

Original Investigation

Prevalence and Extent of Obstructive Coronary Artery Disease Among Patients Undergoing Elective Coronary Catheterization in New York State and Ontario

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IMPORTANCE Prior studies have shown that physicians in New York State (New York) perform twice as many cardiac catheterizations per capita as those in Ontario for stable patients. However, the role of patient selection in these findings and their implications for detection of obstructive coronary artery disease (CAD) are largely unknown.

OBJECTIVE To evaluate the extent of obstructive CAD and to compare the probability of detecting obstructive CAD for patients undergoing cardiac catheterization.

DESIGN, SETTING, AND PATIENTS An observational study was conducted involving patients without a history of cardiac disease who underwent elective cardiac catheterization between October 1, 2008, and September 30, 2011. *Obstructive CAD* was defined as diameter stenosis of 50% or more in the left main coronary artery or stenosis of 70% or more in a major epicardial vessel.

MAIN OUTCOMES AND MEASURES Observed rates and predicted probabilities of obstructive CAD. Predicted probabilities were estimated using logistic regression models.

RESULTS A total of 18 114 patients from New York and 54 933 from Ontario were included. The observed rate of obstructive CAD was significantly lower in New York at 30.4% (95% CI, 29.7%-31.0%) than in Ontario at 44.8% (95% CI, 44.4%-45.3%; $P < .001$). The percentage of patients with left main or 3-vessel CAD was also significantly lower in New York than in Ontario (7.0% [95% CI, 6.6%-7.3%] vs 13.0% [95% CI, 12.8%-13.3%]; $P < .001$). In New York, a substantially higher percentage of patients with low predicted probability of obstructive CAD underwent cardiac catheterization; for example, only 19.3% (95% CI, 18.7%-19.9%) of patients undergoing cardiac catheterization in New York had a greater than 50% predicted probability of having obstructive CAD than those in Ontario at 41% (95% CI, 40.6%-41.4%; $P < .001$). At 30 days, crude mortality for patients undergoing cardiac catheterization was slightly higher in New York at 0.65% (90 of 13 824; 95% CI, 0.51%-0.78%) than in Ontario at 0.38% (153 of 40 794; 95% CI, 0.32%-0.43%; $P < .001$).

CONCLUSIONS AND RELEVANCE In Ontario compared with New York State, patients undergoing elective cardiac catheterization were significantly more likely to have obstructive CAD. This appears to be related to a higher percentage of patients in New York with low predicted probability of CAD undergoing cardiac catheterization.

JAMA. 2013;310(2):163-169. doi:10.1001/jama.2013.7834

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The continuing increase in health care expenditures is threatening the sustainability of the health care system and the economy of many developed countries.¹⁻³ Debates among the public, physicians, funders, and policy makers have concentrated on how to provide better quality of care at a lower cost.⁴ In the United States, a study found that only 1 in 3 patients who received elective cardiac catheterization had obstructive coronary artery disease (CAD), which raises concerns about the necessity of cardiac procedures for many patients with stable CAD.⁵ According to these findings, one might reasonably conclude that a more selective use of cardiac catheterization should be implemented to reduce its associated cost and to improve its diagnostic efficiency. Conversely, other studies have suggested that a restrictive approach is not more efficient in identifying severe CAD and could actually lead to an underdiagnosis of patients who may benefit from coronary revascularization.^{6,7}

Previous cross-country comparison studies between the United States and Canada have highlighted large differences in the utilization of cardiac procedures because of different methods of incentivizing health care.⁸⁻¹⁰ Our group has previously shown that clinicians in New York State (New York) perform twice as many cardiac catheterizations per capita as are performed in Ontario, which could be explained by a difference in the burden of CAD or by a difference in the patient selection process for procedures.¹¹ Given the increasing focus on how best to use scarce health care resources, it is important to understand the reasons underlying the different utilization patterns and their associated implications. Accordingly, the first objective of the present study was to evaluate the extent of obstructive CAD in these jurisdictions. The second objective was to evaluate whether there were different thresholds for selecting patients for cardiac catheterization by comparing the predicted probabilities of obstructive CAD in New York and Ontario.

