Impact of System and Physician Factors on the Detection of Obstructive Coronary Disease With Diagnostic Angiography in Stable Ischemic Heart Disease

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Background—Wide variation exists in the detection rate of obstructive coronary artery disease (CAD) with elective coronary angiography for suspected stable ischemic heart disease. We sought to understand the incremental impact of nonclinical factors on this variation.

Methods and Results—We included all patients who underwent coronary angiography for possible suspected stable ischemic heart disease, from October 1, 2008, to September 30, 2011, in Ontario, Canada. Nonclinical factors of interest included physician self-referral for angiography, the physician type (invasive or interventional), and hospital type. Hospitals were categorized into diagnostic angiogram only centers, stand-alone percutaneous coronary intervention centers, or full service centers with coronary artery bypass surgery available. Multivariable hierarchical logistic models were developed to identify system and physician-level predictors of obstructive CAD, after adjustment for patient factors. Our cohort consisted of 60986 patients, of whom 31726 had obstructive CAD (52.0%), with significant range across hospitals from 37.3% to 69.2%. Fewer self-referral patients (49.8%) had obstructive CAD compared with nonself-referral patients (53.5%), with an odds ratio of 0.89 (95% confidence interval, 0.86–0.93; P<0.001). Angiograms performed by invasive physicians had a lower likelihood of obstructive CAD compared with those by interventional physicians (48.2% versus 56.9%; odds ratio, 0.85; 95% confidence interval, 0.81–0.90; P<0.001). Fewer angiograms at diagnostic only centers showed obstructive CAD (42.0%) compared with full service centers (55.1%; odds ratio, 0.62; 95% confidence interval, 0.39–0.98; P=0.04). Nonclinical factors accounted for 23.8% of the variation between hospitals.

Conclusions—Physician and system factors are important predictors of obstructive CAD with coronary angiography. (Circ Cardiovasc Qual Outcomes. 2014;7:648-655.)

Key Words: angiography ■ coronary disease

Invasive coronary angiography has a central role in the diagnosis and subsequent management of stable ischemic heart disease (SIHD). 1 Angiography is associated with a risk of rare but potentially catastrophic adverse events, such as stroke, myocardial infarction, or death. 1 Moreover, it has substantial acquisition costs. Wide variation exists in the detection rates of obstructive coronary artery disease (CAD) with angiography across hospitals, with recent studies showing high rates of normal angiograms, raising concerns of potential overuse of this invasive and expensive test. 2–4

Many previous studies have studied the reasons for this variation; these have focussed primarily on patient and clinical factors. 2–4 However, substantial differences persist, despite accounting for these clinical differences. 2–4 Given the current environment of budgetary constraint, it is prudent to understand the nonclinical drivers of this residual variation, so as to make efficient use of scarce healthcare resources.

Potential nonclinical drivers include both physician and system factors. Coronary angiography can be performed by physicians with different levels of training and scopes of practice, as well as at a range of hospitals, from those with only diagnostic angiography facilities, to those with stand-alone percutaneous coronary intervention (PCI) capability, and finally full cardiac centers that have coronary artery bypass...
WHAT IS KNOWN

- There is wide variation in the detection of obstructive coronary artery disease by diagnostic coronary angiography in patients with stable ischemic heart disease. Previous reports have identified the patient and clinical factors that predict obstructive coronary artery disease on angiography.

WHAT THE STUDY ADDS

- Almost one quarter of the variation in the detection of obstructive coronary artery disease by angiography was because of physician and system factors.
- Angiograms performed by interventional as opposed to invasive cardiologists were more likely to show obstructive disease, as were angiograms performed at hospitals with percutaneous coronary intervention capability.
- Self-referral was associated with a lower detection of obstructive coronary disease.

Physician self-referral, whereby the physician referring the patient for a test is the same as the physician performing the test, is an area of increasing interest, given the potential for secondary financial gain.5–11 There is a paucity of data on the association between such physician and system factors and the yield of coronary angiography.

