Canadian Journal of Cardiology ■ (2013) 1–8

Clinical Research

Determinants of Percutaneous Coronary Intervention vs Coronary Artery Bypass Grafting: An Interprovincial Comparison

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ABSTRACT

Background: Marked variation exists concerning the utilization of percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG). The objective of this study was to examine differences in predictors of mode of revascularization across 3 provincial

RÉSUMÉ

Introduction : Il existe une variation marquée dans l'utilisation de l'intervention coronarienne percutanée (ICP) et du pontage aorto-coronarien (PAC). L'objectif de cette étude était d'examiner les différences dans les prédicteurs du type de revascularisation de

Percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) are recognized treatment modalities in patients with ischemic heart disease. Despite published guidelines surrounding the utilization of PCI and CABG,[1-3] marked regional variation has been observed in the rates of PCI relative to CABG.[4-7] Hassan and colleagues found a threefold difference in PCI-to-CABG ratios between provinces across Canada.[8] Similarly, Tu and colleagues observed a threefold variation in PCI-to-CABG ratios across 17 hospitals in Ontario.[7] Little is known as to why these discrepancies existed and what factors drove these differences.

The objective of this study was to examine differences in PCI-to-CABG ratios and predictors of mode of revascularization across British Columbia (BC), Alberta (AB), and Nova Scotia (NS), 3 provincial jurisdictions where detailed observational data were in existence.

Received for publication January 28, 2013. Accepted March 18, 2013.

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See page xxx for disclosure information.

http://dx.doi.org/10.1016/j.cjca.2013.03.026

jurisdictions.

Methods: All patients who underwent PCI and isolated CABG in British Columbia, Alberta, and Nova Scotia between 1996 and 2007 were considered. Age- and sex-standardized rates of PCI and CABG per 100,000 population and PCI to CABG ratios were calculated by year and province. Logistic regression models were constructed to identify independent predictors of mode of revascularization in each province.

Results: A total of 32,190 and 69,409 patients underwent CABG and PCI, respectively, during the study period. Significant increases in the age- and sex-adjusted PCI to CABG ratios were observed in all 3 provinces, but these ratios differed between provinces. Across all 3 jurisdictions, female sex and diagnosis of acute coronary syndrome favoured increased PCI vs CABG, and increased age, left main, or 3-vessel disease occurring before myocardial infarction, and diabetes favoured lower PCI vs CABG. After adjusting for clinical and angiographic factors, there remained a significant variation in choice of PCI vs CABG between the 3 provinces over time.

Conclusions: Significant interprovincial variability in PCI to CABG ratios was observed. Though certain patient-related factors predictive of either PCI or CABG were identified, factors beyond clinical presentation played a role in the choice of revascularization approach.

3 compétences provinciales.

Méthodes : Tous les patients qui ont subi une ICP et un PAC isolé en Colombie-Britannique, en Alberta et en Nouvelle-Écosse entre 1996 et 2007 ont été considérés. Les taux standardisés selon l'âge et le sexe de l'ICP et du PAC par population de 100 000 individus, et les ratios ICP-PAC ont été calculés par année et par province. Les modèles de régression logistiques ont été élaborés pour identifier les prédicteurs indépendants du type de revascularisation dans chacune des provinces.

Résultats : Un total de 32 190 et 69 409 patients ont subi respectivement un PAC et une ICP durant la période étudiée. Des augmentations significatives dans les ratios ICP-PAC ajustés selon l'âge et le sexe ont été observées dans les 3 provinces, mais ces rapports diffèrent entre les provinces. Dans les 3 compétences provinciales, le sexe féminin et le diagnostic de syndrome coronarien aigu ont favorisé l'augmentation d'ICP par rapport au PAC, tandis que l'âge avancé, l'atteinte du tronc commun gauche ou l'atteinte tritronculaire, avant l'infarctus du myocarde, et le diabète ont favorisé moins d'ICP par rapport au PAC. Après l'ajustement des facteurs cliniques et angiographiques, une variation significative quant au choix de l'ICP par rapport au PAC subsistait entre les 3 provinces au cours du temps.

Conclusions : Une importante variabilité interprovinciale dans les ratios ICP-PAC a été observée. Tandis que certains facteurs liés au patient et prédictifs de l'ICP ou du PAC ont été identifiés, les facteurs indépendants de la manifestation clinique ont joué un rôle dans le choix de l'approche de revascularisation.