Methods

Data Sources

The New York Cardiac Diagnostic Catheterization Database

The New York Cardiac Catheterization Database was used to evaluate patients undergoing cardiac catheterization.¹² As previously described, it is a voluntary data system maintained by the state's Department of Health. The database collects information on demographics, medical comorbidities, cardiac conditions, ischemic testing, and coronary anatomy among 18 participating hospitals with cardiac catheterization facilities. The database was then linked to the Percutaneous Coronary Intervention (PCI) Reporting System and the Cardiac Surgery Reporting System to determine rates of coronary revascularizations after index cardiac catheterization.¹³ The Social Security Administration Death Master File was used to identify deaths.¹³

This study was approved by the Sunnybrook Health Sciences Centre research ethics board.

The Cardiac Care Network of Ontario Cardiac Registry

The Cardiac Care Network of Ontario maintains an ongoing prospective clinical registry of all patients undergoing cardiac cath-

eterizations, as well as other invasive cardiac procedures in the province. It has been demonstrated to be a valuable source of information in clinically oriented research and has been used extensively.¹⁴ Both the New York and Ontario databases are clinical data sets that contain similar data elements with standardized data definitions that are suitable for comparison. We used the Canadian Institutes for Health Information Database to capture coronary revascularization rates and the Registered Persons Database to capture deaths after cardiac catheterization in Ontario.¹⁴

Study Cohort

All adult patients in Ontario older than 20 years without a history of cardiac disease and who underwent cardiac catheterization between October 1, 2008, and September 30, 2011, for stable CAD were eligible for inclusion. In New York, the study sample was drawn from 18 of 82 cardiac catheterization hospitals that participated in the Cardiac Catheterization Database. We identified patients without a history of cardiac disease undergoing elective cardiac catheterization in a sequential manner as proposed by Patel and colleagues⁵ (Figure). For patients who had multiple cardiac catheterizations during the study period only the first cardiac catheterization was considered.

Definitions of Obstructive CAD

We defined *obstructive CAD* as stenosis of 50% or more of the left main coronary artery or stenosis of 70% or more of a major epicardial or branch vessel. The presence of 3-vessel CAD was defined by stenosis of 70% or more in the left anterior descending coronary artery, left circumflex coronary artery, and right coronary artery.

Statistical Analysis

We compared demographic characteristics, clinical characteristics, the extent of obstructive CAD, and revascularization and mortality rates among patients who underwent elective cardiac catheterization using χ^2 tests for categorical variables and *t* tests for continuous variables. Due to privacy restrictions that limited the transfer of data out of each jurisdiction, statistical calculations were performed without merging the data sets.

To understand potential differences in how patients were selected for cardiac catheterization between New York and Ontario, we first constructed logistic regression models in Ontario to predict the presence of obstructive CAD. Selection of predictor variables was based on clinical knowledge and prior literature.^{5,15} Variables included in our model were age, sex, cardiac risk factors (diabetes, hyperlipidemia, smoking status, hypertension), comorbidities (peripheral vascular disease, cerebrovascular disease, heart failure, dialysis), Canadian Cardiovascular Society (CCS) angina classification, and high-risk ischemia evaluation on noninvasive imaging.

Discrimination ability of the models was determined using the area under the receiver operating characteristics curve (C statistic). No variable in the prediction model had an associated variance inflation factor greater than 5, suggesting no multicollinearity. After model estimation, predicted rates of obstructive CAD for each patient in New York and Ontario were calculated using the coefficient estimates obtained in the On-

tario cohort. This method is analogous to direct standardization, which allowed us to estimate the expected probability of a given patient having obstructive CAD if that patient had resided and managed in Ontario.^{8,9,16} The predicted probability of obstructive CAD of each patient in each jurisdiction was then aggregated at the hospital level or the regional level to allow comparison between New York and Ontario. Therefore, an individual patient was the unit of analysis, and results were then aggregated to calculate average predicted probability of obstructive CAD. We examined the calibration of the predicted probabilities using graphical calibration plots as previously described.^{17,18} To do so, we graphically compared predicted vs observed probabilities of the presence of obstructive CAD across the deciles of risk.

SAS version 9.2 (SAS Institute Inc) was used for statistical analyses. A 2-sided *P* value of .05 or less was considered statistically significant in the comparison of outcomes.

