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Assessing the Association of Appropriateness of Coronary Revascularization and Clinical Outcomes for Patients With Stable Coronary Artery Disease

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Objectives The study assessed the appropriateness of coronary revascularization in Ontario, Canada, and examined its association with longer-term outcomes.

Background Although appropriate use criteria for coronary revascularization have been developed to improve the rational use of cardiac invasive procedures, it is unknown whether greater adherence to appropriateness guidelines is associated with improved clinical outcomes in stable coronary artery disease.

Methods A population-based cohort of stable patients undergoing cardiac catheterization was assembled from April 1, 2006, to March 31, 2007. The appropriateness for coronary revascularization at the time of coronary angiography was retrospectively adjudicated using the appropriate use criteria. Clinical outcomes between coronary revascularization and medical treatment without revascularization, stratified by appropriateness categories, were compared.

Results In 1,625 patients with stable coronary artery disease, percutaneous coronary intervention or coronary artery bypass grafting was only performed in 69% who had an appropriate indication for coronary revascularization. Coronary revascularization was associated with a lower adjusted hazard of death or acute coronary syndrome (hazard ratio [HR]: 0.61; 95% confidence interval [CI]: 0.42 to 0.88) at 3 years compared with medical therapy in appropriate patients. The rate of coronary revascularization was 54% in the uncertain category and 45% in the inappropriate category. No significant difference in death or acute coronary syndrome between coronary revascularization and no revascularization in the uncertain category (HR: 0.57; 95% CI: 0.28 to 1.16) and the inappropriate category (HR: 0.99; 95% CI: 0.48 to 2.02) was observed.

Conclusions Using the appropriateness use criteria, we identified substantial underutilization and overutilization of coronary revascularization in contemporary clinical practice. Underutilization of coronary revascularization is associated with significantly increased risks of adverse outcomes in patients with appropriate indications. (J Am Coll Cardiol 2012;60:1876–84) © 2012 by the American College of Cardiology Foundation

Marked regional variations in the use of coronary revascularization continue to exist in Canada and in the United States (1–5). It is well documented that these discrepancies are not fully explained by differences in demographics and clinical factors but are in part related to the local practice culture (1–4). Growing concerns about the potential misuse of advanced cardiac technologies and rising healthcare costs have rekindled interest in using appropriateness criteria to

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improve the rational use of coronary revascularizations (6,7). The appropriate use criteria for coronary revascularization were recently developed by the American College of Cardiology Foundation and 5 other professional organizations in the United States (6). Using the Delphi panel methodology, an expert panel rated a large number of common clinical scenarios and categorized coronary revascularizations as appropriate, uncertain, or inappropriate (6). Coronary revascularization is considered appropriate when the expected benefits exceeded the expected negative consequences of the procedure (6). Conversely, coronary revascularization is considered inappropriate when it is unlikely to improve the patient's health outcomes or survival (6). These criteria were recently applied by Chan et al. (7), who found that only about half of all patients undergoing percutaneous coronary intervention (PCI) procedures in the United States for nonacute indications were considered appropriate.

Despite the vigorous process that has been put forth for their development, many ratings in the appropriate use criteria were based on experts' opinion and their knowledge of the clinical literature. Accordingly, the validity of the appropriateness use criteria remains unknown. Specifically, do patients with appropriate indications who received coronary revascularization have better outcomes than patients treated with medical therapy in clinical practice? Do patients with inappropriate indications who received coronary revascularization fare worse compared with those that did not? Validation of appropriate use criteria for coronary revascularization in the real world is essential before they are widely disseminated as a measure of quality of care and/or to make reimbursement decisions. Accordingly, our main objective was to perform a population-based study to evaluate the association between appropriateness of coronary revascularization and longer-term outcomes.

Methods

System context. The Ontario government reimburses all cardiac invasive procedures for its citizens without user fees or copayments (2). Provision of cardiac invasive procedures is regionalized in Ontario. There are currently 18 cardiac invasive centers in Ontario serving a population of 13.2 million people. In these centers, 11 perform PCI and coronary artery bypass grafting (CABG) surgery, 3 are stand-alone PCI centers without cardiac surgery backup, and 4 perform only cardiac catheterization. More than 45,000 cardiac catheterizations, 20,000 PCIs, and 8,000 CABGs are performed annually in the province.