Methods

Subject selection

All patients who underwent either PCI or isolated CABG between January 1, 1996, and December 31, 2007 were included in the study population. Only index admissions during the study period were considered. Furthermore, patients having undergone either PCI or CABG in the 6 months before their index admission were excluded from the analysis to ensure that the procedure being performed was the first referral for coronary intervention.

Procedure rates

Provincial counts of PCI and CABG were age- and sex-adjusted using 2001 Statistics Canada Census data and expressed as annual rates per 100,000 of the population older than the age of 20 years. Age- and sex-adjusted rates of PCI vs CABG were expressed as an annual ratio for each province. Procedure rates and ratios were compared across time using regression analysis to test for a linear relationship with a nonzero slope. P trend values < 0.05 were considered statistically significant.

Data sources

Cardiac surgery and cardiac catheterization data sources included the following:

- AB: **A**lberta **P**rovincial **Pro**ject for **O**utcome **A**ssessment in **C**oronary **H**eart Disease (APPROACH)-Alberta; Summit Database, University of AB
- BC: BC Cardiac Registries, APPROACH-British Columbia
- NS: Maritime Heart Center Cardiac Surgery Registry Database, Cardiovascular Health Nova Scotia (CVHNS) database, APPROACH-Nova Scotia.

These databases provided detailed clinical information regarding indication for revascularization, angiographic findings, and comorbid illness, thus allowing for appropriate risk adjustment of comparative PCI-to-CABG ratios on the basis of clinical factors. Of note, detailed observational data from the surgical and cardiac catheterization databases were available for the subset of patients undergoing revascularization during the following calendar years: BC, 2000-2007; AB, 1999-2006; and NS, 2003-2006.

Variable selection

Clinical variables considered in this study included age, sex, and comorbid illnesses that might affect selection of revascularization strategy (renal failure, chronic obstructive pulmonary disease, heart failure [HF], ejection fraction $\leq$ 50%, previous myocardial infarction [MI], cerebrovascular disease, peripheral vascular disease [PVD], diabetes mellitus [DM], and hypertension). Indication for intervention was classified in the following categories: non-ST−segment elevation MI (NSTEMI), ST-segment elevation MI (STEMI), unstable angina (UA), stable angina, or other. Coronary anatomy was evaluated using angiography and categorized on the basis of severity and location of stenoses using the Duke Index.[9] The variable "year" reflected the year in which the procedure was performed.

Data analysis

Descriptive statistics (measures of central tendency and dispersion, frequencies, t tests, χ^2 tests, analysis of variance,

