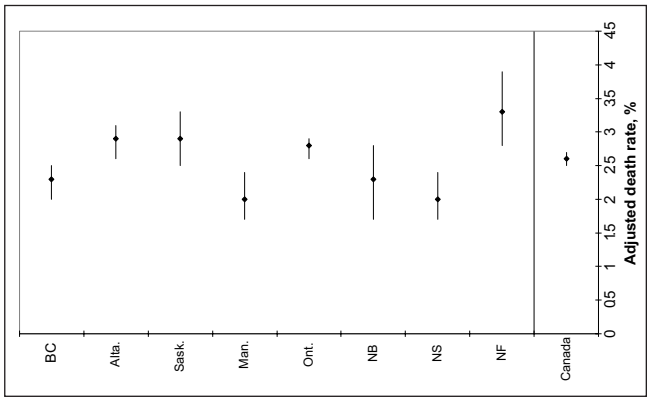

Figure 1) *Risk-adjusted in-hospital mortality rates by province for fiscal years 1992/93 to 2000/01*

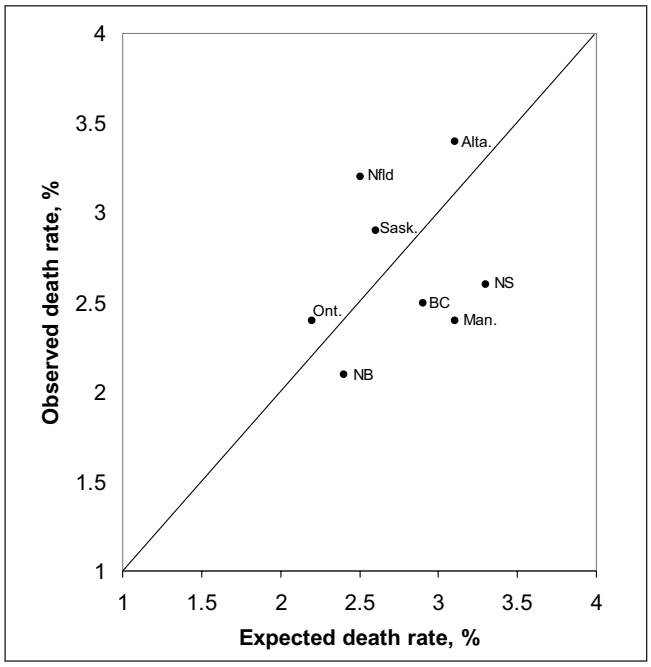

Figure 2) *Observed (ie, crude) versus expected in-hospital mortality rates after coronary artery bypass graft surgery (CABG), listed by province. Observed mortality rate = crude unadjusted mortality rate (crude numbers/volume of CABG patients). Expected mortality is calculated using logistic regression model (expected numbers/volume of CABG patients*

below this diagonal line, indicating that crude mortality rates were lower than expected. Meanwhile, the observed mortality rates were higher than expected in Alberta, Saskatchewan, Ontario and Newfoundland.

The expected mortality rate for a given province reflects the average severity of illness of patients undergoing CABG surgery in the province. This value is plotted on the x-axis of Figure 2 and the spread of provinces along the x-axis indicates that average severity of illness did vary across provinces. Ontario, New Brunswick and Newfoundland had relatively low average severity of illness while Alberta, Manitoba and Nova Scotia were the provinces with the highest average severity of illness according to the risk adjustment model.

In-hospital mortality rates – trends over time

The risk adjustment model was also used to study Canada-wide trends over time in risk adjusted rates of in-hospital mortality after CABG surgery (Table 3). Crude mortality rates decreased gradually from 3.1% in each of the first two years studied to 2.1% in each of the last two years studied. Remarkably, this reduction in crude mortality rates occurred despite a concomitant increase in expected mortality rates from 2.3% to 2.7% that reflects increasing average severity of illness among patients undergoing CABG in Canada. Taking into account both the crude and expected mortality rates across years, the corresponding risk adjusted mortality rates decreased markedly from a high of 3.5% in 1992/93 to 2.0% in 2000/01.

Analysis of mortality trends by province over time reveals that mortality rates have decreased in most regions of the country (Table 4). With the exception of Nova Scotia, where risk adjusted mortality rates were uniformly low across years, all other provinces achieved reduced adjusted mortality rates over time, such that all provinces had adjusted mortality rates below 3% in the last year studied. Alberta, Manitoba and Newfoundland achieved particularly notable decreases in adjusted mortality rates across the years studied (Table 4).