The VRPO study. The VRPO (Variation in Revascularization Practices in Ontario) study was conducted by the Cardiac Care Network (CCN) of Ontario in partnership with the Institute for Clinical Evaluative Sciences to examine variations in the use of PCI and CABG across the province (8). A retrospective chart review was conducted on patients undergoing cardiac catheterization from April 1, 2006, to March 31, 2007, at all the Ontario cardiac invasive centers. A population-based sample of 8,972 patents was randomly selected from the CCN of Ontario cardiac invasive procedure database. This study sample represented 20% of all angiograms performed in the province at the time of the study. Experienced cardiology research nurses abstracted detailed clinical information from hospital charts focusing on data variables used in the appropriate use criteria for coronary revascularization that included: 1) clinical presentation and symptom severity; 2) intensity of anti-ischemic medical therapy; 3) ischemic burden as determined by noninvasive testing; and 4) extent of coronary artery stenosis on coronary angiography (6,7).

Abbreviations and Acronyms

ACS = acute coronary syndrome
CABG = coronary artery bypass grafting
CI = confidence interval
CCN = Cardiac Care Network of Ontario
HR = hazard ratio
PCI = percutaneous coronary intervention

Study sample. The study sample for this analysis was restricted to patients undergoing cardiac catheterization at all the cardiac invasive facilities in Ontario for a suspected diagnosis of coronary artery disease. We did not include patients with acute indications for coronary angiography such as myocardial infarction or unstable angina because a previous study has shown almost all coronary revascularizations to be appropriate (7). We excluded patients who had cardiac catheterization or PCI in the year preceding the index procedure in order to capture an inception cohort of patients undergoing coronary angiography. We also excluded patients with prior CABG. We included only those patients with coronary artery disease, defined as luminal stenosis greater than 50%, because the appropriateness use criteria did not consider patients with normal to mild coronary artery disease. Only patients with a valid health card number were included in the study.

Outcomes. Coronary revascularization procedures (PCI or CABG) occurring within 60 days after the index cardiac catheterization were determined by the CCN database, which tracks clinical data on all cardiac invasive procedures in the province (9). The primary long-term outcome measure was a composite of all-cause mortality and recurrent hospitalizations for acute coronary syndrome (ACS). Mortality was determined using the Ontario Registered Persons Database. Recurrent hospitalization for ACS (myocardial infarction or unstable angina) was identified from the Canadian Institute for Health Information Discharge Abstract Database (International Classification of Diseases, 10th revision, disease codes I20, I21, I22, I23.82, I24) (10). Complete follow-up data were available for all patients through March 31, 2010.

Statistical analysis. The appropriateness for coronary revascularization at the time of coronary angiography was retrospectively adjudicated using the appropriate use criteria. Each cardiac catheterization procedure was assigned an appropriateness score from 1 to 9, with a score of 7 to 9 denoting the patient had an appropriate indication for

coronary revascularization, a score of 4 to 6 denoting uncertain indication, and a score of 1 to 3 denoting inappropriate indication (6). Patients were then followed to determine the treatment they received following the coronary angiography. This construct not only allowed us to determine the use of coronary revascularization among patients with appropriate, uncertain, and inappropriate indications, but also enabled us to examine patients who were treated medically (no coronary revascularization) in different appropriateness categories.

To assess the association between appropriateness of coronary revascularization and longer-term outcomes, we compared the outcomes of patients who were treated with coronary revascularization and medical therapy, according to their appropriateness categories in pre-specified analysis, which was consistent with prior studies in the literature (11,12). In other words, we compared outcomes of revascularization versus no revascularization in patients with appropriate, uncertain, and inappropriate indications in stratified analyses. It is important to note that coronary revascularization patients also received medical therapy, and thus, our analyses examined the incremental benefit of coronary revascularization on top of medical therapy. We used appropriate statistical tests (chi-square test for categorical variables and *t* tests for continuous variables) to compare characteristics of patients treated with coronary revascularization and medical therapy. Multivariable proportional hazards models were used to adjust for the potential impact of confounding factors between the treatment groups in each appropriateness stratum. Coronary revascularization within 60 days of the coronary angiography was modeled as time-varying exposure to account for the potential difference in revascularization time after the index cardiac catheterization. The use of a time-dependent covariate enabled the treatment variable to vary during the observation period after cardiac catheterization and allowed us to minimize the impact of survivorship bias by estimating the effect of current exposure on the instantaneous hazard of adverse outcomes compared with medical therapy. Candidate variables of interests were selected based on clinical knowledge that included demographics (age, sex), severity of angina, extent of coronary artery disease, cardiac risk factors (hypertension, diabetes, hyperlipidemia), comorbidities (prior myocardial infarction, prior heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, and peripheral vascular disease), physician characteristics (invasive or interventional cardiologist), and hospital characteristics (ability to perform cardiac catheterization only, cardiac catheterization and PCI, or cardiac catheterization, PCI, and CABG).