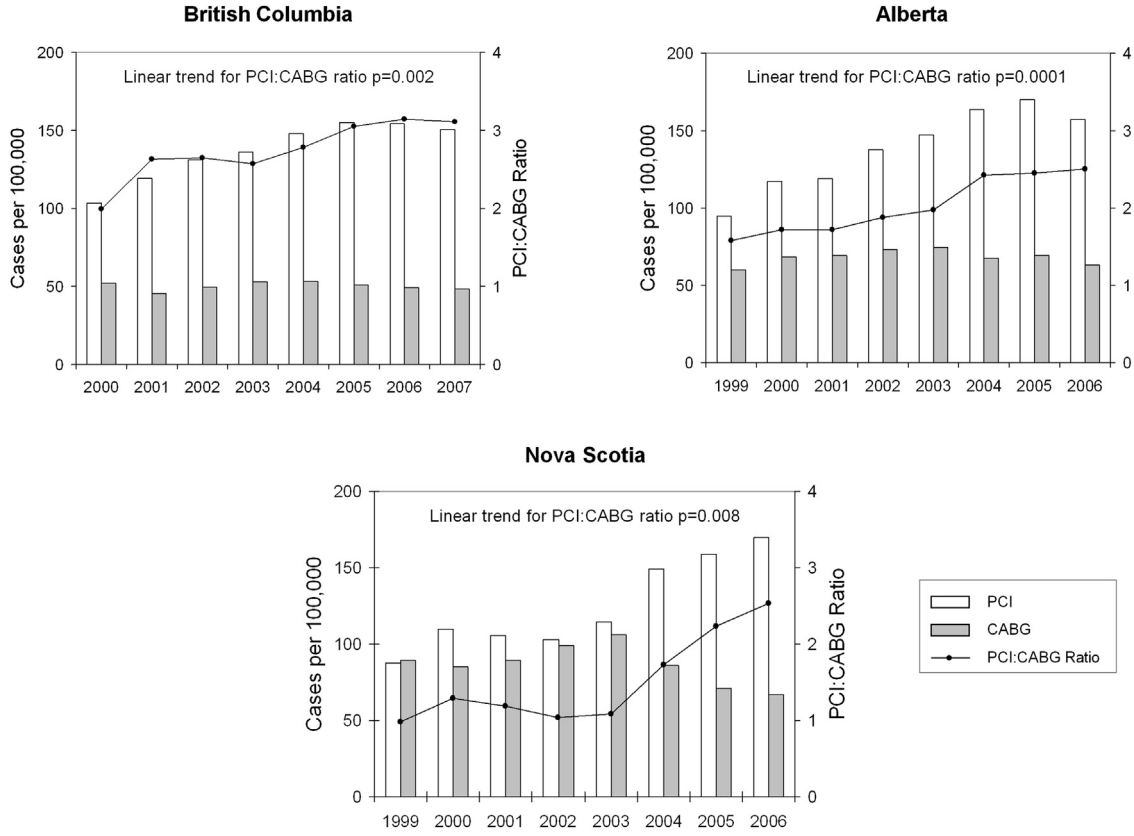

Figure 1. Age- and sex-adjusted rates of PCI and CABG per 100,000 population and PCI-to-CABG ratios per year in each province. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

and Kruskal-Wallis tests) were used to examine the distribution of clinical and nonclinical factors across jurisdictions. For each of the 3 provinces, a logistic regression (LR) model was constructed to examine the likelihood of receiving PCI vs CABG. As part of the model-building process, we first examined year alone and then examined the effect of differences in baseline characteristics including indication for revascularization, coronary anatomy, age, sex, and comorbid illnesses. Design variables were created for reference level coding of categorical variables with more than 2 levels. To avoid bias, we coded a separate level for missing values in categorical variables with missing data thus ensuring that these cases were included in the multivariable models. Collinearity was assessed through correlation matrices as Pearson $r \geq 0.3$; only 1 variable for each correlated pair was retained based on clinical importance. Predictive accuracy of each of the 3 LR models was assessed using the receiver operating characteristic curve. A bootstrap procedure was performed on 200 subsamples, and the 95% confidence interval of the receiver operating characteristic curve was obtained from the 2.5 and 97.5 percentiles of the bootstrap distribution. All statistical analyses were performed using SAS version 8.2.

Revascularization resources

The catheterization laboratory director at each institution within a province providing interventional cardiology services was contacted, and the number of practicing interventional cardiologists and the number of catheterization laboratories was determined for all years of the study. Similarly, each division head of cardiac surgery was contacted, and the number of practicing cardiac surgeons and the number of dedicated cardiac operating rooms was determined for all years of the study.

Ethics

Approval for this study was obtained from the institutional research ethics boards in each jurisdiction.

Results

PCI and CABG rates and ratios

A total of 32,190 and 69,409 patients underwent isolated CABG and PCI, respectively, during the study period. Age- and sex-adjusted rates of PCI and CABG per 100,000 population are shown for each province (Fig. 1). In BC, rates of PCI increased from 103.3 to 150.4 per 100,000 from 2000 to 2007 (P trend = 0.001), whereas rates of CABG remained unchanged (P trend = 0.94). Similarly, in AB, rates of PCI increased from 94.6 to 157.2 per 100,000 from 1999 to 2006 (P trend = 0.0005), whereas rates of CABG remained unchanged (P trend = 0.74). Finally, in NS, rates of PCI increased from 87.4 to 169.4 per 100,000 from 1999 to 2006 (P trend = 0.0007), whereas rates of CABG increased slightly from 1999 to 2003 after which they decreased up until 2006 (overall P trend = 0.20). The age- and sex-adjusted PCI-to-CABG

Table 1. Clinical characteristics of patients undergoing CABG, expressed as percent of patients in each province for the first and last year of available data

Province	British Columbia		Alberta		Nova Scotia	
Year	2000	2007	1999	2006	2003	2006
Indication						
STEMI/NSTEMI	25	22	10	33	22	21
Unstable angina	24	26	28	14	19	21
Stable angina	42	45	32	33	56	56
Other indication	6	5	29	20	3	3
Missing	3.6	1.8	0	0	0	0
Coronary anatomy						
LM	22	30	29	28	25	30
3vd	62	57	57	56	63	57
1vd/2vd	12	9	14	15	11	10
Missing	4	3	0.4	0.5	1	3
Age						
≥ 75 y	19	22	20	25	18	19
65-74 y	39	35	39	33	33	36
50-64 y	35	38	35	36	40	36
20-49 y	6	4	7	5	9	8
Sex						
Male	80	81	78	79	75	79
Ejection fraction						
≤ 50%	35	30	42	45	24	28
> 50%	62	69	55	52	70	70
Missing	2	1	3	3	6	1
Renal failure	2	2	4	8	5	5
Heart failure	9	7	14	12	10	8
Previous MI	35	21	42	23	41	41
Hypertension	56	67	55	75	69	71
Diabetes	28	31	24	31	36	37
Dyslipidemia	69	68	67	85	80	83
PVD	11	12	9	10	12	12
CVD	9	7	8	11	11	7
COPD	8	11	8	11	6	8
Smoking						
Current	16	16	31	23	19	18
Former	45	44	35	42	53	57
Never smoked	39	40	34	35	28	25

