Relationship between Initial Treatment Strategy in Stable Coronary Artery Disease and 1-Year Costs

Short title: Stable angina and 1 year costs

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ABSTRACT

Background:

Cardiovascular disease is one of the most costly chronic diseases, with annual expenditures projected to continue to increase. The relationship between initial treatment strategy and cumulative costs is unknown. Our objective was to examine the variation in patient-level costs and identify drivers of cost in patients with stable coronary artery disease (CAD).

Methods:

In this retrospective cohort study using administrative databases in Ontario, Canada, we identified all patients with stable coronary artery disease identified after index angiography. We categorized hospitals into low, medium or high revascularization ratio centers. The primary outcome was the cumulative 1-year health care costs. We used a hierarchical generalized linear model to identify patient and hospital characteristics associated with patient costs. Our model included two main co-variates of interest: (1) the treatment allocation (medical vs. PCI vs. CABG) and (2) the hospital revascularization ratio. The model was adjusted for patient, physician and hospital factors.

Results:

Our cohort consisted of 39,126 patients (15,138 medical therapy, 23,988 revascularized). The mean 1-year cost was $24,026 (range: $54 to $985,600). The mean cost for medical management versus revascularization was $18,069 and $27,786 respectively. The strongest predictor of 1-year costs was revascularization (PCI: RR 1.27, 95% CI 1.24-1.31; CABG: RR 2.62, 95% CI 2.53-2.71). Hospital revascularization ratio did not significant impact costs, and there was no significant interaction between treatment and revascularization ratio.

Conclusions:

Revascularization is a major predictor of 1-year cumulative health care costs, highlighting the resource utilization impact of decisions regarding initial treatment strategy.

Key Words: Cardiac disease – coronary, Health economics

Introduction

Coronary artery disease (CAD) is a leading cause of morbidity and mortality,[1] and as such represents a major economic burden on healthcare expenditures.[2] In 2005, it was estimated that the cost of cardiovascular disease was $20.9 billion in the United States, with annual expenditures projected to triple by 2030.[1-3]

The treatment for stable CAD includes medical therapy alone or in combination with revascularization by either percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG). There is ongoing controversy as to the best initial treatment strategy despite numerous landmark trials, suggesting that the two treatment choices are equivalent in regards to death and major adverse cardiovascular events as well as symptom relief.[4-6] This debate has resulted in significant variation in clinical practice.[7] Understanding the potential impact of such practice variation on resource utilization is important. This is especially relevant given the current era of substantial budgetary constraints, where there is high priority for the efficient use of scarce health care resources. Indeed, recent guidelines from professional cardiovascular societies reinforce the importance of incorporating value and resource implications into health care decisions.[8]

Although there are studies examining the predictors of initial treatment strategy in patients with stable CAD, there is a paucity of literature on the impact of the different treatment strategies on health care costs. Accordingly, we sought to address this gap in knowledge by studying the cumulative 1-year health care costs in patients diagnosed with stable CAD after a coronary angiogram, using a population-based clinical registry of patients in Ontario, Canada. Ontario is Canada's largest province with approximately 14 million residents, all of whom receive universal health coverage, provided by a single 3rd party payer, the Ministry of Health and Long Term Care (MOHTLC). Our objectives were to determine the degree of variation in health care costs, and understand the predictors of cumulative healthcare costs. In particular, we were interested in the relationship between initial treatment strategy (medical management versus revascularization) as well as the impact of hospital revascularization ratio on subsequent health care utilization.

Methods

This study was approved by the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Canada. Under Ontario's Personal Health Information Protection Act (PHIPA), the need for patient consent was waived.

Study Type

Observational cohort study

Setting

Our primary data source was the Cardiac Care Network (CCN) of Ontario. CCN is comprised of 19 member hospitals that provide adult cardiac services, and includes a clinical registry of patients who undergo cardiac angiography, PCI, or CABG.[9,10] Its accuracy has been validated by retrospective chart review.[11,12] We linked CCN data to population-level administrative databases using unique, encoded identifiers and analyzed it at the Institute for Clinical Evaluative Sciences (ICES).[13-16]