A series of sensitivity analyses were undertaken to examine the robustness of our results. First, we examined the impact of including variables used to categorize appropriateness categories (e.g., symptom severity, medical therapy, noninvasive testing, and coronary stenosis) in all the adjustment models. Second, we reanalyzed our results by including a robust variance estimator to account for the potential impact of clustering of hospitals (13). In the previous sensitivity analyses, our overall results did not significantly change.

All 2-sided p values <0.05 were considered statistically significant. SAS version 9.2 (SAS Institute, Cary, North Carolina) was used to conduct the analyses.

Results

Study sample. The creation of the study sample is shown in Figure 1. The VRPO study included data on 8,972 patients undergoing coronary angiography. There were 3,625 patients who had stable coronary artery disease without prior CABG, coronary angiogram, or PCI in the previous year. We excluded 1,495 patients who had normal to mild coronary arteries. In addition, we were also not able to assign appropriateness scores to 224 patients because of borderline coronary stenosis, 103 patients because of lack of ischemic evaluation prior to coronary revascularization, and 220 patients due to lack of documented angina classification. Our final dataset for analysis included 1,628 patients.

Rate of coronary revascularization according to appropriateness category. The distribution of appropriateness scores in our cohort is shown in Figure 2. At the time of the coronary angiography, 61% of patients with significant coronary artery stenosis had appropriate indications for coronary revascularization, 20% had uncertain indications, and 19% had inappropriate indications. Among patients who received coronary revascularization, 68% of all procedures were considered appropriate, 18% were considered uncertain, and 14% were considered inappropriate.

Of the 991 patients who had appropriate indications, coronary revascularization was performed in 69% (Fig. 3, Table 1). PCI was the mode of coronary revascularization in 57% of appropriate patients and 43% received CABG. Of the 326 patients classified as uncertain candidates, 54% underwent coronary revascularization in which 86% received PCI as the mode of revascularization. Of the 311 patients who had inappropriate indications, 45% underwent coronary revascularization, most (82%) via PCI procedures.

Among the 997 patients who received coronary revascularization, 68% were considered appropriate, 18% were considered uncertain, and 14% were considered inappropriate. For the 654 patients who received PCI, 60% of all PCIs were considered appropriate, 23% were uncertain, and 18% were inappropriate. For the 343 patients undergoing CABG, the majority of patients (85%) were considered appropriate, 8% were uncertain, and 7% were inappropriate.

Baseline characteristics according to treatment and appropriateness categories. The baseline characteristics of patients treated with coronary revascularization and medical therapy with no revascularization, stratified by appropriateness categories, are shown in Table 1. Among patients with appropriate indications, those who received coronary revascularization were slightly younger, were less likely to have cardiac risk factors, and had no prior cardiac history. The 2 treatment groups did not differ significantly in symptom