Ontario is Canada’s largest province, with >13 million residents, all of whom have universal access to physician and hospital services, through a single-payer publicly funded healthcare program, administered by the Ministry of Health and Long Term Care of Ontario. This provides an opportunity to study nonclinical system factors because patient access as a result of financial disadvantage is mitigated. Accordingly, our objective was to address this gap in knowledge by conducting a contemporary population-based assessment of all patients who underwent elective coronary angiography in Ontario, Canada. Our goal was to understand the incremental impact of physician and system factors on the variation in detection of obstructive CAD with coronary angiography after accounting for patient characteristics to identify potentially important foci for quality improvement.

Methods

This study was approved by the Institutional Research Ethics Board at Sunnybrook Health Sciences Center. Under Ontario’s Personal Health Information Protection Act, the need for patient consent was waived.3,12

Data Sources

Our analyses were conducted using data from the Cardiac Care Network (CCN) of Ontario, Canada.7,12 CCN is a network of the 18 member hospitals that provide advanced cardiac services in Ontario.3,12 CCN maintains a prospective clinical registry of all individuals who undergo cardiac angiography, PCI, cardiac surgery, and other invasive cardiac procedures in the province.3,12 This registry contains information on patient demographics, cardiac risk factors, and comorbidities in addition to data on preprocedural testing, such as exercise stress testing, echocardiography, and noninvasive functional stress testing. The CCN registry collects procedural details, including the presence and severity of coronary stenosis.3,13 Using encrypted unique patient identifiers to protect patient confidentiality, data from the CCN registry were linked to population-based administrative databases containing information on all Ontario residents, available at the Institute for Clinical Evaluative Sciences. Administrative databases of interest included the Canadian Institute for Health Information discharge abstract database that contains data on all hospitalizations. The Canadian Institute for Health Information discharge abstract database has comorbidities information that was used to complement the CCN data. In addition, we linked to the Ontario Drug Benefit database, which has comprehensive drug use information on patients over 65 years, for whom full drug coverage is provided for by the Ministry of Health and Long Term Care of Ontario.

Study Population

Our cohort consisted of all patients with an index elective, outpatient angiogram from October 1, 2008, to September 30, 2011. Inclusion criteria included a valid Ontario health card number to facilitate linkage, age over 20 years, and a documented indication for angiography in the CCN registry of investigation for possible SIHD. We excluded all patients whose indications for angiography were myocardial infarction, acute coronary syndrome, or valvular/structural heart disease. We also excluded patients with a hospitalization for a myocardial infarction/acute coronary syndrome in the 90 days before the index angiogram to identify a stable cohort. If multiple angiograms existed for the same patient in the accrual time period, only the first angiogram was retained in the cohort.

Outcomes

The primary outcome was the detection of obstructive coronary disease, defined as stenosis >70% in severity in any major epicardial coronary vessel (the left anterior descending, circumflex, or right coronary artery) or >50% in the left main artery, as recorded in the CCN registry.14 This definition is consistent with that used in previous studies.2,4,13 For patients with previous coronary artery bypass grafting, this definition was refined to a >70% stenosis in the bypass grafts or obstructive disease in epicardial arteries that were not previously bypassed. Secondary outcomes included presence of severe coronary stenosis, defined as either obstructive left main artery disease or triple vessel coronary disease. We also determined whether patients underwent revascularization by either PCI or coronary artery bypass grafting in the 90 days post-index angiography.

Exposures

The main physician factors of interest included the type of physician performing the procedure and physician self-referral. Physicians were classified as either invasive or interventional based on classification in the CCN registry. The CCN registry contains a field identifying the physician who referred the patient for angiography and a separate field identifying the physician who performed the angiogram. Where referral and procedural physician were identical, the case was designated as being self-referral. We also evaluated operator volume based on mean number of angiograms performed annually, as well as operator sex, and operator experience based on age, and number of years since graduation from medical school. The system factor that we studied was the type of hospital, categorized as either diagnostic laboratory only, stand-alone PCI, or full service, with coronary artery bypass grafting available on-site. Of the 18 hospitals in the CCN registry during the accrual period, 4 were diagnostic cath-only hospitals, whereas 3 were stand-alone PCI hospitals, with the remaining 11 being full service cardiac centers.

