

Chapter 22: Outcomes after aortic and mitral valve replacement surgery in Canada: 1994/95 to 1999/2000

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BACKGROUND: Although outcomes after coronary artery bypass grafting (CABG) have been studied extensively across Canada, using both clinical and administrative databases, studies examining outcomes after valve surgery in Canada have been restricted to regional investigations using clinical data sources of limited scope. The objective of the present study was to report on observed and risk-adjusted in-hospital mortality rates after aortic valve replacement (AVR) and mitral valve replacement (MVR) across Canada between 1994/95 and 1999/2000 using administrative data.

METHODS: All cases of AVR and MVR (with and without concomitant CABG) performed between 1994/95 and 1999/2000 were identified using hospital discharge abstract data obtained from the Canadian Institute for Health Information. Rates of in-hospital mortality were risk-adjusted using logistic regression modelling techniques to account for variations in sociodemographic, comorbidity, and disease-specific indicators of average severity of illness across years and provinces. Risk-adjusted outcomes were unavailable for the province of Quebec.

RESULTS: The overall in-hospital mortality rate, excluding Quebec, between 1994/95 and 1999/2000 after isolated AVR with or without CABG was 3.7% and isolated MVR with or without CABG was 5.7%. Although risk-adjusted in-hospital mortality rates by year were unchanged between 1994/95 and 1999/2000, significant interprovincial variation did exist, ranging from 2.6% to 6.8% for AVR with or without CABG and 2.5% to 13.0% for MVR with or without CABG.

CONCLUSION: In-hospital mortality rates after valve surgery have remained stable over time. However, significant variation in outcomes was noted between provinces. The results of this study provide the first comprehensive account of valve surgery outcomes across Canada.

Key Words: Outcomes; Surgery; Valve

While outcomes after coronary artery bypass grafting (CABG) have been studied extensively across Canada using both clinical and administrative data sources (1-5), studies examining outcomes after valve surgery in Canada have been restricted to either single-centre or regional investigations using clinical data sources of limited scope (6-9).

To date, the largest assessments of valve surgery outcomes in North America have used multicentre clinical data sets from New York State (10), the Northern New England Cardiovascular Disease Study Group (11) and the Society of

Issues après une chirurgie de remplacement de la valve mitrale au Canada, de 1994-1995 à 1999-2000

HISTORIQUE : Les issues d'un pontage aortocoronarien ont fait l'objet d'études approfondies au Canada, à l'aide de bases de données tant cliniques qu'administratives, mais celles sur les issues des chirurgies valvulaires au Canada se limitent à des recherches régionales faisant appel à des sources de données cliniques de peu de portée. La présente étude visait à rendre compte des taux de mortalité nosocomiale observés et rajustés au risque après une chirurgie de remplacement de la valve sigmoïde (CRVS) et une chirurgie de remplacement de la valve mitrale (CRVM) au Canada entre 1994-1995 et 1999-2000, à l'aide de données administratives.

MÉTHODOLOGIE : Tous les cas de CRVS et de CRVM (avec ou sans pontage aortocoronarien concomitant) effectués entre 1994-1995 et 1999-2000 ont été repérés à l'aide des données résumées du congé hospitalier obtenues auprès de l'Institut canadien d'information sur la santé. Les taux de mortalité nosocomiale étaient rajustés au risque au moyen de techniques de modélisation de la régression logistique pour tenir compte des variations sociodémographiques, de la comorbidité et d'indicateurs propres à une maladie de gravité moyenne, au fil des ans et entre les provinces. La province de Québec ne disposait pas d'issues rajustées au risque.

RÉSULTATS : Le taux de mortalité nosocomiale global, à l'exclusion de celui du Québec, entre 1994-1995 et 1999-2000 après avoir isolé la CRVS avec ou sans pontage aortocoronarien s'élevait à 3,7 %, et celui de CRVM avec ou sans pontage aortocoronarien, à 5,7 %. Bien que les taux annuels de mortalité nosocomiale rajustés au risque n'aient pas changé entre 1995-1995 et 1999-2000, on observait d'importantes variations interprovinciales, oscillant entre 2,6 % et 6,8 % en cas de CRVS avec ou sans pontage aortocoronarien, et entre 2,5 % et 13,0 % en cas de CRVM avec ou sans pontage aortocoronarien.

CONCLUSION : Les taux de mortalité nosocomiale après une chirurgie valvulaire sont demeurés stables dans le temps. Cependant, d'importantes variations d'issues ont été remarquées entre les provinces. Les résultats de cette étude constituent le premier compte rendu détaillé des issues des chirurgies valvulaires effectuées au Canada.

Thoracic Surgeons (12,13). These larger scale analyses have resulted in regionally relevant risk-predictor models and have allowed for the feedback of risk-adjusted outcomes to practitioners regarding patients undergoing valve surgery.

At present, no clinical database exists that would permit the comprehensive assessment of valve surgery outcomes across Canada. Meanwhile, Canadian administrative databases, while previously shown to be valid in the reporting of nationwide CABG outcomes (14), have not yet been used to describe observed or risk-adjusted mortality rates after valve surgery.

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The objective of the present study was to use administrative data for the first time to report on observed and risk-adjusted in-hospital mortality rates after aortic valve replacement (AVR) and mitral valve replacement (MVR) across Canada between 1994/95 and 1999/2000.