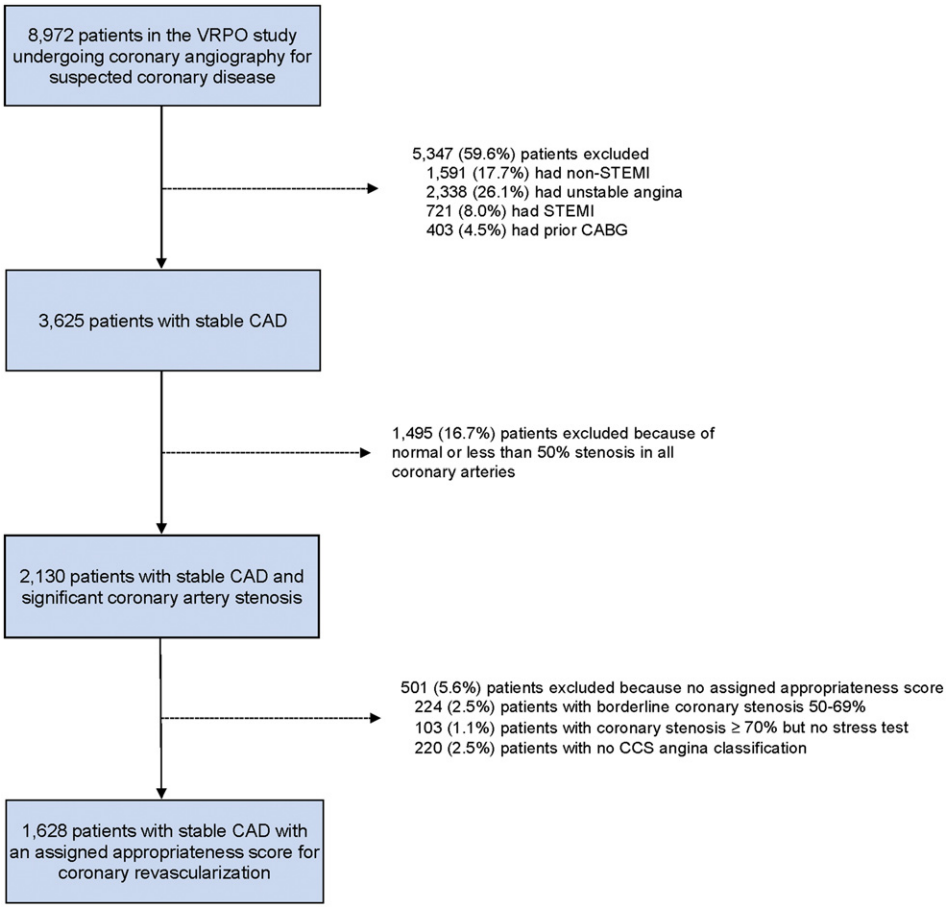

Figure 1 **Creation of the Study Sample**

The diagram details the way the final study sample of 1,628 patients was created. CABG = coronary artery bypass grafting; CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; STEMI = ST-segment elevation myocardial infarction; VRPO = Variations in Revascularization Practices in Ontario.

status, medical management, ischemic evaluation, or extent of coronary artery disease, which were factors used to categorize the appropriateness scores.

Similar trends were also observed in the baseline characteristics among uncertain and inappropriate indications, in which patients who received coronary revascularization were younger and had slightly fewer medical and cardiac conditions. One of the largest differences in the uncertain category was physician characteristics, as interventional cardiologists performed 42% of the cardiac catheterization in patients who subsequently received coronary revascularization versus only performing 26% in the no revascularization group ($p = 0.002$) (Table 1).

Association of coronary revascularization and outcomes across appropriateness categories. In patients who had appropriate indication for coronary revascularization, the composite unadjusted endpoint of death and recurrent ACS at 3 years occurred in 11.8% in the coronary revascularization group compared with 16.1% in the no revascularization group (Table 2). At 3 years, mortality was 3.8% in the coronary revascularization group and 9.0% in the no revascularization group; repeat ACS was 9.4% in the coronary revascularization group and 9.9% in the no revascularization group. Coronary revascularization was associated with a lower hazard of death or repeat ACS (hazard ratio [HR]: 0.61; 95% confidence interval [CI]: 0.42 to 0.88) after adjusting for differences in demographics, comorbidities, and physician and hospital characteristics (Table 2). Patients undergoing CABG had a significantly lower hazard (HR: 0.33; 95% CI: 0.18 to 0.61) as compared with medical therapy, whereas no significant reduction in hazard associated with PCI was observed (HR: 0.83; 95% CI: 0.54 to 1.26). The HR associated with CABG was significantly different as compared with PCI ($p = 0.006$).

In the uncertain category, unadjusted event rates at 3 years among the coronary revascularization group and the no revascularization group were 8.0% and 15.3% for death or repeat ACS, 2.3% and 12.7% for mortality, 5.6% and 5.3% for repeat ACS. Coronary revascularization was not significantly associated with a reduction of death or ACS

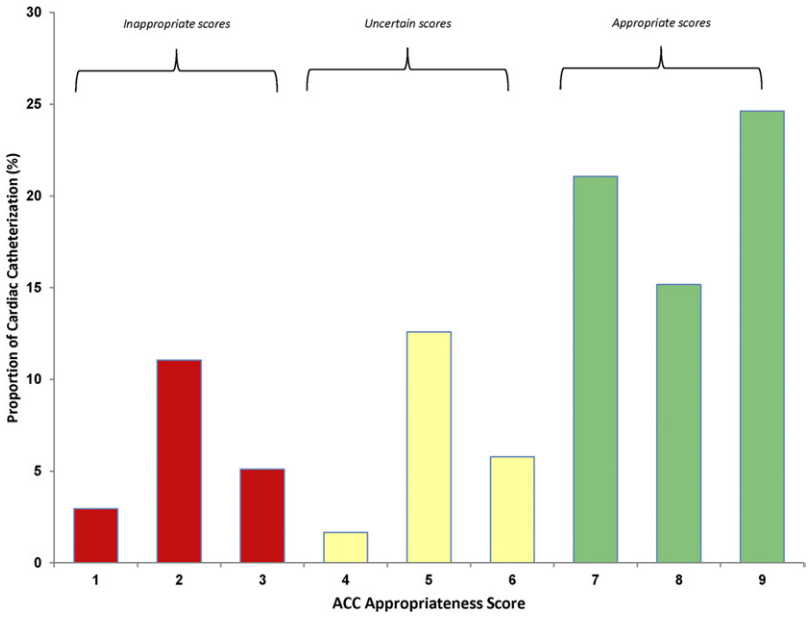

Figure 2 Distribution of Appropriateness Score

Distribution of the appropriateness score in patients with stable coronary artery disease undergoing cardiac catheterization. A score of 1 to 3 indicates inappropriate indication, a score of 4 to 6 indicates uncertain indication, and a score of 7 to 9 indicates appropriate indication for coronary revascularization. ACC = American College of Cardiology.