We used several administrative databases in our study. The Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) contains data on all hospitalizations. The CIHI-DAD includes a "most responsible" diagnosis and up to 24 additional diagnoses codes that can be used to estimate comorbidity. We used the Ontario Registered Persons Database to ascertain death. We obtained data on physician visits/consultation from the fee-for-service claims history in the Ontario Health Insurance Program (OHIP) database, and the National Ambulatory Care Reporting Service database for administrative, clinical, financial, and demographic data for hospital-based ambulatory care, including emergency department visits, outpatient surgical procedures, medical day/night care, and high-cost ambulatory clinics such as dialysis, cardiac catheterization, and oncology. We obtained medication information from the Ontario Drug Database, which has comprehensive drug utilization information on patients over 65 years of age, for whom full drug coverage is provided for by the Ontario Ministry of Health and Long Term Care of Ontario (MOHLTC).

Patients

The cohort consisted of patients who received an angiogram between October 1st 2008 and September 30th 2011, for the indication of stable CAD, and had obstructive coronary stenosis. During this period, there were only 18 CCN member hospitals. For patients who received multiple angiograms during the study period, we considered only the initial angiogram. Refer to Figure 1 for additional inclusion and exclusion criteria. We allocated patients revascularized within 90 days of their index angiogram to the revascularization strategy (and into PCI or CABG subgroups), as is consistent with the literature and known procedural wait-times,[10,11] and all remaining patients to the medical therapy strategy. We categorized patients that received multiple angiograms within this timeframe on the basis of the first procedure they received.

Revascularization to Medical Therapy Ratio

We calculated revascularization to medical therapy ratio (referred to herein as revascularization ratio), defined as the number of patients who were categorized as revascularization patients divided by the number of patients who underwent medical therapy. We then allocated the hospitals into one of three categories, high, medium, or low, based on equal tertiles of revascularization ratio.

Main Outcomes

The primary outcome was the total cumulative cost per patient in the one year following the index angiogram. Complete cost profiles were available for all patients for 1 year or until death. As such, we did not have to consider censored costs in our analyses. The categories of costs were all-cause physician visits and laboratory tests, acute care and chronic care hospitalizations, emergency department visits, same day surgeries, and CAD-related medication use for patients ≥ 65 years of age.[15,16]

We determined costs associated with physician visits and laboratory tests using data from the claims history of the OHIP database.[14] The OHIP database also included shadow billings from providers of organizations covered by alternate payment arrangements. We estimated the cost of hospitalization using the Resource Intensity Weight (RIW) methodology.[16] We multiplied the RIW associated with the case-mix group for each hospitalization in the CIHI-DAD by the average provincial cost per weighted case for all Ontario acute and chronic care hospitals for that year.[16] This method yields a mean cost per hospitalization for cases assigned to a particular case-mix group category. We used a similar RIW methodology to determine the costs for emergency department visits and same day surgeries, both using the National Ambulatory Care Reporting Service database. We adjusted costs to 2013 Canadian dollars using the Consumer Price Index.

Statistical Analyses

We used hierarchical generalized linear models, with a logarithmic link and gamma distribution. The models incorporated hospital-specific random effects to account for within-hospital homogeneity in outcomes. The logarithmic link function is advantageous, as it restricts predicted costs to positive values. In addition, final model coefficients are straightforward to interpret; specifically, the exponential of the coefficient provides a rate ratio (RR), or the relative increase in the mean cost for a one unit change in the predictor variable. We used the gamma distribution because of the skewed distribution of health care costs.[17] Our models included 2 main co-variates of interest: 1) the treatment allocation (medical vs PCI vs CABG) and 2) the revascularization ratio (high vs medium vs low). In addition, the models included an interaction between treatment allocation and revascularization ratio. We adjusted the models for patient, physician and hospital factors, as listed in Table 1. We fit the hierarchical generalized linear models using Proc GLIMMIX using SAS Version 9.3 (SAS Institute Inc., Cary, NC).

Results

Patients

Between October 1st, 2008 and September 30th, 2012, a total of 183,630 angiograms were performed in Ontario. The final cohort was compromised of 39,126 stable CAD patients, of which 15,138 were medically treated and 23,988 were treated with revascularization (PCI: 15,601 patients, CABG: 8,387 patients; Figure 1). There were substantial differences in the baseline characteristics between medical therapy and revascularized groups (Table 1), with medically treated patients being older, more likely to be female, having greater co-morbidity and less severe anginal symptoms based on Canadian Cardiovascular Society (CCS) class.