METHODS

Data sources

Hospital discharge abstract data obtained from the Canadian Institute for Health Information (CIHI) were used for this study. CIHI compiles discharge records for acute care hospitalizations in all Canadian provinces and territories. 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) (15), whereas others were still using the older ICD-9 codes for diagnoses and the Canadian Classification of Procedures (CCP) (16) codes for procedures. For the present study, CIHI created a uniform database by converting codes from provinces using ICD-9-CM to ICD-9 codes for diagnoses and CCP codes for procedures. Data were studied for fiscal years 1994/95 to 1999/2000. Fiscal years began each April 1 and ended the following March 31.

Data from two regional clinical databases were used to validate the CIHI database in reporting on outcomes after AVR and MVR. The two clinical data sets used in this study were the Maritime Heart Centre (MHC) cardiac surgery database based at the Queen Elizabeth II (QEII) Health Sciences Centre in Halifax, Nova Scotia, and the British Columbia Cardiac Registry (BCCR) based at St Paul's Hospital in Vancouver, British Columbia. The MHC's cardiac surgery database prospectively collects detailed pre-, intra- and postoperative information on all cardiac surgery procedures performed in the province of Nova Scotia, while the BCCR collects detailed demographic, clinical and procedural data on all adults undergoing cardiac catheterization, percutaneous interventions or cardiac surgery in the province of British Columbia.

Definitions

AVR was defined as any case in which only the aortic valve was replaced with or without concomitant CABG. All patients who underwent an AVR with a concomitant procedure other than CABG were excluded, including those who underwent 'double' or 'triple' valve procedures. Cases of AVR were identified by screening all hospital discharges for CCP codes 47.24 (aortic valve with tissue graft including autograft, heterograft and homograft) and 47.25 (other replacement of aortic valve including prosthetic valve and those not otherwise specified). Patients who had concomitant CABG performed were identified by screening all hospital discharges for CABG CCP codes 48.11 to 48.19. MVR was defined as any case in which only the mitral valve was replaced with or without simultaneous CABG. All patients who underwent an MVR with a concomitant procedure other than CABG were excluded, including those who underwent 'double' or 'triple' valve procedures. Cases were identified by screening all hospital discharges for CCP codes 47.22 (mitral valve with tissue graft including autograft, heterograft and homograft) and 47.23 (other replacement of mitral valve including prosthetic valve and those not otherwise specified). Patients who had concomitant CABG performed were identified by screening all hospital discharges for CCP codes 48.11 to 48.19.

Exclusions

All cases performed in patients under the age of 20 years and over the age of 105 years were omitted from the analysis. In addition,

all patients from the Canadian territories (Yukon, Northwest Territories and Nunavut) were excluded, as were patients with missing health region information. Finally, any patient who was identified as having had valve surgery in a hospital that was not recognized as an established adult cardiac surgical centre was also excluded because such cases typically represent patients hospitalized in smaller centres after inter-hospital transfer from a surgical centre.

Analysis

Crude and risk-adjusted rates of in-hospital mortality after AVR and MVR were determined by province and by year for fiscal years 1994/95 through 1999/2000. Cases were assigned to the province in which the surgery was performed rather than the patient's province of residence.

Separate risk-adjustment models were constructed for AVR and MVR using multiple logistic regression modelling techniques. These models were used to adjust crude in-hospital mortality rates for variations in age and sex distribution, comorbidity, and disease-specific indicators of average severity of illness across years and provinces. Comorbidity was defined as the presence or absence of each of the 17 comorbidity variables found in the Charlson comorbidity index (17). These variables were identified using an ICD-9 coding scheme and then modelled individually for in-hospital mortality. This was done instead of assigning a summarized Charlson comorbidity score because summarized scores have been shown to suboptimally reflect the prognostic importance of each individual variable in risk-adjusting outcomes after CABG (18). For the purposes of this analysis, "remote myocardial infarction" (defined as occurring beyond three weeks of admission for surgery) and "recent myocardial infarction" (defined as occurring within three weeks of admission for surgery) were treated as separate variables. In addition, the variables "mild liver disease" and "moderate to severe liver disease" were combined to form a single variable entitled "liver disease", while the variables "any neoplasm" and "metastatic disease" were combined to form a single variable entitled "cancer". Disease-specific indicators were selected on the basis of clinical plausibility and previously reported valve surgery risk-adjustment models generated from clinical data sets (10,12,13). These indicators included hypertension (ICD-9 codes 401.x to 405.x), active endocarditis (ICD-9 codes 421.x and 424.9), urgency status (elective versus urgent/emergent), pulmonary hypertension (ICD-9 codes 415.0, 416.0 and 416.8), shock (ICD-9 codes 785.5, 785.51 and 785.59), previous CABG (CCP code V45.81), previous percutaneous coronary intervention (PCI) (CCP code V45.82), previous valve surgery (CCP codes V42.2 and V43.3), concomitant CABG on current admission (CCP codes 48.11 to 48.19), rheumatic mitral valve disease (ICD-9 code 394.x), rheumatic aortic valve disease (ICD-9 code 395.x), rheumatic and nonrheumatic tricuspid valve disease (ICD-9 codes 397.0 and 424.2), and unstable angina (ICD-9 code 411.x). These disease-specific variables were evaluated and modelled individually for associations with in-hospital mortality.