Results

Study Cohort

The creation of the study cohort is shown in the Figure. We included 61 756 patients in New York and 160 563 patients in Ontario who underwent cardiac catheterization between October 1, 2008, and September 30, 2011. We excluded 3854 patients in New York and 8636 in Ontario with prior valvular disease, 6462 patients in New York and 13 208 in Ontario with prior myocardial infarction, 18 117 patients in New York and 32 285 in Ontario with previous coronary revascularizations (PCI and CABG surgery), and 6102 patients in New York and 35 067 in Ontario with urgent or emergent indications (cardiogenic shock and myocardial infarction) for cardiac catheterization. Our final cohort included 18 114 patients in New York and 54 933 patients in Ontario, representing 29.3% and 34.2% of the original cohort.

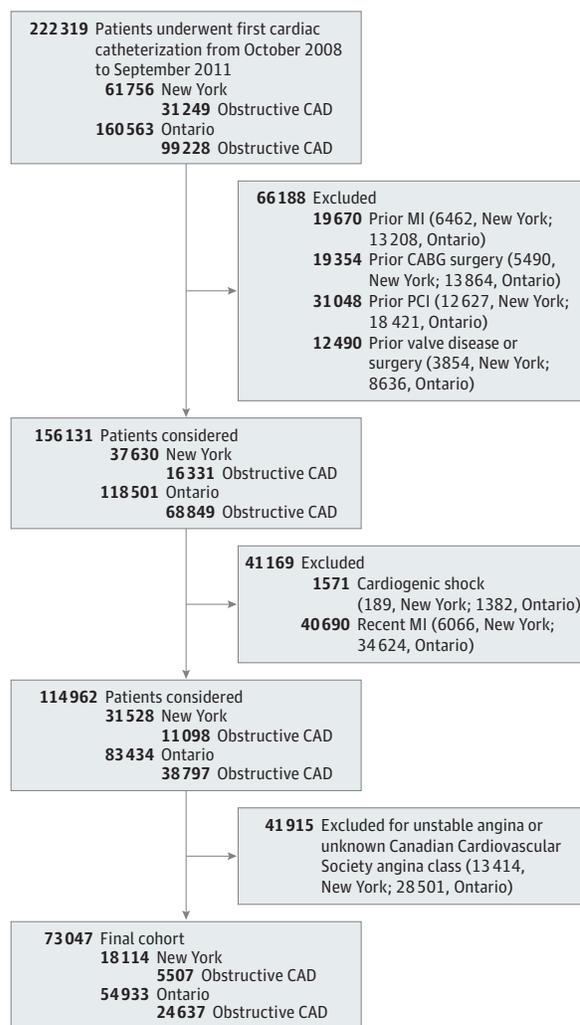
Obstructive CAD

The Figure also details rates of obstructive CAD. Prior to applying any exclusion criteria, obstructive CAD was detected by cardiac catheterization in 50.6% (95% CI, 50.2%-51.0%) of patients in New York and 61.8% (95% CI, 61.6%-62.1%) of patients in Ontario (*P* < .001). After applying sequential exclusions to identify patients with elective procedures without prior heart disease, the rate of obstructive CAD was still lower in New York (30.4%; 95% CI, 29.7%-31.0%) than in Ontario (44.8%; 95% CI, 44.4%-45.3%; *P* < .001).

Clinical and Anatomic Characteristics of Patients

Differences in demographics and clinical characteristics were observed among patients undergoing cardiac catheterization (Table 1). Patients in New York were significantly younger (mean, 61.2 [SD, 12.4] years vs 63.7 [11.4] years) and more likely to be women (45.3% vs 39.0%) than those in Ontario. A higher proportion of asymptomatic patients without typical angina as categorized by the Canadian Cardiovascular Society class 0 was noted in New York (57.7% vs 29.3% in Ontario). Noninvasive ischemic testing prior to cardiac catheterization was per-

Figure. Study Flow Diagram



The flow diagram details the creation of the study cohort and the corresponding rates of obstructive CAD rates in New York and Ontario. Patients may have met more than 1 exclusion criterion. CABG indicates coronary artery bypass graft; MI, myocardial infarction.

formed more often in Ontario than in New York (75.1% vs 63.2%; *P* < .001). Among patients who underwent noninvasive testing, the proportion of patients with high-risk findings on ischemic evaluation was substantially lower in New York (4.7%) than in Ontario (50.9%; *P* < .001). Hospital characteristics of patients who underwent cardiac catheterization differed significantly between New York and Ontario with 56.9% vs 73.2% of patients who received cardiac catheterization at full-service hospitals with capability to perform PCI and coronary artery bypass graft surgery (CABG) (Table 1).