1vd, single vessel disease; 2vd, double vessel disease; 3vd, triple vessel disease; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; LM, left main; MI, myocardial infarction; NSTEMI, non-ST−elevation MI; PVD, peripheral vascular disease; STEMI, ST-elevation MI.

Table 2. Clinical characteristics of patients undergoing PCI, expressed as percent of patients in each province for the first and last year of available data

Province	British Columbia		Alberta		Nova Scotia	
Year	2000	2007	1999	2006	2003	2006
Indication						
STEMI/NSTEMI	40	45	24	61	47	52
Unstable angina	26	27	36	15	26	18
Stable angina	29	23	24	19	25	29
Other indication	4	5	16	5	2	2
Missing	0.3	0.4	0	0	0	0
Coronary anatomy						
LM	2	2	1	2	1	1
3vd	26	26	30	30	35	26
1vd/2vd	67	55	68	68	63	72
Missing	4	16	1.3	0.4	1	1
Age						
≥ 75 y	18	22	15	16	16	14
65-74 y	28	26	26	24	25	25
50-64 y	40	41	41	44	41	45
20-49 y	14	11	19	16	17	16
Sex						
Male	73	71	74	76	69	72
Ejection fraction						
≤ 50%	24	23	33	37	17	13
> 50%	55	58	61	58	67	41
Missing	22	19	6	5	16	46
Renal failure	2	2	3	3	3	3
Heart failure	5	6	6	4	4	4
Previous MI	21	14	30	10	25	20
Hypertension	48	59	41	57	61	58
Diabetes	19	22	17	20	24	24
Dyslipidemia	55	54	57	71	66	65
PVD	7	7	5	3	6	5
CVD	6	7	4	4	6	5
COPD	8	11	8	11	6	8
Smoking						
Current	20	23	30	32	30	33
Former	42	37	31	30	36	37
Never smoked	37	40	39	37	34	30

1vd, single vessel disease; 2vd, double vessel disease; 3vd, triple vessel disease; CVD, cerebrovascular disease; COPD, chronic obstructive pulmonary disease; LM, left main; MI, myocardial infarction; NSTEMI, non-ST−elevation MI; PCI, percutaneous coronary inter

ratio increased in each province over the study period, although the absolute rates and slope of increase differed over time and between provinces (Fig. 1).

Patient characteristics

Detailed clinical data were available for a subset of patients as follows: BC, 33,107 PCI and 12,205 CABG; AB, 21,341 PCI and 10,193 CABG; and NS 4150 PCI and 2334 CABG. Several trends in patient demographic characteristics, indication for cardiac catheterization, coronary anatomy, and comorbid illnesses were observed for patients undergoing CABG (Table 1) and PCI (Table 2). The proportion of patients undergoing surgical revascularization for an indication of stable angina differed between provinces, but was relatively stable over time: BC, 42% in 2000 to 45% in 2007; AB, 32% in 1999 to 33% in 2006; and NS, 56% in 2003 to 56% in 2006. In BC and NS, the proportion of patients undergoing CABG with left main (LM) disease increased over time (22% to 30% and 25% to 30%, respectively), whereas the proportion of patients with triple-vessel disease (3vd) decreased over time (62% to 57% and 63% to 57%, respectively). By contrast, in AB, the proportions of patients undergoing CABG with LM and 3vd were stable over time (29% to 28% and 57% to 56%, respectively).

For patients undergoing PCI, we observed an increase over time in the proportion of patients undergoing intervention for an indication of STEMI/NSTEMI in all 3 provinces. In terms of coronary anatomy, no more than 2% of patients with LM disease underwent PCI during the study period in all 3 provinces. The proportion of patients undergoing PCI with 3vd stayed constant at 26% in BC and 30% in AB, and decreased in NS from 35% in 2003 to 26% in 2006.