Diagnosis-type indicators enabled the authors to determine whether a particular medical comorbidity or disease-specific indicator was present at the time of admission or had developed after admission. Where it has been shown that risk-adjusting outcomes after CABG without such diagnosis-type indicators may yield misleading results (19), only those variables that

TABLE 1
Prevalence (%) of clinical and demographic risk variables by year in Canada for patients undergoing aortic valve replacement, 1994/95 to 1999/2000 (excluding Quebec)

Variable	1994/95 – 1999/2000 (n=11,427)	1994/95 (n=1604)	1995/96 (n=1758)	1996/97 (n=1790)	1997/98 (n=1942)	1998/99 (n=2142)	1999/2000 (n=2191)
Age (mean years)	66.7	65.6	66.3	66.4	66.9	67.1	67.4
Age (median years)	69.0	68.0	68.0	69.0	69.0	69.0	70.0
Female (%)	32.2	30.6	32.8	32.1	33.0	32.5	31.9
Myocardial infarction (recent) (%)	3.1	2.9	2.7	3.1	3.1	2.7	3.8
Myocardial infarction (old) (%)	4.1	3.6	4.2	4.5	5.4	4.9	2.2
Congestive heart failure (%)	17.8	15.5	16.0	18.1	17.6	19.6	19.0
Peripheral vascular disease (%)	4.0	3.1	3.9	3.7	4.1	4.2	4.8
Cerebrovascular disease (%)	4.4	3.6	3.9	4.2	4.6	4.7	5.0
Dementia (%)	0.1	0.0	0.1	0.1	0.2	0.1	0.1
Chronic pulmonary disease (%)	8.3	7.4	7.5	8.4	8.0	9.5	8.6
Rheumatologic disease (%)	0.8	1.3	0.9	0.8	0.5	0.8	0.8
Peptic ulcer disease (%)	1.0	0.8	0.8	1.2	0.9	1.3	0.8
Diabetes (%)	12.4	9.8	13.9	13.3	11.8	12.2	12.9
Diabetes with chronic complications (%)	0.7	0.5	0.8	0.7	0.7	0.7	0.9
Hemiplegia or paraplegia (%)	0.5	0.4	0.3	0.6	0.5	0.5	0.3
Renal disease (%)	1.7	1.6	1.6	1.4	2.0	1.9	1.4
Liver disease (%)	0.4	0.3	0.2	0.3	0.4	0.6	0.7
Cancer (%)	1.4	1.8	1.0	1.5	1.1	1.7	1.3
Hypertension (%)	24.9	20.2	19.7	23.5	23.8	26.9	32.5
Active endocarditis (%)	2.4	2.1	2.6	2.4	2.3	2.4	2.4
Pulmonary hypertension (%)	2.3	1.8	1.9	2.4	2.1	2.5	3.0
Shock (%)	0.6	0.6	0.6	0.5	0.5	0.5	0.8
Previous CABG or PCI (%)	2.3	1.9	2.1	2.3	1.8	2.6	2.9
Concomitant CABG on current admission (%)	43.6	40.0	41.1	43.1	45.1	44.4	46.7
Previous valve surgery (%)	1.5	1.8	1.7	1.8	1.2	1.2	1.6
Rheumatic mitral valve insufficiency and/or stenosis (%)	0.3	0.4	0.3	0.3	0.0	0.4	0.3
Rheumatic aortic valve insufficiency and/or stenosis (%)	4.7	5.2	5.4	5.1	3.8	5.0	4.2
Tricuspid valve insufficiency and/or stenosis (%)	0.9	0.9	0.7	0.8	0.8	1.2	1.0
Unstable angina (%)	6.0	4.9	6.0	7.7	6.9	7.2	3.3

CABG Coronary artery bypass grafting; PCI Percutaneous coronary intervention

were present at the time of admission were considered in the risk-adjustment model. The province of Quebec reported data without such diagnosis-type indicators and was hence excluded from the risk-adjustment analysis.

Variables that occurred in fewer than 10 cases, had no associated mortality or had large amounts of missing data were not included in the risk-adjustment models. The remaining eligible variables were included in the final risk-adjustment models. The risk-adjustment models for AVR and MVR are presented in Appendix A and Appendix B, respectively. The model c-statistic values (AVR 0.736, MVR 0.786) indicate that they perform very well in discriminating patients who died from patients who did not.

The risk-adjustment models were used to calculate the predicted probability of in-hospital mortality for each patient. The average of the predicted probabilities among cases in a given year or province was calculated to yield an expected mortality rate (E). The observed mortality rate (O) was divided by E to generate an O:E ratio. To calculate the risk-adjusted mortality rate for a given year or province, the O:E ratio was multiplied by the overall Canadian mortality rate for the entire study period. The risk-adjustment models were tested for goodness of fit by comparing the expected and observed mortality rates within deciles of predicted risk using the

Hosmer-Lemeshow test (Appendix C and Appendix D), and each model displayed excellent calibration with a high degree of correlation within each decile of risk. Ninety-five per cent CIs were determined for each risk-adjusted mortality rate and used to determine whether statistically significant differences existed across years and provinces. Statistical analyses were performed using the Statistical Analyzing Software package, version 8.2 (SAS Inc, USA).