For calendar years 1998 and 1999, 10,319 isolated CABG surgery cases were performed in Quebec. Only crude in-hospital mortality rates can be reported. For calendar years 1998 and 1999, the crude mortality rates were 3.9% and 4.0%, respectively. These crude mortality rates were somewhat higher than

TABLE 3
Crude and risk-adjusted in-hospital mortality rate per 100 patients by year in Canada, 1992/93 to 2000/01

Year	Volume	Crude deaths	Expected deaths	In-hospital mortality		
				Crude rate	Expected rate	Risk-adjusted (95% CI)
1992/93	10,827	334	251	3.1	2.3	3.5 (3.2 to 3.8)
1993/94	10,854	341	255	3.1	2.3	3.5 (3.2 to 3.8)
1994/95	11,632	338	284	2.9	2.4	3.1 (2.8 to 3.4)
1995/96	12,009	314	302	2.6	2.5	2.7 (2.4 to 3.0)
1996/97	13,222	361	355	2.7	2.7	2.6 (2.4 to 2.9)
1997/98	14,202	321	366	2.3	2.6	2.3 (2.0 to 2.5)
1998/99	14,304	338	368	2.4	2.6	2.4 (2.1 to 2.6)
1999/00	14,656	311	391	2.1	2.7	2.1 (1.8 to 2.3)
2000/01	14,834	316	402	2.1	2.7	2.0 (1.8 to 2.3)

Data source: Canadian Institute for Health Information, hospital discharge data

TABLE 4
Crude (CR) and risk-adjusted (RA) in-hospital mortality rate per 100 patients by year and province in Canada, 1992/93 to 2000/01

Province	1992/93		1993/94		1994/95		1995/96		1996/97		1997/98		1998/99		1999/00		2000/01	
	CR	RA	CR	RA	CR	RA	CR	RA	CR	RA	CR	RA	CR	RA	CR	RA	CR	RA
Canada	3.1	3.5	3.1	3.5	2.9	3.1	2.6	2.7	2.7	2.6	2.3	2.3	2.4	2.4	2.1	2.1	2.1	2.0
Newfoundland	3.5	3.8	4.6	4.0	3.1	2.7	4.5	3.7	3.5	3.4	4.4	4.5	2.0	2.9	2.4	3.1	1.8	2.1
Nova Scotia	2.3	2.2	3.6	2.9	2.3	1.7	2.4	2.0	2.0	1.4	1.2	0.9	3.7	3.0	3.3	2.5	2.7	2.3
New Brunswick	2.2	2.7	2.9	3.3	3.4	3.5	1.8	1.7	3.6	3.8	0.9	1.1	1.9	2.1	0.9	1.0	1.1	1.1
Ontario	2.9	3.7	3.0	4.0	2.7	3.3	2.4	2.9	2.3	2.6	2.2	2.5	2.2	2.5	2.0	2.2	2.1	2.3
Manitoba	4.1	3.5	3.8	3.6	3.6	3.0	1.8	1.5	1.5	1.2	1.9	1.6	2.3	2.0	2.2	1.9	1.9	1.5
Saskatchewan	3.1	2.8	3.3	3.1	3.4	3.6	3.2	3.2	3.3	3.4	2.8	2.7	2.5	2.5	2.2	2.3	2.6	2.7
Alberta	5.0	5.4	3.7	3.3	3.8	3.6	3.5	3.4	4.3	3.4	3.2	2.6	3	2.4	2.4	1.9	2.5	1.9
British Columbia	2.6	2.5	2.7	2.6	2.7	2.7	2.8	2.5	3.4	3.0	2.3	2.2	2.3	2.0	2.0	1.8	1.8	1.6

Data source: Canadian Institute for Health Information, hospital discharge data

the unadjusted mortality rates of other provinces in the same years, but this information needs to be interpreted with caution because it was not possible to include Quebec data in risk adjustment analyses that adjust mortality rates to account for severity of illness. More detailed analyses of Quebec outcomes were not possible because Quebec data did not include diagnosis-type indicators for risk adjustment and only selected years are compiled by CIHI.

DISCUSSION

This analysis reveals that CABG is being performed in more patients who are on average older and sicker than were patients in the earlier years studied. Despite this shift toward increasing case complexity, outcome analyses impressively reveal a steady and continuing trend of declining in-hospital mortality rates after isolated CABG surgery. Some variation in outcomes is found across provinces but this variation is small in both absolute and relative terms. Notably, declining mortality rates are being achieved in most of the provinces studied, with the only exception being Nova Scotia, which has had uniformly low mortality rates throughout the entire study period.

The changing demographic profile of patients undergoing CABG surgery may be partially related to Canada's aging population. This demographic shift appears to be accompanied by a tendency among cardiac care providers to perform CABG surgery and other cardiac procedures in patients of advanced age (21,22). This increasingly aggressive approach to cardiac care for the elderly is defensible based on recently published evidence suggesting benefits from coronary revascularization over medical therapy, even among the 'old elderly', ie, those 80 years of age and over (23,24).