Revascularization Ratio

The average revascularization ratio across the 18 Ontario hospitals was 1.58, ranging from 1.09 to 2.31 (Appendix Figure 1).

Variation in Cumulative 1-Year Health Care Cost

Individual patient 1-year cost varied substantially, from a minimum of $54 to a maximum of $985,600. As seen in Figure 2, the overall cost was heavily skewed, with an overall median of $15,707 and overall mean of $24,026. The mean (and median) costs for medical and revascularization treatments were $18,069 ($7,867) and $27,786 ($21,428) respectively. The mean cost by hospital ranged from $19,749 to $28,473.

Components of Health Care Costs

The majority of healthcare costs were due to acute care hospitalization with a significantly higher cost for patients undergoing revascularization than patients managed with medical therapy (Table 2). This was primarily driven by the cost of CABG.

Predictors of Health Care Costs

The results of the fully adjusted model are found in Table 3. In so far as our 2 primary co-variates of interest, there was no significant difference in cost associated with the hospital tertile revascularization ratio. In contrast, revascularization was a significant predictor of mean cost regardless of the modality (PCI: RR 1.27, 95% CI 1.24-1.31; CABG: RR 2.62, 95% CI 2.53-2.71*; P*<0.001 for both).

In addition, sex was a statistically significant predictor of mean cost, with a RR of 0.96 (95% CI 0.95-0.98) for males (*P*<0.001), indicating that the mean per-patient cost was 4% less for males compared to females (Table 3). Peripheral vascular disease (RR 1.25, 95% CI 1.21-1.28, *P*<0.001), hypertension (RR 1.11, 95% CI 1.08-1.13, *P*<0.001), and higher Charlson score (RR 1.17, 95% CI 1.16-1.17, *P*<0.001) were associated with higher mean cost. Previous cardiac surgery was associated with a 17% reduction in mean cost. Symptom severity, as measured by CCS class, had an impact on mean cost, with more symptomatic patients, in general, having lower mean cost. The specialty of the referral physician was a predictor of cost, with patients who were referred by either cardiologists or other physicians having an increased 1-year cumulative cost compared to those referred by their family physicians. In general, busier hospitals (as measured by their annual cardiac catheterization volume) had lower cost, although the magnitude of this effect was small.

In our interaction model (see Appendix Table 1), we were able to compare the cost of each initial strategy, stratified by the type of hospital (low, medium or high revascularization ratio). We found that, on average, there was no difference in cumulative 1-year health care cost for patients treated medically compared to those undergoing revascularization at the different strata defined by the hospital revascularization ratio.

Similarly, patients treated initially by PCI had similar costs at high vs medium vs low revascularization hospitals, as did CABG patients.

Interpretation

In this study we found significant variation in the 1-year cumulative health care costs among stable CAD patients treated at different hospitals. Patients with greater co-morbidity had higher cost, as did patients treated with either type of revascularization. Our analysis suggests that the majority of the variation in cost was attributable to the differences in treatment strategy. Importantly, the variation observed between-hospitals based on revascularization ratio was not associated with a statistically significant difference in cumulative health care costs, regardless of the management strategy.

To the best of our knowledge, ours is the first study to evaluate cumulative health care costs associated with differing initial treatment strategies among stable CAD patients in over a decade and the first to look at the drivers of these costs. It has previously been reported that the direct cost of stable CAD accounted for 1.3 % of the UK national health expenditures.[18] The vast majority of this cost was related to revascularization procedures (35% of cost) and hospital bed occupancy (31% of cost). Additionally, drug treatment accounted for 12% of total expenditures. Similar findings were found in several other UK and European studies.[19,20]

In our study, the major driver for 1-year cumulative costs was the receipt of revascularization. If revascularization offers no impact on mortality and if symptom relief is equivocal, as previous RCTs have shown, then our study suggests that the decision to pursue a revascularization strategy will translate into a substantial impact on healthcare resources. It follows that revascularization in patients with minimal symptoms in whom clinical benefit may be marginal may concurrently place an important financial burden on the healthcare system. This reinforces the importance of appropriate selection of patients who should receive PCI or CABG. Interestingly, the cumulative cost for each of the treatment strategies did not vary with hospital revascularization ratio – i.e. the cost of a strategy was similar regardless of the sites tendencies to favor revascularization or medical management. This implies a similar degree of efficiency for hospitals at different revascularization strata, which is a reassuring finding.