RESULTS

AVR

The annual number of cases of AVR in the outcome analysis increased steadily from 1604 in 1994/95 to 2191 in 1999/2000 (Table 1). The average age of patients undergoing AVR remained stable over time, as did the proportion of patients who were female. However, the proportion of patients who presented with congestive heart failure, peripheral and cerebrovascular disease, hypertension, and history of prior CABG or PCI increased between 1994/95 and 1999/2000, as did the proportion of patients who underwent concomitant CABG.

The overall Canadian in-hospital mortality rate after AVR with or without concomitant CABG between 1994/95 and 1999/2000, excluding Quebec, was 3.7%. The in-hospital mortality rate for isolated AVR without CABG was 2.5%, while

TABLE 2
Crude and risk-adjusted in-hospital mortality rate per 100 patients undergoing aortic valve replacement by year in Canada, excluding Quebec, 1994/95 to 1999/2000

Year	N	Observed deaths	Expected deaths	In-hospital mortality		
				Crude rate	Expected rate	Risk-adjusted (95% CI)
1994/95	1604	60	54	3.7	3.4	4.1 (3.1–5.0)
1995/96	1758	72	62	4.1	3.5	4.3 (3.4–5.2)
1996/97	1790	64	65	3.6	3.6	3.6 (2.8–4.5)
1997/98	1942	61	74	3.1	3.8	3.0 (2.2–3.8)
1998/99	2142	85	83	4.0	3.9	3.8 (3.0–4.6)
1999/00	2191	84	88	3.8	4.0	3.5 (2.8–4.3)
1994/95–1999/2000	11,427	426	426	3.7	3.7	3.7 (3.4–4.1)

Data from the Canadian Institute for Health Information

TABLE 3
Crude and risk-adjusted in-hospital mortality rate per 100 patients undergoing aortic valve replacement by year in Canada, excluding Quebec, 1994/95 to 1999/2000

Province	N	Observed deaths	Expected deaths	In-hospital mortality		
				Crude rate	Expected rate	Risk-adjusted (95% CI)
Newfoundland	216	13	7	6.0	3.2	6.8 (4.1–9.4)
Nova Scotia	657	18	26	2.7	4.0	2.6 (1.2–3.9)
New Brunswick	421	12	16	2.9	3.8	2.8 (1.0–4.5)
Ontario	5534	221	194	4.0	3.5	4.2 (3.7–4.7)
Quebec*	4055	246	176	6.1	4.3	6.0 (5.4–6.6)
Manitoba	519	24	27	4.6	5.2	3.3 (2.0–4.5)
Saskatchewan	599	19	21	3.2	3.5	3.4 (1.9–5.0)
Alberta	1201	45	47	3.7	3.9	3.5 (2.5–4.5)
British Columbia	2280	74	88	3.2	3.9	3.1 (2.4–3.8)
Canada (excluding Quebec)	11,427	426	426	3.7	3.7	3.7 (3.4–4.1)
Canada (including Quebec)	15,482	672	672	4.3	4.3	4.3 (4.0–4.7)

*Rates of in-hospital mortality for the province of Quebec were age- and sex-adjusted only due to the lack of diagnosis-type indicators. Data from the Canadian Institute for Health Information

the in-hospital mortality rate for combined AVR and CABG was 5.3%. This reflects the increased risk associated with concomitant CABG on current admission as seen in the risk-adjustment model for AVR (Appendix A).

From 1994/95 to 1999/2000, the observed and risk-adjusted in-hospital mortality rate by year remained stable (Table 2). When reporting risk-adjusted in-hospital mortality rates by province, significant interprovincial variation was noted (Table 3). In particular, compared with the overall Canadian rate of in-hospital mortality rate after AVR of 3.7% (excluding Quebec), the province of Newfoundland had a significantly higher risk-adjusted in-hospital mortality rate at 6.8% (95% CI 4.1% to 9.4%). The remaining provinces had in-hospital mortality rates that did not differ significantly from the overall Canadian rate.

The province of Quebec was analyzed separately from the other provinces because differences in data availability (ie, lack of diagnosis-type indicators) did not allow us to risk-adjust the outcomes beyond age and sex. The observed in-hospital mortality rate in Quebec between 1994/95 and 1999/2000 was 6.1% while the age- and sex-adjusted in-hospital mortality rate was 6.0% (95% CI 5.4% to 6.6%). This was significantly higher than the overall Canadian in-hospital mortality rate after AVR of 4.3% (including Quebec).

MVR

The number of cases in this outcome analysis population increased from 716 in 1994/95 to 900 in 1999/2000 (Table 4).

The average age of patients undergoing MVR remained stable over the years, as did the proportion of patients who were female. However, the proportion of patients who presented with congestive heart failure, hypertension, pulmonary hypertension, and history of prior CABG or PCI increased between 1994/95 and 1999/2000. No changes were noted over time in the proportion of patients undergoing concomitant CABG. Furthermore, there were no changes over time in the proportion of patients presenting with a history of prior valve surgery and rheumatic mitral valve insufficiency and/or stenosis.