The anatomic results of the cardiac catheterizations are shown in Table 2. In New York, 2.5% (95% CI, 2.3%-2.8%) of patients who underwent cardiac catheterization were found to have left main stenosis, 5.2% (95% CI, 4.9%-5.5%) had 3-vessel CAD, and 7.0% (95% CI, 6.6%-7.3%) had left main or 3-vessel disease. In Ontario, patients were significantly more likely

Table 1. Demographic and Clinical Characteristics of Patients With Stable Coronary Artery Disease Undergoing Cardiac Catheterization in New York State and Ontario

	No. (%) of Patients		P Value
	New York State (n = 18 114)	Ontario (n = 54 933)	
Age, mean (SD), y	61.2 (12.4)	63.7 (11.4)	<.001
Age categories, y			
<65	10 712 (59.1)	28 475 (51.8)	
65-74	4536 (25.0)	16 181 (29.5)	<.001
≥75	2866 (15.8)	10 277 (18.7)	
Women	8211 (45.3)	21 400 (39.0)	<.001
CCS angina classification ^a			
0	10 451 (57.7)	16 072 (29.3)	
I	869 (4.8)	8793 (16.0)	<.001
II	5099 (28.1)	18 955 (34.5)	
III to IV	1695 (9.4)	11 113 (20.2)	
Cardiac risk factors			
Hypertension	13 949 (77.0)	35 751 (65.1)	<.001
Diabetes	5163 (28.5)	14 766 (26.9)	<.001
Hypertlipidemia	10 883 (60.1)	36 529 (66.5)	<.001
Current smoker	2946 (16.3)	11 641 (21.2)	<.001
Former smoker	4258 (23.5)	14 281 (26.0)	<.001
Medical and cardiac comorbidities			
Previous heart failure	1752 (9.7)	3389 (6.2)	<.001
Cerebrovascular disease	871 (4.8)	2893 (5.3)	.008
Peripheral vascular disease	1001 (5.5)	2672 (4.9)	<.001
Dialysis	427 (2.4)	833 (1.5)	<.001
Ischemia evaluation			
Performed prior to cardiac catheterization	11 448 (63.2)	41 243 (75.1)	<.001
High risk for ischemia ^b	539 (4.7)	20 983 (50.9)	
Hospital characteristics			
Cardiac catheterization only	595 (3.3)	8160 (14.9)	<.001
Cardiac catheterization and PCI	7215 (39.8)	6551 (11.9)	<.001
Cardiac catheterization, PCI and CABG surgery	10 304 (56.9)	40 222 (73.2)	<.001

Abbreviations: CABG, coronary artery bypass graft; CCS, Canadian Cardiovascular Society; PCI, percutaneous coronary intervention.

^a A CCS score of 0 was used to denote patients with no typical angina. Higher CCS angina classification score indicates higher burden of angina.

^b Proportion among patients who received ischemia evaluation prior to cardiac catheterization.

to have severe CAD; 5.0% (95% CI, 4.9%-5.2%) had left main stenosis, 9.8% (95% CI, 9.6%-10.1%) had 3-vessel coronary artery stenosis, and 13.0% (95% CI, 12.8%-13.3%) had left main or 3-vessel disease (all $P < .001$).

Predicted Probability of Obstructive CAD

Factors predicting the presence of obstructive CAD were found to have similar coefficient estimates, suggesting that they are of similar importance in both jurisdictions (eTable 1 in Supplement). The Ontario regression model had a C statistic of 0.74 to predict the presence of obstructive CAD. We then assessed its performance using New York data as a validation or test sample. When the coefficient estimates obtained from the Ontario data were applied to the New York data, the C statistic was 0.70, suggesting generalizability of the model. We also examined the calibration of the predicted probabilities by comparing predicted vs observed probabilities of the presence of obstructive CAD across the deciles of risk, which demonstrated strong concordance between observed and predicted rates in the calibration plot (eFigure 1 in Supplement).