(HR: 0.57; 95% CI: 0.28 to 1.16). In the inappropriate category, unadjusted event rates at 3 years among the coronary revascularization group and the no revascularization group were 14.2% and 9.4% for death or repeat ACS, 2.8% and 5.3% for mortality, 12.0% and 5.3% for repeat ACS. Similarly, no significant difference in the adjusted hazard of death and repeat ACS (HR: 0.99; 95% CI: 0.48 to 2.02) between the treatment groups in patients who had an inappropriate indication (Table 2).

Discussion

Our study provides validation to the appropriate use criteria by demonstrating not receiving revascularization among appropriate candidates was associated with significantly increased risks of adverse events compared with those who had undergone revascularization. In our population-based cohort of patients with stable coronary artery disease, we found that 68% of all coronary revascularizations were considered appropriate, 18% were considered uncertain, and 14% were considered inappropriate. We also found underutilization of coronary revascularization in which more than 30% of patients with appropriate indications did not receive revascularization. By contrast, although the absolute number of uncertain and inappropriate coronary revascularizations was low, almost 50% of patients who had uncertain or inappropriate indications at coronary angiography received coronary revascularization.

In a large PCI cohort in the United States, it was recently demonstrated that more than 98% of the procedures in patients with acute indications were considered appropriate (7). For patients with nonacute indications, however, it was shown that PCI procedures were considered appropriate in only 50%, uncertain in 38%, and inappropriate in 12% (7). Other studies have shown that the United States perform substantially more coronary revascularization procedures as compared with Canada in patients with stable coronary artery disease (2,14). Our data suggest higher revascularization rates in the United States may in part be related to higher rates of revascularization in patients with uncertain indications. Future evaluation is needed to confirm whether discrepancies in appropriateness of coronary revascularization exist and whether they can be attributed to differences in implicit and explicit incentives associated with the different models of healthcare financing between the 2 countries.

Our findings extend prior knowledge and provide new insights into the appropriateness of coronary revascularization in current clinical practice. By assessing the appropriateness of coronary revascularization at the time of coronary angiography and following patients for treatment strategies, we were able to demonstrate underutilization (i.e., patients with appropriate indication but no revascularization) and overutilization (i.e., patients with inappropriate indications and received revascularization). Although proliferation of cardiac technology has been the focus of recent healthcare reforms (1,15), underutilization of beneficial therapy con-

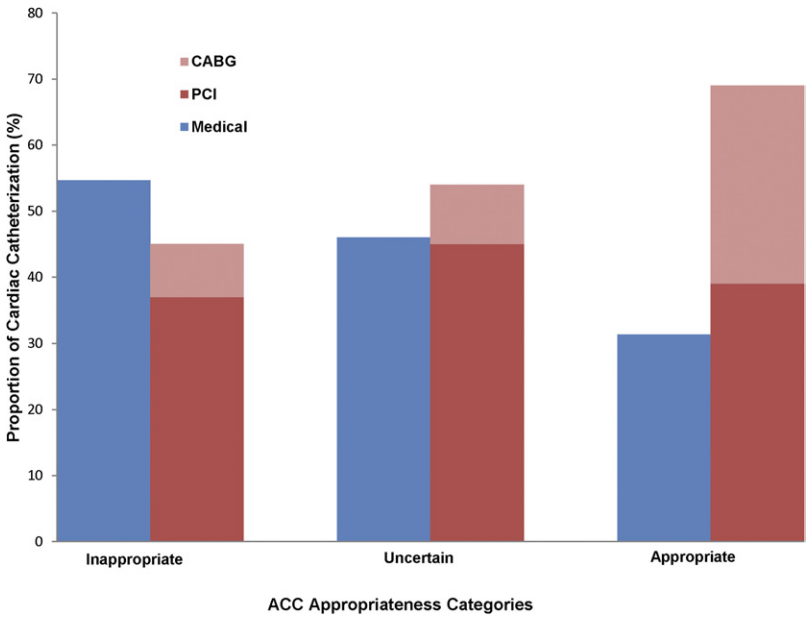

Figure 3 **Treatment According to Appropriateness Categories**

Proportions of patients undergoing medical therapy, percutaneous coronary intervention (PCI), or coronary artery bypass grafting (CABG) in different appropriate categories. ACC = American College of Cardiology.

tinues to exist for a significant proportion of patients in clinical practice. We observed higher risk characteristics and more frequent comorbidities among patients who did not receive coronary revascularization, consistent with the phenomenon previously described as "treatment-risk paradox," a pervasive pattern in medicine in which treatment propensity decreases as a result of increasing risk profiles of patients (16,17). It is also possible that underutilization of appropriate coronary revascularization is in part related to increasing complexity of coronary artery disease.