The overall Canadian in-hospital mortality rate after MVR with or without concomitant CABG between 1994/95 and 1999/2000, excluding Quebec, was 5.7%. The in-hospital mortality rate for isolated MVR was 3.1%, while the in-hospital mortality rate for combined MVR and CABG was 10.1%. This reflects the increased risk associated with concomitant CABG on current admission as seen in the risk-adjustment model for MVR (Appendix B).

From 1994/95 to 1999/2000, both the observed and risk-adjusted in-hospital mortality by year remained stable (Table 5). When reporting risk-adjusted in-hospital mortality rates by province, significant interprovincial variation was noted (Table 6). In particular, when compared with the overall Canadian rate of in-hospital mortality after MVR of 5.7% (excluding Quebec), the province of Newfoundland had a significantly higher risk-adjusted in-hospital mortality rate at 13.0% (95% CI 7.9% to 18.1%). On the other hand, the province of Manitoba had a significantly lower risk-adjusted

TABLE 4
Prevalence (%) of clinical and demographic risk variables by year in Canada for patients undergoing mitral valve replacement, 1994/95 to 1999/2000 (excluding Quebec)

Variable	1994/95–1999/2000 (n=4865)	1994/95 (n=716)	1995/96 (n=776)	1996/97 (n=779)	1997/98 (n=820)	1998/99 (n=874)	1999/2000 (n=900)
Age (mean)	63.0	62.9	62.4	62.8	63.7	62.6	63.3
Age (median)	66.0	65.0	65.0	66.0	66.5	65.0	66.0
Female (%)	53.8	54.9	55.8	50.2	55.0	54.5	52.6
Myocardial infarction (recent) (%)	6.8	8.7	8.0	6.4	8.3	5.5	4.8
Myocardial infarction (old) (%)	6.4	6.3	7.6	5.4	7.4	7.8	3.8
Congestive heart failure (%)	27.4	25.1	25.9	28.5	26.0	29.3	29.1
Peripheral vascular disease (%)	1.7	1.4	2.2	1.8	2.0	2.0	1.1
Cerebrovascular disease (%)	5.8	5.3	4.6	5.7	5.7	6.5	6.8
Dementia (%)	0.1	0.3	0.0	0.1	0.1	0.0	0.2
Chronic pulmonary disease (%)	7.1	7.1	6.8	7.3	5.9	8.2	7.0
Rheumatologic disease (%)	1.0	0.7	0.4	0.8	0.7	1.6	1.6
Peptic ulcer disease (%)	1.1	1.4	0.4	1.7	1.0	0.7	1.2
Diabetes (%)	10.9	10.3	12.2	13.0	10.1	10.6	9.3
Diabetes with chronic complications (%)	1.1	1.0	1.0	1.3	1.0	1.1	1.0
Hemiplegia or paraplegia (%)	0.9	0.7	0.6	0.8	1.3	0.8	1.1
Renal disease (%)	2.0	1.3	2.3	2.2	2.7	2.0	1.6
Liver disease (%)	0.2	0.4	0.3	0.1	0.0	0.2	0.3
Cancer (%)	0.9	0.4	0.8	0.8	1.1	0.9	1.3
Hypertension (%)	17.3	11.9	13.7	16.1	17.1	21.1	22.4
Active endocarditis (%)	4.1	2.7	5.2	4.0	3.8	4.2	4.7
Pulmonary hypertension (%)	10.8	9.5	10.3	11.3	10.1	10.2	13.0
Shock (%)	2.8	2.9	3.5	3.2	2.7	2.0	2.7
Previous CABG or PCI (%)	3.2	2.1	2.2	4.1	3.5	3.7	3.6
Concomitant CABG on current admission (%)	36.3	34.9	35.2	38.8	37.8	35.1	35.9
Previous valve surgery (%)	2.7	3.5	2.2	1.9	3.7	2.3	2.8
Rheumatic mitral valve insufficiency and/or stenosis (%)	30.1	32.3	32.0	29.1	30.1	31.4	26.2
Rheumatic aortic valve insufficiency and/or stenosis (%)	0.2	0.1	0.1	0.1	0.4	0.2	0.1
Tricuspid valve insufficiency and/or stenosis (%)	3.1	2.8	3.7	2.8	3.3	3.6	2.7
Unstable angina (%)	5.8	4.2	6.1	8.5	7.1	6.5	2.9

CABG Coronary artery bypass grafting; PCI Percutaneous coronary intervention

in-hospital mortality rate at 2.5% (95% CI 0.2% to 4.8%). The remaining provinces had risk-adjusted mortality rates that did not differ significantly from the overall Canadian rate. The province of Quebec was analyzed separately from the other provinces because differences in data availability (ie, lack of diagnosis-type indicators) did not allow us to risk-adjust the outcomes beyond age and sex. The observed in-hospital mortality rate in Quebec was 8.0%, while the age- and sex-adjusted in-hospital mortality rate was 8.5% (95% CI 7.3% to 9.7%). This was significantly higher than the overall Canadian in-hospital mortality rate after MVR of 6.3% (including Quebec).

Data validation

A comparison between in-hospital mortality rates after AVR and MVR generated from clinical databases from Nova Scotia and British Columbia and from administrative databases from CIHI was carried out (Appendix E). In both provinces, mortality rates derived from clinical data were highly correlated with those derived from administrative data for AVR (including combined AVR and CABG) and MVR (including combined MVR and CABG).