Predictors of PCI vs CABG

The clinical predictors of PCI vs CABG were consistent across all 3 provinces in our nonparsimonious LR models (Fig. 2). The patients' indication for cardiac catheterization

was highly predictive of mode of revascularization, with those presenting with NSTEMI/STEMI or UA being much more likely to undergo PCI than CABG compared with a referent group made up of patients with stable angina. Coronary anatomy was also highly predictive, with patients presenting with LM or 3vd being far more likely to receive CABG. In all 3 provinces, female sex was predictive of PCI, whereas older age, HF, previous MI, DM, and PVD were predictive of patients receiving CABG. Of note, the LR model for each province had excellent discriminatory ability, with areas under the curve ranging from 0.89 to 0.90. The complete models are presented in Supplemental Table S1.

We examined year as a predictor of PCI vs CABG in an effort to determine the effect of nonclinical or system-related factors on the choice of mode of revascularization. We examined the effect of year using LR analysis, both unadjusted and adjusted for differences between patients in indication for revascularization, severity of coronary artery disease, and comorbid illness (Fig. 3). We found that after adjustment for clinical factors, the effect of year differed between province and over time.

Revascularization resources

The increases in PCI rates observed in this study were associated with a corresponding increase in the number of interventional cardiologists in all 3 provinces during the study period (Fig. 4). In BC, the number of interventional cardiologists increased from 18 in 2000 to 20.5 in 2007 (P trend = 0.001); similarly, in AB, the number increased from 14 in 1999 to 20 in 2006 (P trend = 0.002), and from 5 in 1999 to 9 in 2006 in NS (P trend = 0.005). Although the number of cardiac surgeons increased in all 3 provinces during the study period (BC: from 15 in 2000 to 18.5 in 2007; P trend = 0.0003; AB: from 11.5 in 1999 to 13.5 in 2006; P trend = 0.03; NS: from 7 in 1999 to 9 in 2006, P trend = 0.02), this was not associated with an increase of CABG rates (Fig. 5). The number of catheterization laboratories and operating rooms remained stable over the study period.

Discussion

During the study period, PCI rates increased in all 3 provinces, whereas CABG rates remained stable in BC and AB and declined in NS. Significant increases in the PCI-to-CABG ratio were observed in all jurisdictions, although differences in absolute PCI-to-CABG ratios and rates of increase in PCI-to-CABG ratios existed between the 3 provinces. Coronary anatomy and indication for cardiac catheterization were independent predictors of PCI vs CABG in all 3 provinces. After adjusting for clinical and angiographic factors, there remained significant interprovincial variation over time in the effect of year on choice of PCI vs CABG, suggesting a role of nonclinical factors in determining mode of revascularization.

The trends observed in this study confirm those noted in numerous other regions including the United States and Europe,[10-12] suggesting an ongoing shift in practice patterns away from surgical revascularization toward percutaneous interventions. Of interest, however, are the differing rates at which PCI utilization is rising compared with CABG utilization. An examination of these differing rates revealed the effect of clinical and system-related factors in determining PCI-to-CABG ratios within a provincial jurisdiction. Common clinical factors were noted to be predictors of 1 form of revascularization over another across the 3 provinces. For instance, patients from all 3 provinces were more likely to undergo a PCI if they were female or presented with NSTEMI/STEMI or UA. Conversely, they were more likely to undergo a CABG procedure if they were elderly, had more comorbid disease in the form of HF, previous MI, DM, and PVD, and had more extensive coronary disease. These clinical predictors are in keeping with recently published guidelines that favour the role of early PCI in the setting of acute coronary syndromes and CABG in patients with complex coronary occlusive disease and greater comorbid illness.[1-3] Furthermore, the presence of these common clinical predictors would appear to suggest a fairly consistent approach to patients on the basis of clinical presentation across provincial boundaries. However, the persisting differences in PCI-to-CABG ratios between provinces suggest that a uniform approach across provincial jurisdictions does not exist and that other factors might be at play.

Undoubtedly, there exists a great amount of physician discretion in the decision to revascularize a patient and the mode of revascularization itself. In most institutions, cardiologists are the gatekeepers to revascularization in most patients and depending on the culture of the institution, there might be a bias in favour of PCI. In a retrospective chart review of just under 9000 patients in Ontario, Tu and colleagues identified several nonclinical factors associated with high PCI-to-CABG ratios including whether the treating physician was an interventionalist and whether the patient was treated at a hospital with a high PCI-to-CABG ratio.[7] In New York State, patients received more recommendations for PCI and fewer recommendations for CABG than indicated in the US guidelines.[13] Similarly, in a study of 254,028 PCI procedures, an increasing number of patients with a class I indication for CABG underwent PCI after the introduction of drug-eluting stents in 2003.[14] The choice of therapy for patients with ischemic heart disease appears to be influenced by a range of factors, including geographic region, clinical site, financial structure, medicolegal concerns, and patient preference for less invasive procedures.[7,15-19]