Statistical Analysis

To identify predictors of obstructive CAD, a multilevel hierarchical logistic model was developed, clustered by hospital. The dependent variable was the presence or absence of obstructive coronary stenosis.
First, we developed a null model, which only included the hospital-specific random effect. Then, patient factors were entered for risk adjustment based on clinical judgment. We included demographics, comorbidities, as well as findings on preprocedural noninvasive stress testing and left ventricular function. Continuous variables were centered using median values. Finally, we evaluated the impact of the physician and system factors. The c-statistic (equivalent to the area under the receiver operator curve) was used to evaluate the model discrimination, the ability to separate patients with and without the outcome of interest.16,17

The variance of the distribution of the hospital-specific random effect is a measure of the between-hospital variation. To understand the relative contribution of clinical and system factors to the variation between hospitals, we determined the proportional change in the variance of the hospital-specific random effect because we sequentially introduced patient and then nonclinical factors to the null model.

**Sensitivity Analysis: Unmeasured Confounders**

Given the observational nature of our analyses, we were concerned with the potential impact of referral/selection bias and specifically the potential impact of unmeasured confounders on our conclusions.18 To evaluate the robustness of our analyses, we conducted a sensitivity analysis to determine the impact of a hypothetical unmeasured confounder that was as strong a predictor of obstructive CAD as our most influential measured confounder. We restricted this sensitivity analysis to the comparison of interventional versus invasive physicians. We determined the required prevalence of the hypothetical unmeasured confounder that would negate our overall findings by causing the adjusted odds ratio (OR) between interventional and invasive physicians to reduce to unity (ie, OR of 1) or for the upper bound of the 95% confidence interval (CI) to cross unity. SAS version 9.3 (SAS Institute Inc, Cary, NC) was used for all analyses; *P*<0.05 was significant.

**Result**

### Study Population

As illustrated in the Figure, there were a total of 183,630 angiograms performed from October 1, 2008, to September 30, 2011, for the investigation of possible SIHD. Data on the referring physician were missing on 9397 patients (5.1%). The final cohort consisted of 60,986 patients, of whom 31,726 patients had obstructive coronary stenosis (52.0%). Across the 18 hospitals, the rate of obstructive coronary disease ranged from 37.3% to 69.2%. The baseline characteristics of the final cohort are shown in Table 1. In Appendix Table 1 in the Data Supplement, the preprocedural medication use for the 28,267 patients above the age of 65 years is reported. Overall, the rates of medication use before the angiogram were good, with over 70% of patients on statins.

Of the total cohort, 24,229 patients (39.7%) were classified as self-referral. There was a substantial range in self-referral rates across the 18 hospitals, from a low of 4.8% to a high of 74.6%. Interventional physicians performed 44.3% of the angiograms. The majority of angiograms were performed at the 11 full service centers (n=43,181; 70.8%), with 10,303 (16.9%) done at the cath-only hospitals and 7,502 (12.3%) at stand-alone PCI hospitals.

Between the 3 categories of hospitals, and types of physicians, there was substantial variation in the baseline characteristics and in the presence of preprocedural testing (Appendix Table II in the Data Supplement). In particular, more patients who had angiograms at diagnostic-only hospitals had more preprocedural testing (59.8% for diagnostic versus 55.8% for full service). In contrast, patients who were classified as self-referral had fewer preprocedural functional tests compared with nonself-referral patients (52.9% versus 56.9%, respectively), as did patients whose angiograms were performed by invasive cardiologists (52.2%) compared with interventional cardiologists (57.8%).

### Unadjusted Outcomes

There were consistent differences in the rates of obstructive coronary stenosis, severe disease, and revascularization among all physician and hospital groups (Table 2). Angiograms that were performed by interventional physicians had higher rates of obstructive CAD (56.9% versus 48.2%; *P*<0.001), a greater proportion of severe disease (11.2% versus 9.2%; *P*<0.001), and led to more revascularization (40.8% versus 30.7%; *P*<0.001) compared with those done by invasive cardiologists. Similar findings were seen for angiograms performed at full service compared with diagnostic-only hospitals, as well as for angiograms which were not self-referral cases compared with those that were (Table 2).