DISCUSSION

The overall Canadian in-hospital mortality rate after AVR with or without concomitant CABG between 1994/95 and

1999/2000, excluding Quebec, was 3.7%, with an in-hospital mortality rate after isolated AVR without CABG of 2.5% and an in-hospital mortality rate after combined AVR and CABG of 5.3%. Meanwhile, the overall Canadian in-hospital mortality rate after MVR with or without concomitant CABG between 1994/95 and 1999/2000, excluding Quebec, was 5.7% with an in-hospital mortality rate after isolated MVR of 3.1% and an in-hospital mortality rate after combined MVR and CABG of 10.1%. These results were comparable with those reported by large cardiac surgery registries from New York State (isolated AVR 3.3%, combined AVR and CABG 7.1%, isolated MVR 6.2%, combined MVR and CABG 12.8%) (10), the Northern New England Cardiovascular Disease Study Group (AVR with or without concomitant CABG 5.3%, MVR with or without concomitant CABG 8.2%) (11), the Society of Thoracic Surgeons (isolated AVR 4.0%, combined AVR and CABG 6.8%, isolated MVR 6.0%, combined MVR and CABG 13.3%) (12) and the European Heart Survey (isolated AVR 2.7%, combined AVR and CABG 4.3%, isolated MVR 1.7%, combined MVR and CABG including MV repair 8.2%) (20).

Between 1994/95 and 1999/2000, AVR and MVR were being performed in an increasing number of patients. During this time period, risk-adjusted rates of in-hospital mortality following AVR and MVR remained stable despite the increasing comorbidity

TABLE 5
Crude and risk-adjusted in-hospital mortality rate per 100 patients undergoing mitral valve replacement by year in Canada, 1994/95 to 1999/2000, excluding Quebec

Year	N	Observed deaths	Expected deaths	In-hospital mortality		
				Crude rate	Expected rate	Risk-adjusted (95% CI)
1994/95	716	47	39	6.6	5.4	6.9 (5.2–8.5)
1995/96	776	37	45	4.8	5.8	4.7 (3.2–6.3)
1996/97	779	49	45	6.3	5.8	6.2 (4.7–7.7)
1997/98	820	36	48	4.4	5.9	4.2 (2.8–5.7)
1998/99	874	47	48	5.4	5.5	5.6 (4.1–7.1)
1999/00	900	60	51	6.7	5.7	6.7 (5.2–8.1)
1994/95–1999/2000	4865	276	276	5.7	5.7	5.7 (5.0–6.3)

Data from the Canadian Institute for Health Information

TABLE 6
Crude and risk-adjusted in-hospital mortality rate per 100 patients undergoing mitral valve replacement by province in Canada, 1994/95 to 1999/2000

Province	N	Observed deaths	Expected deaths	In-hospital mortality		
				Crude rate	Expected rate	Risk-adjusted (95% CI)
Newfoundland	94	10	4	10.6	4.3	13.0 (7.9–18.1)
Nova Scotia	214	14	15	6.5	7.0	5.5 (2.8–8.2)
New Brunswick	120	6	7	5.0	5.8	5.2 (1.2–9.2)
Ontario	2085	114	111	5.5	5.3	5.8 (4.9–6.8)
Quebec*	1644	132	97	8.0	5.9	8.5 (7.3–9.7)
Manitoba	295	8	18	2.7	6.1	2.5 (0.2–4.8)
Saskatchewan	250	17	13	6.8	5.2	5.8 (4.9–6.8)
Alberta	480	29	27	6.0	5.6	6.1 (4.2–8.0)
British Columbia	1327	78	80	5.9	6.0	5.5 (4.4–6.7)
Canada (excluding Quebec)	4865	276	276	5.7	5.7	5.7 (5.0–6.3)
Canada (including Quebec)	6509	408	408	6.3	6.3	6.3 (5.7–6.9)

*Rates of in-hospital mortality for the province of Quebec were age- and sex-adjusted only because of the lack of diagnosis-type indicators. Data from the Canadian Institute for Health Information

with which patients presented for surgery over the years. The finding of increasing patient complexity over time parallels the findings of studies examining outcomes after CABG across Canada (1-5), as well as studies assessing regional outcomes after valve replacement surgery in the United States (11,21).

The reporting of in-hospital mortality rates by province allows one to compare valve surgery outcomes across health regions and to identify areas where in-hospital mortality rates may either exceed or fall below the national rate. In the present study, significant variation in valve surgery outcomes was found between provinces. In particular, the province of Newfoundland was found to have risk-adjusted rates of in-hospital mortality after AVR and MVR that were significantly higher than the national average. In addition, the province of Quebec had age- and sex-adjusted in-hospital mortality rates after AVR and MVR that were significantly higher than the national average. On the other hand, the province of Manitoba had an in-hospital mortality rate after MVR that was significantly lower than the national average. In the past, when significant interprovincial variation in CABG outcomes was reported across Canada (3,4), subsequent evaluation demonstrated that these differences were much less marked in the years following the publication of the prior study and that there was a general trend to improved outcomes in all provinces (5). While the mechanism for the improvements seen after surgical 'report carding' remain to be elucidated, it is plausible that government and institutional responses to the initial

report, in terms of resource allocation and quality improvement initiatives, may play an important role.