Table 3 depicts the proportion of patients undergoing cardiac catheterization stratified by predicted probability of obstructive

coronary disease based on the model fitted to the Ontario cohort. The results presented in Table 3 demonstrated that patients who received cardiac catheterization in New York had a significantly lower predicted probability of obstructive CAD than those in Ontario. Overall, only 19.3% (95% CI, 18.7%-19.9%) of patients in New York were predicted to have a greater than 50% probability of having obstructive CAD compared with 41.0% (95% CI, 40.6%-41.4%) in Ontario. At the lowest-risk category, when the predicted probability of obstructive CAD was less than 15%, the proportion of patients in this category was 15.1% (95% CI, 14.6%-15.6%) in New York and 6.9% (95% CI, 6.7%-7.1%) in Ontario. At the highest-risk spectrum, when the predicted probability of obstructive CAD was greater than 75%, the proportion of patients was 1.4% (95% CI, 1.2%-1.6%) in New York vs 7.9% (95% CI, 7.7%-8.1%) in Ontario.

In New York, predicted probabilities of obstructive CAD were 31.4% for hospitals that performed cardiac catheterization, 32.8% for hospitals that performed cardiac catheterization and PCI, and 34.4% for full service hospitals. In Ontario, predicted probabilities of obstructive CAD were 44.6% for hospitals that performed cardiac catheterization, 43.8% for hospitals that performed cardiac catheterization and PCI, and 45.1% for full service hospitals ($P < .001$).

Rates of Coronary Revascularization and Mortality

We compared rates of coronary revascularization and mortality among patients who had undergone cardiac catheterization between October 1, 2008, and December 31, 2010, which included 13 824 patients in New York and 40 794 patients in Ontario. Patients who had obstructive CAD in New York were significantly more likely to undergo PCI and CABG surgery within 30 days after cardiac catheterization than patients in Ontario (54.9% vs 34.6% for PCI, 20.4% vs 14.1% for CABG, $P < .001$ for both comparisons). Mortality within 30 days of cardiac catheterization was low in both New York and Ontario. At 30 days, crude mortality for patients undergoing cardiac catheterization was slightly higher in New York at 0.65% (90 of 13 824; 95% CI, 0.51%-0.78%) vs 0.38% (153 of 40 794; 95% CI, 0.32%-0.43%) in Ontario ($P < .001$). However, this difference was driven primarily by higher mortality for patients without obstructive CAD in New York at 0.62% (60 of 9709; 95% CI, 0.46%-0.77%) vs 0.27% (59 of 22 232; 95% CI, 0.20%-0.33%) in Ontario ($P < .001$). There was no significant difference in New York and Ontario in 30-day mortality among patients with obstructive CAD 0.73% (30 of 4115; 95% CI, 0.47%-0.99%) vs 0.51% (94 of 18 562; 95% CI, 0.40%-0.61%, $P = .08$), or patients who received PCI at 0.29% (7 of 2393; 95% CI, 0.08%-0.51%) vs 0.25% (17 of 6698; 95% CI, 0.13%-0.37%, $P = .75$) or CABG surgery at 0.67% (6 of 892; 95% CI, 0.14%-1.21%) vs 0.90% (24 of 2667; 95% CI, 0.54%-1.26%; $P = .52$).

Discussion

We found that increased use of cardiac catheterization in New York relative to Ontario was primarily the result of selecting more patients at low predicted probability of obstructive CAD. As a result, the diagnostic yield (ie, the proportion of tested patients in whom disease was diagnosed) of cardiac catheterization in New York was significantly lower than in Ontario. It is anticipated that the cost of cardiac catheterization is higher in New York than Ontario; however, consistent cost estimates of outpatient procedures are not widely available in New York. If we assumed all car-

diac catheterizations were performed on an outpatient basis at around \$3000 per procedure as estimated in Ontario^{19,20} and 30% of the population undergoing cardiac catheterization had no prior cardiac disease, the hypothetical scenario of New York's adopting the same population rate of cardiac catheterization as in Ontario (from 1185 per 100 000 to 605 per 100 000) could lead to potential savings of approximately \$75 million per year.