### Predictors of Obstructive CAD

The fully adjusted model is summarized in Table 3. After accounting for patient factors, self-referral was associated with an OR of 0.89 (95% CI, 0.86–0.93; *P*<0.001) in predicting obstructive coronary stenosis. Angiograms performed by invasive physicians had a lower likelihood of showing obstructive coronary stenosis (OR, 0.85; 95% CI, 0.81–0.90; *P*<0.001) compared with those performed by interventional
Table 1. Baseline Characteristics

<table>
<thead>
<tr>
<th>Covariates*</th>
<th>Total (n=60986)</th>
<th>Obstructive CAD (n=31726)</th>
<th>Nonobstructive CAD (n=29260)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient-level factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>64.1±11</td>
<td>65.9±10.4</td>
<td>62.1±11.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>39.244 (64)</td>
<td>23.865 (75)</td>
<td>15.379 (53)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rural</td>
<td>8298 (14)</td>
<td>4483 (14)</td>
<td>3815 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Medical comorbidities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>23.86 (75)</td>
<td>13.761 (43)</td>
<td>9.906 (34)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>50.206 (82)</td>
<td>27.385 (86)</td>
<td>22.821 (78)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>45.489 (75)</td>
<td>25.493 (80)</td>
<td>19.996 (68)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>History smoking</td>
<td>17.692 (29)</td>
<td>9.952 (31)</td>
<td>7.740 (27)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardiac risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>6.183 (3.0)</td>
<td>10.44 (3.3)</td>
<td>7.94 (2.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>75.3 (12)</td>
<td>435 (1.4)</td>
<td>318 (1.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PVD</td>
<td>4.483 (7.4)</td>
<td>2962 (9.3)</td>
<td>1521 (5.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous MI</td>
<td>13.61 (20)</td>
<td>849 (27)</td>
<td>387 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>COPD</td>
<td>12.461 (20)</td>
<td>6559 (21)</td>
<td>5857 (20)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Malignancy</td>
<td>11.943 (20)</td>
<td>6431 (20)</td>
<td>5512 (19)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Charlson score</td>
<td>0.8±1.3</td>
<td>0.9±1.3</td>
<td>0.7±1.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Cardiac status/testing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Had previous CABG</td>
<td>6145 (10)</td>
<td>4124 (13)</td>
<td>2021 (6.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV function</td>
<td>30.37 (5.0)</td>
<td>1701 (5.4)</td>
<td>1336 (4.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Exercise ECG risk</td>
<td>14.65 (24)</td>
<td>888 (28)</td>
<td>576 (20)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Functional imaging risk</td>
<td>17.08 (28)</td>
<td>10.22 (32)</td>
<td>686 (24)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CCS class</td>
<td>12.043 (20)</td>
<td>5284 (17)</td>
<td>6759 (23)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Hospital-level factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital type</td>
<td>726 (70)</td>
<td>379 (53)</td>
<td>297 (37)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetic angiocardiography</td>
<td>10.303 (17)</td>
<td>4331 (14)</td>
<td>5972 (20)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Data are n (%) unless otherwise indicated. †P-values are for the comparison of patients with obstructive to nonobstructive disease; ‡t-test was used for continuous variables while χ² test for categorical variables. §Income quintile by area: 1=lowest, 5=highest.

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Table 1. Continued

<table>
<thead>
<tr>
<th>Covariates*</th>
<th>Total (n=60986)</th>
<th>Obstructive CAD (n=31726)</th>
<th>Nonobstructive CAD (n=29260)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physician-level factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician self-referral</td>
<td>24.229 (40)</td>
<td>12.075 (38)</td>
<td>12.154 (42)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Interventional physician</td>
<td>26.997 (44)</td>
<td>15.356 (48)</td>
<td>11.641 (40)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operator age</td>
<td>48.6±9.4</td>
<td>48.3±9.1</td>
<td>49.0±9.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operator male sex (%)</td>
<td>57.776 (95)</td>
<td>30.054 (95)</td>
<td>27.722 (95)</td>
<td>0.370</td>
</tr>
<tr>
<td>Operator years since graduation</td>
<td>23.7±9.6</td>
<td>23.36±9.3</td>
<td>24.12±9.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operator annual volume</td>
<td>287.7±159.0</td>
<td>288.2±159.2</td>
<td>287.1±158.8</td>
<td>0.398</td>
</tr>
</tbody>
</table>