Although the use of administrative databases has been previously validated with regard to the reporting of CABG outcomes in Canada (14), their use with regard to the reporting of valve surgery outcomes has not been established. While no clinical databases exist to permit the assessment of mortality rates after valve surgery across Canada, the present study represents the first attempt at using administrative data to report on nationwide valve surgery outcomes. It also represents the first attempt at developing risk-adjustment models for AVR and MVR based entirely on sociodemographic, comorbidity and disease-specific variables found within administrative data. A comparison between administrative data and clinical data from the provinces of Nova Scotia and British Columbia indicated that administrative data were highly correlated with clinical data sources for ascertainment of outcomes (Appendix E). Furthermore, the risk-adjustment models for AVR and MVR outcomes (Appendix A and Appendix B) were well calibrated and demonstrated excellent discrimination across all deciles of risk (Appendix C and Appendix D), a finding that indicates that we have been able to successfully extract clinical information from administrative data that documents severity of illness and permits prediction of event rates and corresponding risk adjustment.

The above strengths are balanced by some study limitations. To begin with, although the risk-adjustment models

demonstrate strong discrimination, the use of administrative data in place of detailed clinical data results in the omission of clinically relevant variables from the risk-adjustment models such as preoperative intra-aortic balloon pump insertion and left ventricular ejection fraction. Also, it is important to note that the province of Quebec was excluded from the risk-adjustment analysis due to the absence of diagnosis-type indicators in that province. Therefore, we were limited to providing only age- and sex-adjusted in-hospital mortality rates after AVR and MVR for the province of Quebec and were unable to determine whether fully risk-adjusted results would have altered the high mortality rates observed in Quebec relative to the overall Canadian mortality rate. Furthermore, it has been reported that the province of Newfoundland has among the lowest provincial rates of reporting of diagnoses per inpatient case in the general CIHI discharge abstract database (22). The likely under-reporting of comorbidities for valve patients may not accurately reflect the known excess of cardiovascular risk factors and cardiovascular disease-related mortality in the province of Newfoundland (23,24). Thus, risk-adjusted outcomes in these patients would potentially underestimate their comorbidity burden and report misleadingly low expected mortality rates. We did, however, perform a sensitivity analysis in which we assigned Newfoundland the highest expected mortality rate among Canadian provinces (an assignment that assumes the highest average severity of illness in the country). The results of this analysis demonstrated that the Newfoundland mortality rates remained the highest across Canada for both AVR and MVR. However, it is important to note that they were no longer statistical outliers. Finally, traditional risk-adjustment strategies adjust for patient-to-patient differences in comorbidity burden and illness severity. The risk adjustment models for AVR and MVR used in this study were created using data from all provinces (except Quebec) and as such, may not necessarily reflect province-specific differences in patient referral patterns, health care resource allocation and surgical volume. For example, in the present issue of *The Canadian Journal of Cardiology*, we report that the province of Newfoundland had the lowest rates of valve surgery use across Canada between 1994/95 and 1999/2000 (pages 149-154 [25]). This may reflect differences in referral patterns, surgical wait times, or access to care between Newfoundland and the rest of Canada. In fact, it has been reported that patients waiting for CABG surgery in Newfoundland experienced considerably prolonged wait times (26,27), compelling the Department of Health and Community Services in the province of Newfoundland to arrange for elective cardiac surgery patients to be transferred out of province for more timely surgery (28). Unfortunately, data describing these regional differences are not yet available across Canada and hence could not be accounted for in the risk-adjustment strategy used in the present study. All of these limitations emphasize the need for a detailed Canada-wide clinical cardiac surgery registry that would provide accurate, fully risk-adjusted procedure outcomes for all provinces and centres.

CONCLUSION

Risk-adjusted in-hospital mortality rates following AVR and MVR remained stable between 1994/95 and 1999/2000. When provincial mortality rates were compared, significant inter-provincial variation was noted. These results represent the first use of administrative data to examine risk-adjusted valve surgery

outcomes across Canada. We anticipate that these results will provide an impetus for quality improvement initiatives throughout Canada and a starting point from which to evaluate their impact on future outcome trends.

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APPENDIX A Risk-adjustment models for aortic valve replacement

Variable	β -coefficient	Odds ratio (95% CI)
Age 20 – 64 years	Reference	
Age 65 – 74 years	0.52	1.68 (1.26–2.23)
Age 75+ years	0.86	2.35 (1.76–3.15)
Female sex	0.47	1.59 (1.29–1.97)
Myocardial infarction (recent)	0.76	2.15 (1.47–3.13)
Myocardial infarction (old)	–0.01	0.99 (0.62–1.58)
Congestive heart failure	0.57	1.77 (1.41–2.21)
Peripheral vascular disease	0.86	2.36 (1.64–3.39)
Cerebrovascular disease	0.24	1.27 (0.85–1.89)
Chronic pulmonary disease	0.00	1.00 (0.71–1.41)
Rheumatologic disease	–0.17	0.84 (0.26–2.71)
Peptic ulcer disease	0.56	1.75 (0.79–3.88)
Diabetes	0.07	1.08 (0.81–1.44)
Diabetes with chronic complications	–0.58	0.56 (0.17–1.87)
Hemiplegia or paraplegia	0.67	1.96 (0.72–5.31)
Renal disease	1.12	3.05 (1.91–4.87)
Liver disease	2.48	11.97 (6.09–23.50)
Cancer	0.79	2.21 (1.23–3.94)
Hypertension	–0.36	0.70 (0.55–0.90)
Active endocarditis	0.36	1.43 (0.77–2.66)
Pulmonary hypertension	0.17	1.19 (0.70–2.03)
Shock	1.85	6.36 (3.39–11.91)
Previous CABG or PCI	–0.14	0.87 (0.46–1.66)
Concomitant CABG on current admission	0.66	1.93 (1.55–2.41)
Previous valve surgery	0.89	2.42 (1.31–4.51)
Rheumatic mitral valve insufficiency and/or stenosis	–0.17	0.84 (0.11–6.73)
Rheumatic aortic valve insufficiency and/or stenosis	–0.43	0.65 (0.35–1.21)
Tricuspid valve insufficiency and/or stenosis	0.54	1.72 (0.82–3.62)
Unstable angina	0.17	1.19 (0.84–1.68)