Although proliferation of cardiac technology has been the focus of recent healthcare reforms, underutilization of beneficial therapy continues to exist for a significant proportion of patients in clinical practice. Among patients who had appropriate indications but no coronary revascularization, 36% were recommended medical treatment by the cardiologist, 4.5% were turned down for coronary revascularization, and 2.6% of patients had a preference for treatment. However, the majority of appropriate patients had no documented reasons to explain why coronary revascularization was not performed. In addition, we observed higher risk characteristics and more frequent comorbidities among patients who did not receive coronary revascularization, consistent with the phenomenon previously described as "treatment-risk paradox"—a pervasive pattern in medicine in which treatment propensity decreases as a result of increasing risk profiles of patients (18). Previously, Cabana et al. (19) identified physician knowledge, attitude, and external factors as the 3 main barriers as to why physicians do not practice in accordance with guidelines.

Hemingway et al. (11,12,20) previously validated appropriateness criteria derived in the mid-1990s and found an association between underutilization of cardiac invasive procedures and increased risk of adverse outcomes among appropriate candidates. Indeed, 1 of the most important findings of our study was the observation that coronary revascularization was associated with lower hazards of death or recurrent ACS in appropriate patients with stable coronary artery disease using the revised criteria. This may be surprising given the results of the COURAGE (Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation) study, which showed no difference in clinical outcomes between PCI and medical therapy among patients with stable coronary artery disease (21). However, it is important to note that many patients in our study would likely be excluded in the COURAGE trial as they had substantial ischemic burden (40% with Canadian Cardiovascular Society class III or IV angina, 45% multiple vessel disease or left main stenosis, and 65% with high-risk stress test). In fact, 40% of the appropriate candidates in our study received CABG, which was not a treatment option for the COURAGE patients. Indeed, CABG was associated with a significantly lower hazard of adverse outcomes compared with medical therapy among patients with appropriate indications. There was no significant different in the adjusted HRs of death or ACS between coronary revascularization and no revascularization in the uncertain and inappropriate category. Test of interactions between coronary revascularization and appropriateness category was not significant ($p = 0.56$).

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Table 1 Clinical Characteristics According to Appropriateness Categories and Coronary Revascularization