Hospital factors

- Full service: 43.181 (71)
- Stand-alone PCI: 7502 (12)
- Diagnostic angiography only: 10.303 (17)

Cardiologists. Operator experience, age, and sex were not significant predictors (Table 3). Although operator annual volume was a significant predictor of obstructive disease, its effect size was small (OR 1.02 per increase in 50 cases per year; 95% CI, 1.01–1.03; P<0.001). Hospital type was also a significant predictor, with angiograms at diagnostic centers having a 38% lower likelihood of showing obstructive disease compared with full service centers (OR, 0.62; 95% CI, 0.39–0.98; P=0.04).

The c-statistic of the full model was 0.74. The variance of the hospital random effects in the null model was 0.1095. There was minimal reduction to 0.1081 with the addition of patient factors. With the addition of hospital and physician factors, the variance of the hospital random effects reduced by 23.8% to 0.0824. Thus, the between-hospital variation in the detection of obstructive CAD for a standardized patient (ie one whose covariates are set to 0) was substantially less when hospital and physician factors were accounted for.

Sensitivity Analysis

We calculated the difference in prevalence required to negate our overall findings for an unmeasured confounder with an effect size as strong as that of male sex, which was the most influential predictor. Male sex had an OR of 2.8 for predicting obstructive CAD (Table 3). An unmeasured confounder, with an effect size as strong as male sex, would need to have a difference in prevalence between the interventional and invasive groups of 70% to reduce the OR of physician type to 1; the difference in prevalence would need to be 48% to have the 95%
CI cross unity. These are highly unlikely scenarios. To provide context, none of the measured confounders had a difference in prevalence of >10% between groups.

### Discussion

In this population-based multicenter registry, we found that yield of elective coronary angiography varied considerably across institutions and that nonclinical factors were important contributors to the observed variation. Having an interventional cardiologist perform the procedure and the absence of self-referral were associated with improvements in the detection of obstructive CAD. In particular, angiograms performed at diagnostic only centers were associated with a 39% less likelihood of obstructive CAD. This research sets the stage for further work into understanding the drivers of the differences observed between physicians and hospitals, so as to identify foci for quality improvement.

In SIHD, the goal of coronary angiography is to establish or rule out the presence of hemodynamically significant disease; as such there is value in a normal angiogram. Importantly, there is no ideal proportion of procedures with significant disease that institutions should target.19 Our objective was not to recommend such a target but rather to understand whether physician and hospital characteristics contribute to the variation in the detection of obstructive CAD. Our study builds on the previous studies conducted in this area, which predominately examined clinical factors.2–4,15 Patel et al4 found that only teaching hospital status was associated with a higher yield, with a \( P \) value of 0.03.2 However, the importance of teaching status as a key hospital-level predictor has been inconsistent among previous studies.2,3,15

Practice variation has been observed in many procedures, and if such variation is because of factors other than patient characteristics, such variation may translate into poorer quality of care, with differences in patient outcomes and unnecessarily high costs.21 Our study specifically addressed this point by focussing on the incremental impact of physician and hospital types, after accounting for patient-level differences. We found that for a standardized patient undergoing elective angiography (ie, 1 with similar clinical features and preprocedural testing), there remained important variation between the type of physician, the presence of self-referral, and the type of hospital. These nonclinical factors accounted for almost one quarter of the between-hospital variation observed. Moreover, the impact of these nonclinical factors in predicting obstructive CAD was substantial.

Our study cannot establish the underlying reason for these discrepancies, but we can postulate as to several potential mechanisms. First, the different types of physicians and hospitals may have variable access to preprocedural testing. This is particularly relevant, given the excess capacity currently for angiography evidenced by absence of wait times, in contrast to the limited capacity for some types of noninvasive testing, such as stress echocardiography. Interestingly, we found discordant results in that factors such as hospital type, which were associated with lower yield of angiography, in fact were associated with more preprocedural testing. This suggests that it is not the availability of preprocedural noninvasive testing but rather the interpretation and subsequent management based on noninvasive results that differ.