Interestingly, revascularization resource allocation did not appear to affect procedure utilization. Resources for PCI and CABG in terms of manpower increased over time, although it should be noted that we did not have data on clinical full-time equivalents among surgeons and interventionalists. However, during this time, rates of PCI increased while rates of CABG either remained constant or declined. More surgeons doing fewer cases might reflect the increasing complexity of the surgical patient population. The notable increase in PCI-to-CABG ratios in NS between 2003 and 2004 might have been because of an increase in the number of cardiac catheterization labs and interventionalists in NS at that time, with the resulting increase in the capacity to perform PCI. Though

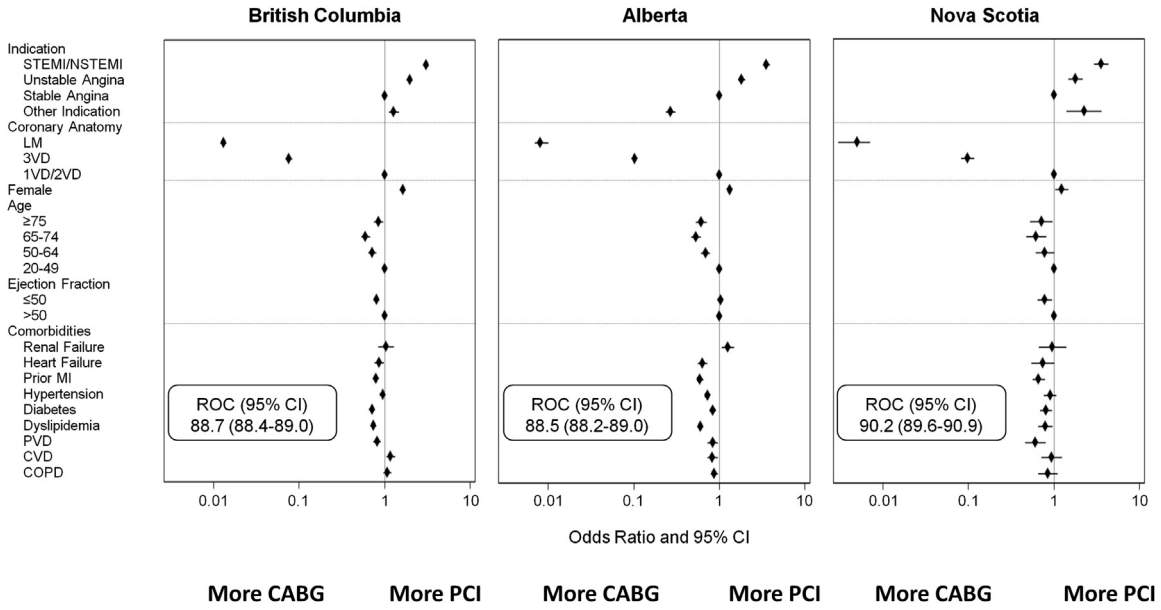

Figure 2. Clinical and angiographic predictors of PCI vs CABG in each province. 1VD/2VD, single or double vessel disease; 3VD, triple vessel disease; CABG, coronary artery bypass grafting; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; LM, left main; MI, myocardial infarction; PVD, peripheral vascular disease; ROC, receiver operating characteristic curve; STEMI/NSTEMI, ST-elevation or non-ST–elevation MI.

there was clearly a more pronounced step up in PCI volumes in NS, the absolute magnitude of the increase in PCI volumes during the study period was similar between eastern and western provinces.

There are several limitations of this study, including its observational nature, with the attendant possibility of selection bias from unmeasured confounders. Furthermore, it remains unclear exactly which system-related variables contributed to the differences observed in this study. In provinces with more than 1 cardiac catheterization laboratory and/or cardiac surgery centre, we did not explore intraprovincial or interinstitutional variability in PCI-to-CABG ratios. More details regarding the institutional or individual practitioner's approach to revascularization might further explain the observed regional variability. We did not have data regarding access to services, rates of ad hoc PCI, or whether the treating physician was an interventional cardiologist. Finally, we did not have data on clinical outcomes of patients undergoing these procedures, and in light of the differential outcomes noted in