Characteristics	Inappropriate Indications			Uncertain Indications			Appropriate Indications		
	No Revascularization (n = 170)	Revascularization (n = 141)	p Value*	No Revascularization (n = 150)	Revascularization (n = 176)	p Value*	No Revascularization (n = 311)	Revascularization (n = 680)	p Value*
Age, yrs	65.0 ± 9.7	62.6 ± 10.8	0.04	65.5 ± 10.2	63.9 ± 9.9	0.14	66.9 ± 10.2	65.1 ± 10.2	0.01
Female	54 (31.8%)	39 (27.7%)	0.43	42 (28.0%)	40 (22.7%)	0.27	78 (25.1%)	156 (22.9%)	0.46
Severity of chest pain			0.22			0.32			0.08
No angina	39 (22.9%)	21 (14.9%)		49 (32.7%)	42 (23.9%)		51 (16.4%)	68 (10.0%)	
CCS class I	24 (14.1%)	19 (13.5%)		19 (12.7%)	27 (15.3%)		29 (9.3%)	68 (10.0%)	
CCS class II	65 (38.2%)	62 (44.0%)		65 (43.3%)	83 (47.2%)		100 (32.2%)	241 (35.4%)	
CCS class III	34 (20.0%)	36 (25.5%)		16 (10.7%)	24 (13.6%)		119 (38.3%)	276 (40.6%)	
CCS class IV	8 (4.7%)	≤5 (2.1%)		≤5 (0.7%)	0 (0.0%)		12 (3.9%)	27 (4.0%)	
Extent of coronary disease			<0.001			0.66			0.13
Mild disease (50%–69%)	44 (25.9%)	≤5 (2.8%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	
1 vessel	93 (54.7%)	75 (53.2%)		94 (62.7%)	103 (58.5%)		93 (29.9%)	198 (29.1%)	
2 vessels	33 (19.4%)	60 (42.6%)		40 (26.7%)	55 (31.3%)		80 (25.7%)	170 (25.0%)	
3 vessels	0 (0.0%)	≤5 (1.4%)		16 (10.7%)	18 (10.2%)		94 (30.2%)	176 (25.9%)	
Left main stenosis	0 (0.0%)	0 (0.0%)		0 (0.0%)	0 (0.0%)		44 (14.1%)	136 (20.0%)	
Cardiac history									
Previous myocardial infarction	33 (19.4%)	39 (27.7%)	0.09	54 (36.0%)	43 (24.4%)	0.02	96 (30.9%)	148 (21.8%)	0.002
Previous heart failure	10 (5.9%)	≤5 (3.5%)	0.34	11 (7.3%)	≤5 (2.3%)	0.03	35 (11.3%)	27 (4.0%)	<0.001
Previous PCI	40 (23.5%)	26 (18.4%)	0.27	27 (18.0%)	32 (18.2%)	0.97	42 (13.5%)	89 (13.1%)	0.86
Cerebrovascular disease	10 (5.9%)	≤5 (3.5%)	0.34	15 (10.0%)	15 (8.5%)	0.65	27 (8.7%)	47 (6.9%)	0.33
Peripheral vascular disease	21 (12.4%)	7 (5.0%)	0.02	14 (9.3%)	11 (6.3%)	0.30	38 (12.2%)	45 (6.6%)	0.003
Cardiac risk factors and medical comorbidities									
Hypertension	108 (63.5%)	96 (68.1%)	0.40	112 (74.7%)	121 (68.8%)	0.24	237 (76.2%)	491 (72.2%)	0.19
Hyperlipidemia	124 (72.9%)	99 (70.2%)	0.60	117 (78.0%)	136 (77.3%)	0.88	266 (85.5%)	529 (77.8%)	0.01
Diabetes	55 (32.4%)	39 (27.7%)	0.37	50 (33.3%)	45 (25.6%)	0.12	113 (36.3%)	198 (29.1%)	0.02
Chronic kidney disease	41 (24.1%)	32 (22.7%)	0.77	37 (24.7%)	34 (19.3%)	0.24	95 (30.5%)	160 (23.5%)	0.02
COPD	17 (10.0%)	≤5 (3.5%)	0.03	15 (10.0%)	8 (4.5%)	0.06	22 (7.1%)	29 (4.3%)	0.06
Depression	9 (5.3%)	12 (8.5%)	0.26	6 (4.0%)	7 (4.0%)	0.99	20 (6.4%)	24 (3.5%)	0.04
Cancer	8 (4.7%)	≤5 (2.1%)	0.22	11 (7.3%)	11 (6.3%)	0.70	25 (8.0%)	38 (5.6%)	0.14
Stress test			0.19			0.10			0.06
Not done	84 (49.4%)	61 (43.3%)		38 (25.3%)	45 (25.6%)		68 (21.9%)	97 (14.3%)	
Low risk	86 (50.6%)	78 (55.3%)		54 (36.0%)	84 (47.7%)		53 (17.0%)	138 (20.3%)	
Intermediate risk	0 (0.0%)	≤5 (1.4%)		13 (8.7%)	11 (6.3%)		11 (3.5%)	25 (3.7%)	
High risk	0 (0.0%)	0 (0.0%)		45 (30.0%)	36 (20.5%)		178 (57.2%)	418 (61.5%)	
Number of antianginal medications									
0	40 (23.5%)	30 (21.3%)	0.30	36 (24.0%)	36 (20.5%)	0.28	47 (15.1%)	90 (13.2%)	0.56
1	95 (55.9%)	71 (50.4%)		63 (42.0%)	90 (51.1%)		132 (42.4%)	287 (42.2%)	
2	29 (17.1%)	29 (20.6%)		41 (27.3%)	44 (25.0%)		97 (31.2%)	238 (35.0%)	
3	6 (3.5%)	11 (7.8%)		10 (6.7%)	6 (3.4%)		35 (11.3%)	65 (9.6%)	
Left ventricular ejection fraction			0.02			0.07			<0.001
>60%	96 (56.5%)	70 (49.6%)		79 (52.7%)	101 (57.4%)		137 (44.1%)	375 (55.1%)	
40%–59%	40 (23.5%)	35 (24.8%)		27 (18.0%)	36 (20.5%)		91 (29.3%)	169 (24.9%)	
20%–39%	17 (10.0%)	7 (5.0%)		16 (10.7%)	≤5 (2.8%)		47 (15.1%)	32 (4.7%)	
≤20%	≤5 (1.2%)	0 (0.0%)		≤5 (0.7%)	0 (0.0%)		12 (3.9%)	10 (1.5%)	
Physician characteristics			0.11			0.002			0.01
Interventional cardiologist	46 (27.1%)	50 (35.5%)		39 (26.0%)	74 (42.0%)		81 (26.0%)	236 (34.7%)	
Noninterventional cardiologist	124 (72.9%)	91 (64.5%)		111 (74.0%)	102 (58.0%)		230 (74.0%)	444 (65.3%)	
Hospital characteristics			0.23			0.32			0.36
Cath-only hospitals	41 (24.1%)	26 (18.4%)		33 (22.0%)	31 (17.6%)		51 (16.4%)	128 (18.8%)	
PCI/CABG hospitals	129 (75.9%)	115 (81.6%)		117 (78.0%)	145 (82.4%)		260 (83.6%)	552 (81.2%)	