We have previously compared the market-oriented financing approach of New York with the government-funded single-payer system of Ontario and found that New York has twice as many interventional cardiologists, twice as many hospitals with cardiac invasive capabilities, and accordingly performs almost exactly twice as many cardiac

Table 2. Coronary Anatomy of Patients With Stable Coronary Artery Disease Undergoing Cardiac Catheterization^a

	No. (%) of Patients	
	New York State (n = 18 114)	Ontario (n = 54 933)
Location of significant coronary artery stenosis		
Left main artery	460 (2.5)	2770 (5.0)
Proximal left anterior descending artery	1308 (7.2)	7357 (13.4)
Mid or other left anterior descending artery	2688 (14.8)	12 214 (22.2)
Left circumflex artery	2452 (13.5)	11 739 (21.4)
Right coronary artery	2890 (16)	14 322 (26.1)
No. of major epicardial vessels with significant stenosis		
Any ^b	5507 (30.4)	24 637 (44.8)
1	2865 (15.8)	11 617 (21.1)
2	1524 (8.4)	7333 (13.3)
3	942 (5.2)	5389 (9.8)
Left main or 3-vessel coronary artery disease	1263 (7.0)	7168 (13.0)

^a $P < .001$ for all comparisons between New York State and Ontario.

^b Any obstructive coronary artery disease was defined as diameter stenosis of 50% or more in the left main coronary artery or 70% or more in a major epicardial vessel.

Table 3. Predicted and Observed Rate of Obstructive Coronary Artery Disease in New York State and Ontario

Predicted Probability of Obstructive CAD, %	No. (%) of Patients				P Value Comparing Observed CAD Rate ^a
	New York State		Ontario		
	Prevalence of Cohort	Observed Obstructive CAD	Prevalence of Cohort	Observed Obstructive CAD	
≤15	2739 (15.1)	244 (8.9)	3796 (6.9)	336 (8.9)	.94
>15-25	3979 (22.0)	708 (17.8)	7039 (12.8)	1377 (19.6)	.02
>25-35	3652 (20.2)	971 (26.6)	8502 (15.5)	2526 (29.7)	<.001
>35-45	3026 (16.7)	1117 (36.9)	8669 (15.8)	3533 (40.8)	<.001
>45-55	2304 (12.7)	1064 (46.2)	8581 (15.6)	4456 (51.9)	<.001
>55-65	1465 (8.1)	779 (53.2)	7765 (14.1)	4752 (61.2)	<.001
>65-75	698 (3.9)	404 (57.9)	6253 (11.4)	4295 (68.7)	<.001
>75	251 (1.4)	179 (71.5)	4328 (7.9)	3362 (77.7)	.02
Total	18 114 (100.0)	5507 (30.4)	54 933 (100.0)	24 637 (44.8)	<.001

Abbreviation: CAD, coronary artery disease.

^a P value <.001 comparing prevalence rate of cohort categorized by different predicted rate of obstructive CAD.

catheterizations per capita as Ontario.¹¹ This study represents an extension of the previous work, which included detailed clinical characteristics and anatomical information of patients undergoing cardiac catheterization. In addition to finding that New York patients undergoing cardiac catheterization had a much lower predicted probability of having obstructive CAD, several individual factors differed significantly between the 2 regions. First, the majority of patients (58%) undergoing cardiac catheterization in New York did not have typical chest pain as categorized by the Canadian Cardiovascular Society classification. Second, although the majority of patients in both regions had noninvasive ischemic evaluation performed prior to cardiac catheterization, only 5% of patients undergoing cardiac catheterization in New York vs 50% in Ontario had high-risk findings on noninvasive stress testing. Although both data sets defined high-risk findings in a similar manner, it is possible that the large discrepancy may be partly due to systematic differences in the manner in which physicians interpret high-risk findings on noninvasive stress testing in each region.

One of the primary reasons to perform cardiac catheterization is to detect patients with severe CAD, for which coronary revascularization may improve clinical outcomes.²¹ We found that a more restrictive approach in selecting higher-risk patients for cardiac catheterization was associated with improved detection of patients with single-vessel as well as multivessel CAD. New York has historically performed twice as many cardiac catheterizations as Ontario (1185 per 100 000 in New York vs 605 per 100 000 in Ontario).¹¹ In this study, we observed that the detection rate for left main or 3-vessel CAD suggests that New York was about half that of Ontario. Accordingly, the estimated per capita detection rate was similar in both jurisdictions with the population rate of left main stenosis of 29.6 per 100 000 in New York and 30.3 per 100 000 in Ontario, and the population rate of 3-vessel disease estimated at 61.6 per 100 000 in New York and 59.3 per 100 000 in Ontario. These findings demonstrated that a more restrictive approach in selecting patients for cardiac catheterization did not lead to substantial underdetection of patients with surgical coronary anatomy on a per capita basis.