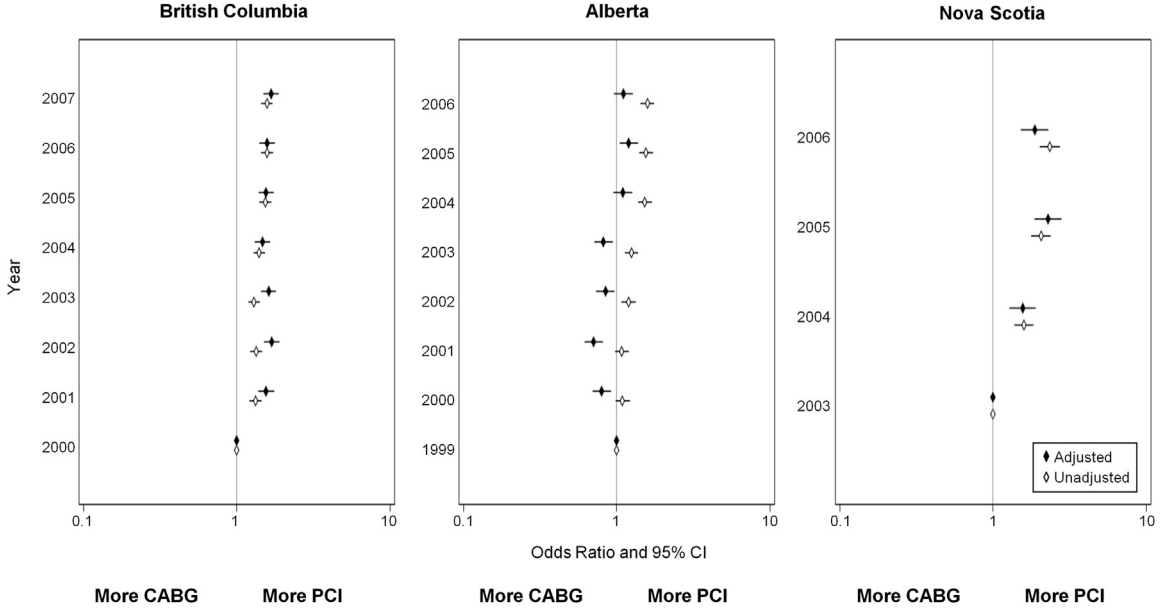

Figure 3. Year of revascularization as a predictor of PCI vs CABG in each province, both unadjusted and adjusted for indication for revascularization, coronary anatomy, and comorbid illness. For each province, the referent year (first year of available data) has an odds ratio of 1.0. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