Values are as mean ± SD or n (%). *Comparing the coronary revascularization and the no revascularization groups.

CABG = coronary artery bypass grafting; CCS = Canadian Cardiovascular Society; COPD = chronic obstructive pulmonary disease; PCI = percutaneous coronary intervention.

Table 2 Unadjusted Rates and Adjusted Hazards of Death or Recurrent Acute Coronary Syndrome at 3 Years, According to Appropriateness Categories and Coronary Revascularization

Appropriateness Category	n	Crude Rate %		HR (95% CI)	Adjusted p Value
		No Revascularization	Revascularization		
Inappropriate*	311	16 (9.4%)	20 (14.2%)	0.99 (0.48–2.02)	0.97
Uncertain*	326	23 (15.3%)	14 (8.0%)	0.57 (0.28–1.16)	0.12
Appropriate†	991	50 (16.1%)	80 (11.8%)	0.61 (0.42–0.88)	0.0087

*Hazard ratio (HR) to compare outcomes in the inappropriate and uncertain patients adjusted for age, sex, clinical characteristics (hypertension, diabetes, chronic kidney disease, prior myocardial infarction, heart failure, peripheral vascular disease), physician characteristics, and hospital characteristics. †Hazard ratio comparing outcomes in the appropriate patients adjusted for age, sex, clinical characteristics (CCS angina classification, extent of coronary artery disease, hypertension, diabetes, chronic kidney disease, COPD, prior myocardial infarction, heart failure, peripheral vascular disease), left ventricular ejection fraction, physician characteristics, and hospital characteristics.

CI = confidence interval; other abbreviations as in Table 1.

Furthermore, we did not have data to examine changes in health-related quality of life in patients receiving coronary revascularization and medical therapy in the uncertain and inappropriate categories. Therefore, we cannot completely exclude possible beneficial effects of coronary revascularization in these patients.

Although we observed a progressive decrease in utilization of coronary revascularization from appropriate to uncertain to inappropriate candidates, the revascularization rate was still 45% in patients in the inappropriate category. One possible reason for the relatively high inappropriate rates is that our study cohort was assembled in 2006 to 2007, around the time the COURAGE study was published and before the publication of the appropriateness use criteria (6,21). On the other hand, a recent study has shown that the COURAGE study has had little impact on contemporary clinical practice (22). In patients with uncertain and inappropriate indications, we did not observe significant differences in clinical outcomes in the coronary revascularization group and the no revascularization group, but the wide confidence intervals of these estimates precluded conclusive determination of whether coronary revascularization is beneficial or harmful in these patients. Furthermore, we did not have information on the severity of chest pain or health-related quality of life after the revascularization, which may be a more robust outcome for patients with stable coronary artery disease.

Study limitations. Several additional limitations of our study merit consideration. Despite our efforts to adjust for confounding variables in comparing outcomes of patients treated with coronary revascularization versus medical therapy, patients in our cohort were not randomized and our findings are therefore subject to selection biases and unmeasured confounding. In addition, only a small number of patients experienced death or repeat ACS in the uncertain and inappropriate categories, and thus there are greater uncertainties in these estimates. Second, we chose a period of 60 days after cardiac catheterization to determine the use of coronary revascularization to take into account the wait times for coronary revascularization in Ontario. Although it is possible that patient status may have substantially altered this period, many studies have demonstrated that decisions of coronary revascularization are made at the time of the cardiac catheterization (23). Third, we were unable to examine the characteristics of patients within the appropriate subgroup who derived the most benefit because of limited sample size. Finally, we did not have information on patients' preference in their willingness to undergo or forgo coronary revascularization.

Conclusions

Our findings provide validation to the use of appropriateness use criteria in stable coronary artery disease patients to identify underutilization and overutilization of coronary revascularization in clinical practice. Failing to treat appropriate patients with coronary revascularization was associated with a significantly increased risk for adverse outcomes at 3-year follow-up, whereas treating inappropriate patients was not associated with lower mortality or readmission rates for ACS.

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Key Words: appropriateness ■ coronary revascularization ■ outcomes.