c-statistic=0.736. CABG Coronary artery bypass grafting; PCI Percutaneous coronary intervention

APPENDIX B Risk-adjustment model for mitral valve replacement

Variable	β -coefficient	Odds ratio (95% CI)
Age 20 – 64 years	Reference	
Age 65 – 74 years	0.57	1.76 (1.28–2.43)
Age 75+ years	0.99	2.68 (1.87–3.85)
Female sex	0.06	1.06 (0.81–1.40)
Myocardial infarction (recent)	0.44	1.55 (1.04–2.31)
Myocardial infarction (old)	-0.39	0.67 (0.40–1.14)
Congestive heart failure	0.50	1.65 (1.26–2.16)
Peripheral vascular disease	-0.22	0.80 (0.33–1.94)
Cerebrovascular disease	0.53	1.71 (1.07–2.72)
Chronic pulmonary disease	0.32	1.37 (0.87–2.15)
Rheumatologic disease	-0.03	0.97 (0.26–3.65)
Peptic ulcer disease	-1.18	0.31 (0.06–1.47)
Diabetes	0.32	1.37 (0.95–1.98)
Diabetes with chronic complications	0.44	1.55 (0.66–3.65)
Hemiplegia or paraplegia	-0.48	0.62 (0.18–2.09)
Renal disease	1.04	2.84 (1.59–5.08)
Liver disease	1.53	4.60 (1.02–20.71)
Cancer	0.41	1.51 (0.53–4.35)
Hypertension	0.08	1.09 (0.78–1.51)
Active endocarditis	0.90	2.46 (1.43–4.23)
Pulmonary hypertension	0.17	1.19 (0.78–1.81)
Shock	1.92	6.81 (4.35–10.67)
Previous CABG or PCI	-0.19	0.83 (0.39–1.74)
Concomitant CABG on current admission	0.79	2.20 (1.61–3.01)
Previous valve surgery	1.00	2.71 (1.40–5.25)
Rheumatic mitral valve insufficiency and/or stenosis	-0.35	0.70 (0.49–1.02)
Rheumatic aortic valve insufficiency and/or stenosis		
Tricuspid valve insufficiency and/or stenosis	0.33	1.40 (0.71–2.76)
Unstable angina	0.23	1.32 (0.86–2.03)

c-statistic=0.786. CABG Coronary artery bypass grafting; PCI Percutaneous coronary intervention

APPENDIX C Deciles of risk for the Hosmer-Lemeshow test for the aortic valve replacement risk-adjustment model

Group	Total	Mortality = 1		Mortality = 0	
		Observed	Expected	Observed	Expected
1	1468	7	13.51	1461	1454.49
2	1235	18	16.62	1217	1218.38
3	1141	26	19.41	1115	1121.59
4	1269	21	26.79	1248	1242.21
5	1146	28	30.01	1118	1115.99
6	1143	43	36.06	1100	1106.94
7	1003	32	37.96	971	965.04
8	1137	51	53.05	1086	1083.95
9	1145	82	76.10	1063	1068.90
10	740	118	116.20	622	623.80

Test statistic *p*-value > 0.27

APPENDIX D Deciles of risk for the Hosmer-Lemeshow test for the mitral valve replacement risk-adjustment model

Group	Total	Mortality = 1		Mortality = 0	
		Observed	Expected	Observed	Expected
1	487	1	4.91	486	482.09
2	560	8	7.87	552	552.13
3	491	10	8.99	481	482.01
4	486	9	11.80	477	474.20
5	484	15	14.51	469	469.49
6	489	18	19.00	471	470.00
7	482	22	24.52	460	457.48
8	487	46	32.74	441	454.26
9	489	46	47.63	443	441.37
10	410	101	103.94	309	306.06

Test statistic *p*-value > 0.25

APPENDIX E Comparison between Canadian Institute for Health Information (CIHI) database and Maritime Heart Centre (MHC) and British Columbia Cardiac Registry (BCCR) databases between 1996/97 and 1999/2000

	AVR			MVR		
	Number	Deaths	%	Number	Deaths	%
CIHI	458	13	2.8	136	8	5.9
MHC	460	11	2.4	142	10	7.0
CIHI	1576	59	3.7	949	53	5.6
BCCR	1541	61	4.0	931	54	5.8

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