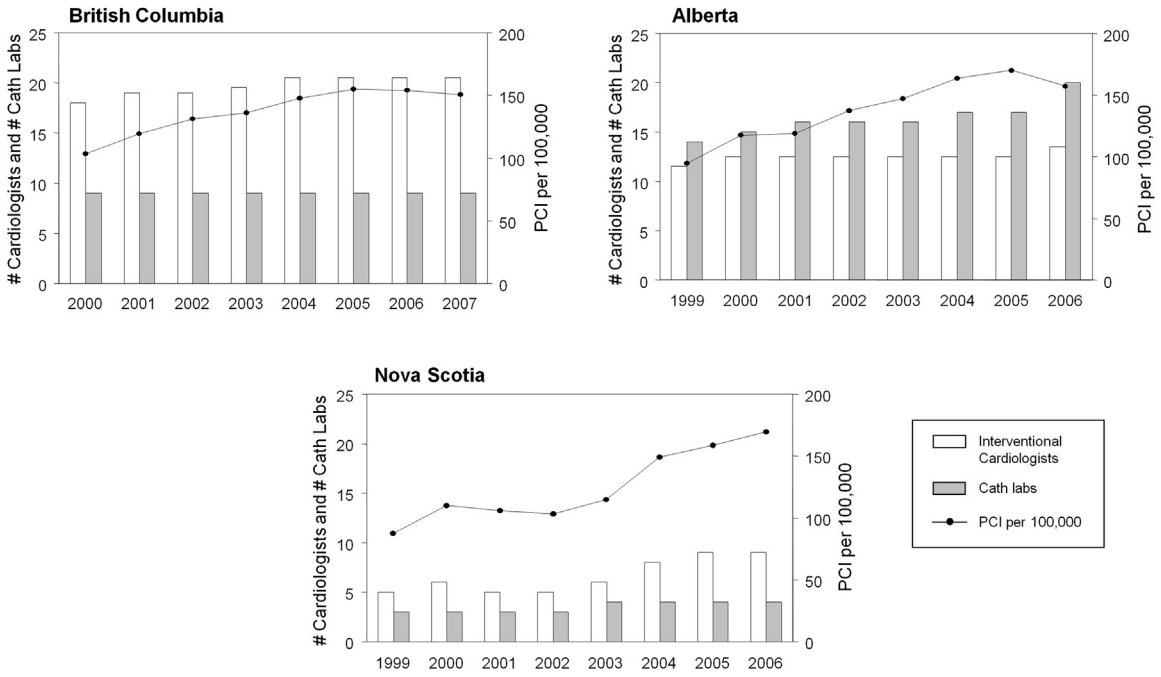

Figure 4. Number of interventional cardiologists, number of cardiac catheterization laboratories, and age- and sex-adjusted rates of PCI per 100,000 population per year in each province. PCI, percutaneous coronary intervention.

observational and randomized studies,[20-22] careful evaluation of long-term mortality and repeat revascularization is warranted in both of these groups.

In conclusion, significant interprovincial variability in rates of PCI, rates of CABG, and PCI-to-CABG ratios was observed in this study. Though certain patient-related factors predictive of either PCI or CABG were identified, factors beyond the clinical presentation play an important role in the decision-making regarding choice of revascularization approach. Further studies are warranted to determine what system-related factors are responsible for mode of revascularization and whether regional variability in treatment of coronary disease, as seen in this study, is associated with differential outcomes.

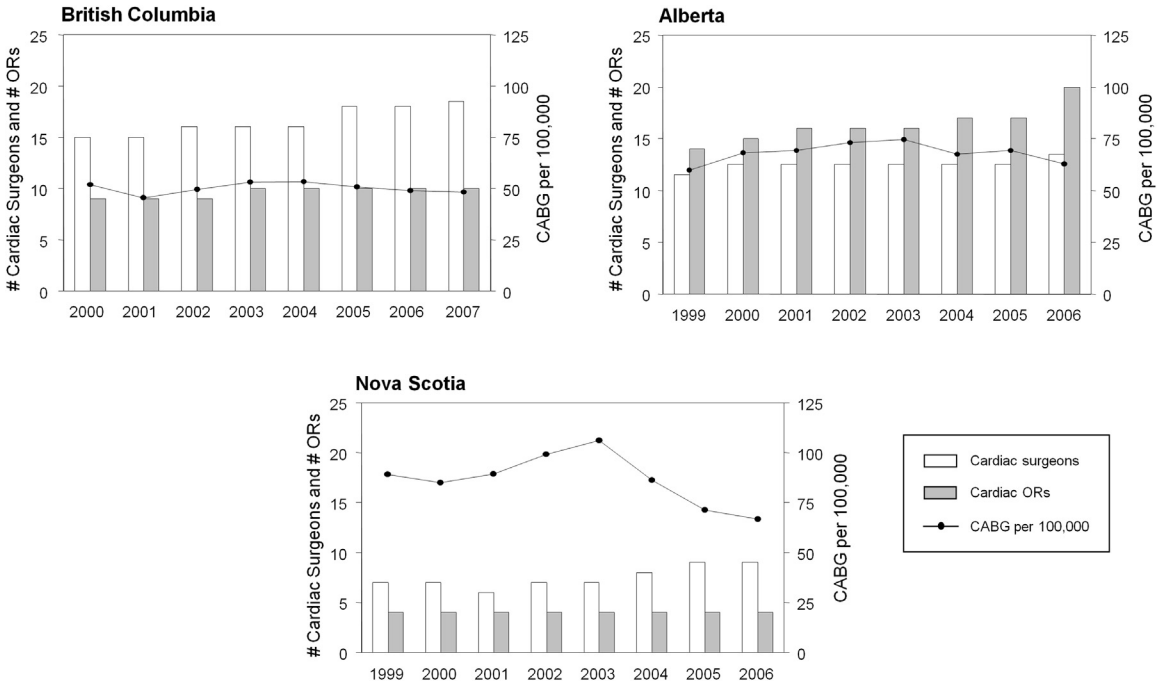

Figure 5. Number of cardiac surgeons, number of cardiac ORs, and age- and sex-adjusted rates of CABG per 100,000 per year in each province. CABG, coronary artery bypass grafting; OR, operating room.

Funding Sources

This work was funded by a CIHR Team Grant in Cardiovascular Outcomes Research to the Canadian Cardiovascular Outcomes Research Team.

Disclosures

The authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Cardiology* at www.onlinecjc.ca and and at http://dx.doi.org/10.1016/j.cjca.2013.03.026.