Our findings should be interpreted in the context of several limitations that merit discussion. First, we were limited to administrative databases, and thus do not have information on several important factors, such as intensity of medical optimization that may influence cost. Second, we were unable to calculate the indirect costs, such as productivity losses, which has been reported to account upwards to 75% of the total cost of CAD.[19] Third, based on our allocation of treatment strategy, there is a risk of survivorship bias, in that patients who died within 90 days were allocated to the medical therapy group and thus have lower costs. This risk is mitigated by the fact that our cohort was a stable CAD population with very low mortality – indeed, our previous work showed a 90 day mortality that was <1%.[21] Finally, we limited our analyses to health care costs over a restricted 1 year time-horizon in a cohort of patients post coronary angiography. As such, our results cannot be generalized to stable CAD patients who have not undergone angiography.

In conclusion, the majority of costs associated with stable CAD are due to acute care hospitalization, with the primary driver being revascularization. Our study highlights the resource implications of an initial revascularization strategy.

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CONFLICTS

The authors do not have any potential conflicts of interest or industry relationships to disclose.

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FIGURE LEGENDS

Figure 1. Study population

Figure 2. Variation in individual and hospital level costs

Table 2. Components of 1-year mean costs

Cost category	Total cost	Medical	Revascularization	p-value
Acute care hospitalization	$11,373	$7,038	$14,109	<0.001
ER	$372	$367	$375	0.262
Surgery	$2,691	$2,090	$3,071	<0.001
Physician visits	$5,449	$4,079	$6,313	<0.001
Medication*	$1,810	$1,857	$1,780	0.004
Laboratory	$194	$195	$193	0.326
Long term care	$54	$93	$29	<0.001

ER = emergency room

* For patients over 65 years of age

CABG	PCI	p-value
$25,927	$7,755	<0.001
$403	$361	<0.001
$1,901	$3,699	<0.001
$10,086	$4,284	<0.001
$1,476	$1,944	<0.001
$217	$180	<0.001
$47	$19	<0.001

Table 3. Predictors of 1-year cumulative health care costs

Covariates	RR (95% CI)	p-value
Treatment		
Medical management	referent	
PCI	1.27 (1.24-1.31)	<0.001
CABG	2.62 (2.53-2.71)	<0.001
Hospital revascularization ratio		
Low	referent	
Medium	1.03 (0.93-1.15)	0.560
High	1.08 (0.97-1.21)	0.130
Patient-level factors		
Demographics		
Age, yrs	1.01 (1.01-1.01)	<0.001
Male gender	0.96 (0.95-0.98)	<0.001
Rural	0.97 (0.95-0.99)	<0.001
Income*		
5	referent	
1	1.10 (1.07-1.12)	<0.001
2	1.04 (1.02-1.07)	<0.001
3	1.02 (1.00-1.05)	0.072
4	1.02 (1.00-1.05)	0.036
Medical comorbidities		
PVD	1.25 (1.21-1.28)	<0.001
Previous MI	0.95 (0.93-0.97)	<0.001
COPD	1.10 (1.07-1.13)	<0.001
Charlson score	1.17 (1.16-1.17)	<0.001
Cardiac risk factors		
Diabetes	1.00 (0.99-1.02)	0.640
Hypertension	1.11 (1.08-1.13)	<0.001
Hyperlipidemia	0.95 (0.93-0.97)	<0.001
History smoking	1.00 (0.99-1.02)	0.930
Cardiac status/testing		
Native stenosis†		
LM	1.12 (1.09-1.15)	<0.001
Prox LAD	1.10 (1.08-1.11)	<0.001
Mid/distal LAD	1.08 (1.06-1.09)	<0.001
Circumflex	1.11 (1.09-1.12)	<0.001
RCA	1.09 (1.07-1.11)	<0.001
Previous CABG	0.83 (0.82-0.85)	<0.001
LV function		