Despite the shift toward CABG surgery in patients of progressively advanced age and with greater burden of comorbidity, marked reductions in mortality rates have been achieved. The mechanism(s) through which these reduced mortality rates have been realized is the subject of considerable speculation and a number of factors may be responsible. Possible contributors are improved methods of cardiac anesthesia, increased use of internal mammary artery grafts, improved methods of cardiac protection, enhanced perioperative medical care with appropriate use of evidence-based therapies such as beta-blockers, angiotensin-converting enzyme inhibitors and statins, and increased attention to quality issues, with coordinated quality assessment and improvement programs in place in many hospitals or regions. It is likely that each of these proposed explanations, and perhaps others, have contributed to the continuing declines in mortality rates across years.

CABG surgery 'report cards' have drawn considerable attention in the United States and Canada (1-4), partially because of their tendency to provide good material for news headlines (often focusing on providers or regions with poor outcomes), but also because of their potential to reduce CABG surgery mortality rates through improved quality of care (25,26), particularly when coupled with continuous quality

improvement endeavours such as those being done in northern New England (26). While the jury is still out as to whether outcome report cards directly affect provider outcomes (27), there is growing consensus that outcome reporting should continue and in fact become more widespread so that providers and the general public can be made aware of hospital-specific or region-specific outcomes.

We have presented outcomes by province in this report and, while some provinces have better outcomes than others, interprovincial outcome differences are quite small. More important, all provinces have achieved improvements in outcomes over time, such that the variation in crude and adjusted mortality rates was much less marked in 2000/01 than it was in the first year studied (1992/93). Whatever the mechanisms are for reduced mortality rates from CABG surgery in Canada, they appear to be at play in all Canadian provinces.

Our study has limitations. The first is that we used administrative data rather than a detailed clinical registry to generate the outcome reports. This results in the omission of potentially important variables such as left ventricular ejection fraction from risk adjustment analyses. We encourage continued efforts toward the establishment of a Canada-wide CABG surgery registry. Until such a registry is developed, however, we will continue to rely on the fact that administrative data provide a reasonably accurate Canada-wide profile of CABG surgery outcomes (7). A second limitation is our exclusion of Quebec from risk adjustment analyses. This was necessary because Quebec does not report hospital discharge data with diagnosis-type indicators to CIHI, and data from that province can therefore not be used in the risk adjustment analyses conducted for this outcome report. A third limitation is our focus on only in-hospital mortality. This is a short term 'hard' clinical end point that does not necessarily reflect the longer term well-being of patients undergoing CABG surgery.

A final methodological consideration is that we have intentionally avoided the use of complex hierarchical modelling methods in this outcome report because this is part of a general *Cardiovascular Atlas* initiative of the Canadian Cardiovascular Outcomes Research Team (28,29), which targets broad readership in the general public. The impact of this methodological decision is, however, relatively minor because we have not attempted to identify high or low 'outliers' (ie, designations that can be influenced by the increased variance estimates that tend to arise from hierarchical models). Reassuringly, a sensitivity analysis using the GLIMMIX macro for hierarchical modeling in SAS (SAS Institute, USA) revealed little if any effect on variance estimates and overall results.

Despite the above limitations and methodological considerations, this updated Canadian CABG surgery outcome report provides important information for cardiac care providers and the general public. There are generally favourable provincial outcome profiles with either sustained decline in mortality rates or persistently low mortality rates after CABG surgery in the provinces studied. These favourable outcomes have been achieved despite an accompanying increase in the general case complexity of patients undergoing CABG in Canada. While the reasons for the decreased mortality rates are not clear, it seems appropriate to recommend continued attention to quality issues in CABG surgery programs across Canada, so that the favourable outcomes can be maintained and perhaps improved further in the coming years.

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APPENDIX 2
Logistic regression model used for the risk-adjustment analyses described in the methods and results*

Variable	Beta coefficient	Variable	Beta coefficient
Intercept	–8.2965	Percutaneous coronary intervention, same admission	1.0554
Age over 65	0.0569	Ventricular aneurysm	2.9935
Female sex	0.2908	Hemiplegia, congestive heart failure*	–0.9266
Urgent admission	0.4808	Cerebrovascular disease, urgent admission*	–0.4297
Peripheral vascular disease	0.6432	Chronic renal disease, urgent admission*	–0.6541
Cerebrovascular disease	0.8877	Congestive heart failure, age over 65*	–0.0176
Hemiplegia	1.1381	Congestive heart failure, peripheral vascular disease*	–0.7355
Chronic renal disease	1.4946	Recent myocardial infarction, urgent admission*	–0.4542
Metastatic disease	1.1945	Recent myocardial infarction, age over 65*	–0.0133
Congestive heart failure	2.3414	Percutaneous coronary intervention,	–1.0044
Recent myocardial infarction	1.9635	peripheral vascular disease*	
Prior coronary artery bypass graft surgery	0.2423	Ventricular aneurysm, age over 65*	–0.0354

**Odds ratios are not presented in this table because the model includes interaction terms that make odds ratios uninterpretable in isolation*

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