Second, there may be differences in education and expectations among the physician and hospital groups, in terms of the need for angiography to confirm or rule out disease. In particular, this may explain the differences between interventional and invasive physicians and the difference in practice between the hospital types. These 2 factors are likely highly related because interventional physicians are more likely to practice in PCI alone or full service centers.
Finally, although Ontario has universal health care, physicians are remunerated on a fee-for-service basis and institutions receive funding based on meeting specific procedural volumes. As such, despite the absence of formal individual physician volume requirements for diagnostic angiography in the province, we cannot discount that secondary financial incentives may play a role in the variations we observed, especially in regard to self-referral and potentially operator volume. However, it should be noted that although statistically significant, the association between both self-referral or operator volume and the detection of obstructive CAD were somewhat modest.

The variation in detecting obstructive CAD reflects differences in the approach to diagnostic angiography because of wide spectrum of training, financial incentives, and local practices style. We would argue that this variation in the use of angiography is undesirable, given that it is an invasive test with potential for harm, as well as substantial expense. Therefore, this variation should be a focus for quality improvement. These quality improvements should target the physician and system factors identified in our study to determine whether alternative approaches to suspected ischemic heart disease can be developed or alternative incentives such that this variation can be reduced.

An important caveat to our work is that we used anatomic criteria to define obstructive CAD, similar to previous publications in this area. Although this is the traditional method of defining significant CAD, and therefore central to both guidelines and Appropriate Use Criteria in diagnostic angiography, it is important to recognize the importance of complementary functional information, specifically with fractional flow reserve (FFR). This is particularly the case for borderline lesions (ie, 50%–70%), where FFR has been shown to be useful in determining hemodynamic significance and potential benefit of revascularization. The CCN data did not contain FFR data over this time period, and as such, we cannot comment on how FFR may have played a role in the yield of angiography or its impact on the variation between institutions. This is relevant as FFR is restricted to interventional
cardiologists and centers with PCI capability. Because the use of FFR has grown, this is an important area for further study.

Our study must be interpreted in the context of several limitations that warrant discussion. The actual referral mechanism for angiography across the 18 hospitals varies. In some institutions, a scheduling coordinator will book patients that are referred directly to the catheterization laboratory, and the procedural physician will meet the patient only at the time of angiography. In this setting, there is the potential that higher risk patients will be preferentially booked with interventional physicians by the coordinator to facilitate same-sitting PCI. This potential bias is mitigated by the fact that we excluded patients with acute presentations; in addition, our risk adjusted models continued to show an association between physician type that was independent of clinical factors. Second, given the registry-based nature of our analyses, there may be reporting errors; this potential limitation is mitigated by previous chart audits that have validated the accuracy of the clinical data in the CCN registry. Third, there may be systematic under or over reading of coronary artery severity by physician groups. We are reassured that there was good agreement seen in a previous validation study comparing coronary anatomy as recorded in the CCN registry against a core laboratory, and this was consistent across the CCN member hospitals. Our study was conducted in a single Canadian province. Although the referral patterns, as well as physician and hospital incentives, are potentially different in other jurisdictions such as the United States, previous studies conducted in those areas have also found similar variation in the yield of diagnostic angiography. Given the fee-for-service physician remuneration model in Ontario, we think that the findings are likely to be directly applicable to other jurisdictions with similar remuneration models. Finally, this is an observational study, and as such despite the use of multivariable statistical techniques to account for patient differences between hospitals and physician type, we cannot discount the possibility of residual confounding because of factors not included in the CCN database. We conducted sensitivity analyses that suggest that unmeasured confounders are unlikely to qualitatively change our conclusions. Nonetheless, our findings should be considered hypothesis generating and not conclusive.

In conclusion, we found that hospital and physician factors are important predictors of obstructive CAD with elective coronary angiography in SIHD. Understanding the reasons for why particular hospital and physician groups have a lower threshold for angiography should be a focus of quality improvement initiatives to make more efficient use of this invasive procedure. This will translate into both cost savings, as well as improved care for patients by eliminating exposure to the risks of unnecessary testing.

Acknowledgments

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Disclosures

None.

References


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