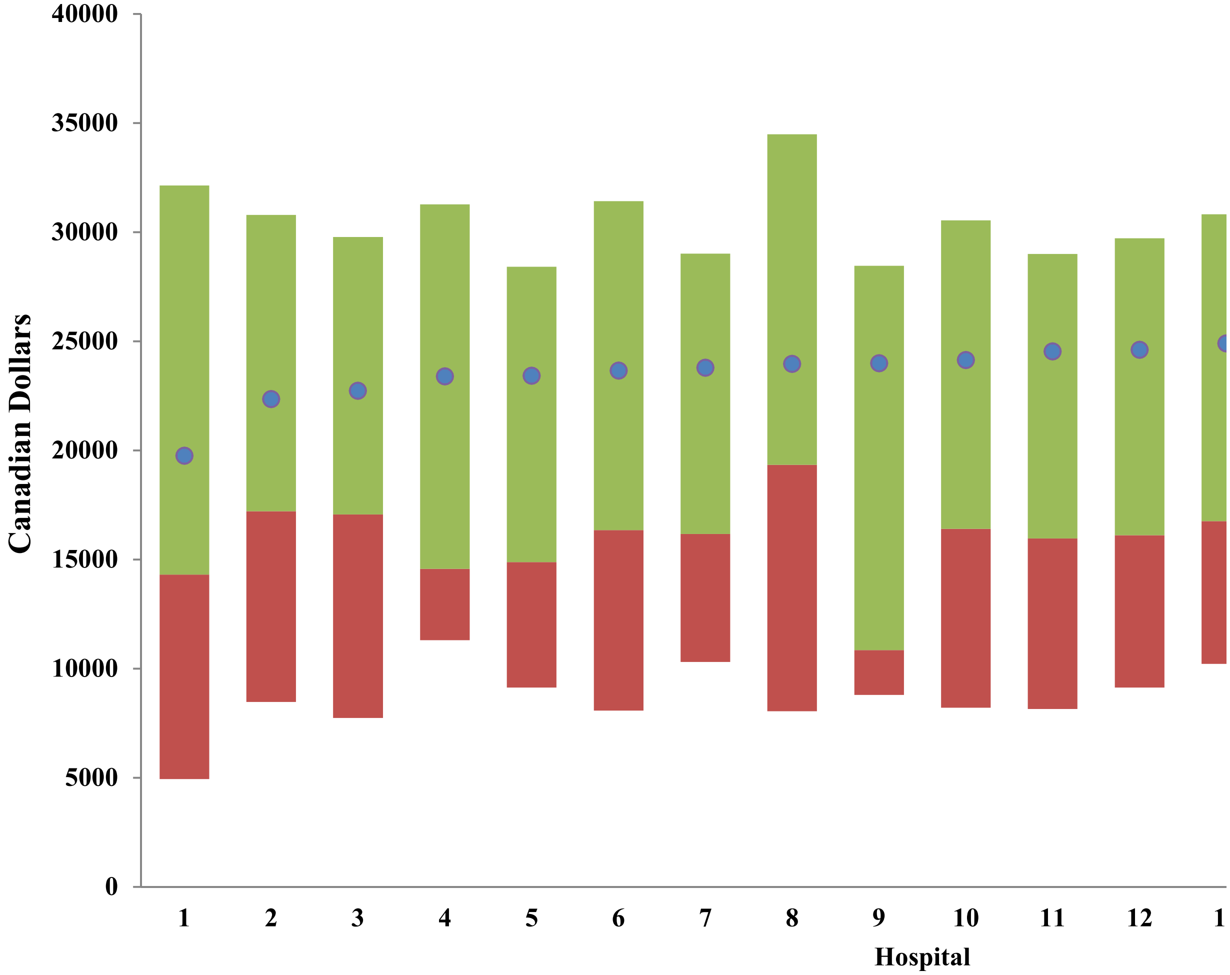
≥50%	referent	
35-49%	1.03 (1.00-1.05)	0.020
≤34%	1.14 (1.10-1.18)	<0.001
NA	0.95 (0.93-0.97)	<0.001
Exercise ECG risk		
Low risk	referent	
High risk	1.04 (1.02-1.06)	0.003
Uninterpretable	1.09 (1.05-1.14)	<0.001
NA	1.24 (1.21-1.27)	<0.001
Functional imaging risk		
Low risk	referent	
High risk	1.01 (0.99-1.03)	0.280
Unknown/NA	1.05 (1.03-1.08)	<0.001
CCS class		
0	referent	
1	0.90 (0.87-0.92)	<0.001
2	0.88 (0.85-0.90)	<0.001
3	0.90 (0.88-0.92)	<0.001
4	0.86 (0.82-0.90)	<0.001
Physician factors		
Referral physician		
Family physician	referent	
Cardiology	1.02 (1.01-1.05)	0.005
Internal medicine	1.00 (0.98-1.03)	0.680
Other	1.22 (1.19-1.27)	<0.001
Missing	1.03 (1.00-1.05)	0.023
Hospital factors		
Annual cath volume	0.99 (0.99-0.99)	<0.001