Several groups have proposed using obstructive CAD rate as a potential quality indicator to enhance efficiency and improve quality.^{22,23} Our study lends support to these proposals as we demonstrated the ability to increase diagnostic yield of cardiac catheterization through improved patient selection. However, we do not believe the current study can be used to determine the optimal rate of obstructive CAD or optimal selection criteria for cardiac catheterization because decisions for procedure use are based on complex interactions be-

tween patients, physicians, and the local environment.²⁴ We do not wish to imply that the selection approach in Ontario is necessarily optimal.

We observed a higher rate of use for PCI and CABG at 30 days in New York than in Ontario among patients with obstructive CAD. Mortality at 30 days among patients with obstructive CAD did not differ significantly between the cohorts. These findings are consistent with prior regional comparisons that suggest a region with much higher invasive capacity usually leads to greater use of PCI procedures for more discretionary indications but may not reduce the frequency of adverse cardiac outcomes.⁸⁻¹⁰

Several potential limitations of this study deserve consideration. First, we compared population-wide data from Ontario with a selected study sample of patients undergoing cardiac catheterization in New York. To ensure generalizability of the New York cohort, we compared the demographics and prevalence of risk factors among patients who underwent coronary revascularization between our study sample and the entire New York, which demonstrated comparable results. Second, although the availability of many clinical variables and a large study sample allowed us to compare many characteristics associated with obstructive CAD, we were unable to assess the effect of race, body mass index, or physician characteristics because these variables were not collected in both databases. Finally, we were unable to formally apply appropriate-use criteria to compare the suitability of cardiac catheterization because we lack data to create appropriateness scores in Ontario.²⁵ The appropriateness-use criteria have been developed as 1 of the many existing tools designed to assist in improving quality of care and the use of scarce health care resources. For patients with suspected CAD, the appropriate use criteria categorized the appropriateness of procedure use based on the probability of CAD and most of the patients at low risk of CAD are considered as having inappropriate indications for cardiac catheterization. Similarly, we developed a prediction model to assess the probability of CAD and found that New York selects patients at lower risk of having CAD, suggesting that New York may have lower appropriateness scores than patients undergoing cardiac catheterization in Ontario. Although we were unable to formally apply the appropriate-use criteria because of the lack of suitable data, our study afforded similar insights by demonstrating that there is a significant opportunity to improve patient care and improve the use of health care resources.

In conclusion, we found increased use of cardiac catheterization in New York compared with Ontario and this reflects selection of patients at low risk of obstructive CAD. The observed pattern of selecting patients with a higher probability of having coronary disease for cardiac catheterization in Ontario was associated with improved diagnostic yield of the procedure.

ARTICLE INFORMATION

Author Contributions: Dr Ko had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Ko, Tu, Samadashvili, Hannan.

Acquisition of data: Samadashvili, Hannan.

Analysis and interpretation of data: All authors.

Drafting of the manuscript: Ko.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Samadashvili, Guo.

Obtained funding: Tu, Ko.

Administrative, technical, or material support: Hannan.

Study supervision: Tu, Hannan.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

Funding/Support: This study was supported by the Institute for Clinical Evaluative Sciences (ICES), which is funded by an annual grant from the Ontario Ministry of Health and Long-term Care (MOHLTC). The authors acknowledge that the clinical registry data used in this publication are from the Cardiac Care Network of Ontario and its member hospitals. The Cardiac Care Network of Ontario serves as a system support to the MOHLTC, Local Health Integration Networks, and service providers and is dedicated to improving the quality, efficiency, access and equity in the delivery of the continuum of adult cardiovascular services in Ontario, Canada. The Cardiac Care Network of Ontario is funded by the MOHLTC. The analysis of this study was supported by a Canadian Institutes of Health Research (CIHR) operating grant MOP (102487). Dr Ko is supported by a CIHR New Investigator Award. Dr Tu is supported by a Canada Research Chair in Health Services Research and a Career Investigator Award from the Heart and Stroke Foundation of Ontario. Dr Austin is supported by a Career Investigator Award from the Heart and Stroke Foundation of Ontario.

Role of the Sponsor: The sponsors had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit this manuscript.

Disclaimer: No endorsement by any of the supporting organizations is intended or should be inferred.

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