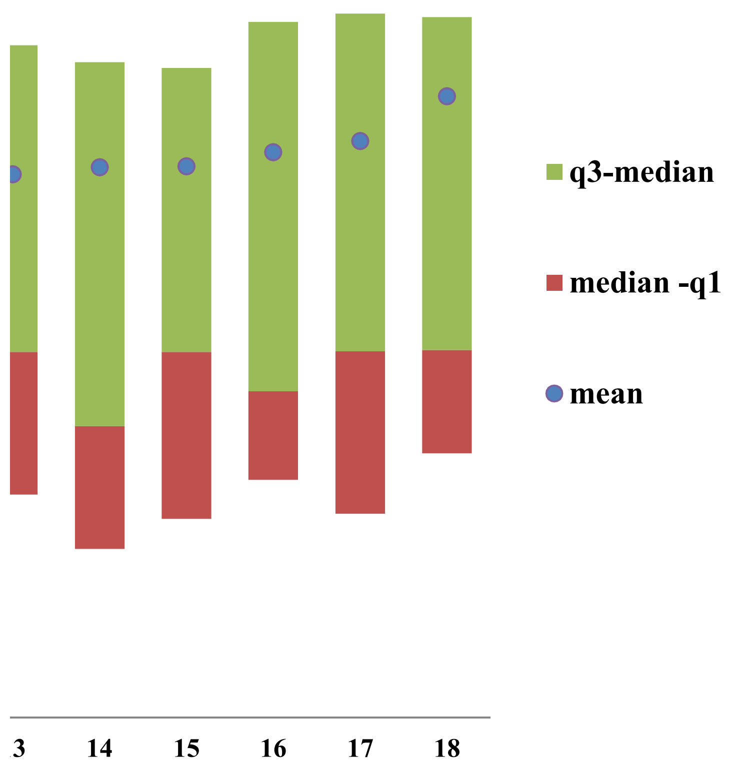
CABG= coronary artery bypass grafting, Cath = catheterization, CI = confidence interval, COPD = chronic obstructive pulmonary disease, ECG = electrocardiogram, LAD = left anterior descending, LM = left main, LV = left ventricular, MI = myocardial infarction, NA implies not done or missing, PCI = percutaneous coronary intervention, PVD = peripheral vascular disease, RCA = right coronary artery, RR= rate ratio.

* Income quintile: 1=lowest, 5 = highest.

†LM if ≥50% stenosis, Prox LAD if ≥70% stenosis, Mid/distal LAD if ≥70% stenosis, Circumflex if ≥70% stenosis, RCA if ≥70% stenosis.

Figure 2. Variation in individual and hospital level costs

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Appendix table 1. Predictors of 1-year cumulative health care costs*

Covariates	RR (95% CI)	p-value
Treatment:		
Medical management:		
High vs. low	1.08 (0.98-1.20)	0.127
Medium vs. low	1.03 (0.93-1.13)	0.562
High vs. medium	1.05 (0.95-1.16)	0.318
PCI:		
High vs. low treatment	1.04 (0.94-1.15)	0.415
Medium vs. low treatment	1.06 (0.96-1.17)	0.237
High vs. medium treatment	0.98 (0.89-1.08)	0.719
CABG:		
High vs. low	1.00 (0.90-1.10)	0.964
Medium vs. low	1.00 (0.91-1.11)	0.929
High vs. medium	0.99 (0.90-1.10)	0.893

CABG = coronary artery bypass graft, CI = confidence interval, PCI = percutaneous coronary intervention, RR= rate ratio.
*Fully adjusted model for patient characteristics

Appendix figure 1. Variation in initial treatment strategy across Ontario