Association Between Hospital Cardiac Management and Outcomes for Acute Myocardial Infarction Patients

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Background: Randomized trials have shown that medical and interventional therapies improve outcomes for acute myocardial infarction (AMI) patients. The extent to which hospital quality improvement translates into better patient outcomes is unclear.

Objectives: To determine hospital cardiac management markers associated with improved outcomes.

Research Design, Subjects: Population-based longitudinal cohort study of 98,115 adults hospitalized with first episode of AMI during 2000 to 2006 in 77 Ontario hospitals with >50 annual AMI admissions.

Measures: Rates of 30-day and 1-year mortality, readmissions for AMI or death, and major cardiac events (readmissions for AMI, angina, heart failure, or death) within 6 months, according to index hospital cardiac management markers, including appropriate initial emergency department (ED) assessment (rate of high acuity triage) high-acuity and intensity of interventional (30-day cardiac catheterization rate) and medical (discharge statin prescribing rate) therapy.

Results: Thirty-day risk-adjusted mortality varied 2.3-fold (7.2%–16.9%) and major cardiac events rates varied 2-fold (18.2%–35.6%) across hospitals in 2006. Patients admitted to hospitals with the highest versus lowest rates of combined medical and interventional management had lower rates of 30-day mortality (adjusted relative rate [aRR] = 0.84, 95% CI, 0.78–0.91), 1-year mortality (aRR = 0.86, 0.81–0.91), AMI readmissions or death (aRR = 0.74, 0.69–0.78), and major cardiac event (aRR = 0.65, 0.61–0.68). Patients admitted to EDs with the highest rates of appropriate initial assessment had lower 30-day (aRR = 0.93, 0.88–0.98) and 1-year mortality (aRR = 0.96, 0.93–1.00).

Conclusions: Hospitals with higher levels of both medical and interventional management and higher quality initial ED assessment had better outcomes. Readmissions were particularly sensitive to care processes. In the face of the unwarranted variations in outcomes across hospitals, strategies that promote better ED and inpatient management of AMI patients are needed.

Key Words: emergency medicine, health services research, hospital quality, myocardial infarction, outcomes research, performance measurement, practice variations, survival analysis

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The past 10 years has been an era of rapidly evolving cardiac therapies with the emergence of randomized trial evidence of improved outcomes from statins and early invasive strategies for acute myocardial infarction (AMI) patients.[1–3] The decreased mortality from coronary heart disease over the last 30 years is estimated to be largely due to reductions in major cardiovascular risk factors and increased use of evidence-based medical therapies,[4] because pharmacotherapy often improves mortality to a greater degree than interventional therapy.[5–7] Select hospital cardiac process measures have been incorporated into recent American College of Cardiology/American Heart Association (ACC/AHA) guidelines.[8,9] To promote quality improvement and accountability, the United States and United Kingdom collect and publicly report core hospital process measures and outcomes, although Canada does not.[10–12]

Hospital quality and outcomes have been continually improving in Canada and the United States following dramatic increases in the provision of invasive cardiac interventions and evidence-based medications, although rates of invasive care in Canada are far below those in the United States.[13–16] Canadian hospitals rely primarily on thrombolytics to reperfuse AMI patients; in 2004, 11.1% of Ontario STEMI patients received percutaneous coronary intervention (PCI) within 24 hours of admission (J. Tu, CCORT study, personal communication). Supply of cardiac technology and specialists is much lower in Canada than in the United States; in 2002, Ontario had 0.36 cardiac catheterization (CATH) laboratories and 3.8 cardiologists per 100,000 residents, as

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compared with 1.2 CATH laboratories and 6.3 cardiologists per 100,000 United States. residents in 1996.[17] To improve access to invasive cardiac services, the Ontario Cardiac Care Network implemented a macro-level initiative to facilitate evidence-based, timely, equitable access for urgent patients using a regionalized system and explicit urgency ratings based on clinical criteria.[18,19] In spite of these quality improvements, rates of provision of interventional services remain low and variations in 30-day mortality rates across Ontario hospitals remain high.[20,21]

Hospital quality improvement initiatives may not translate into improved outcomes because randomized clinical trials are conducted on ideal patients, not all ideal patients will benefit from improved evidence-based management because the number needed to treat may be large, and evidence-based therapies may not be targeted at patients most likely to benefit.[22] For this reason, many have advocated using outcomes as a more direct measure of performance, especially in high-volume hospitals.[11,23–25]

Our objectives were to explore emergency department (ED) and inhospital markers of hospital cardiac management that were associated with better AMI outcomes. We focused on higher volume hospitals as these were more likely to be centers of excellence having uniformly better outcomes through early adoption of evidence-based care and using strategies that might be adopted by lower volume hospitals to improve their care.

METHODS

Design Overview

We undertook a longitudinal cohort study of AMI patients admitted to higher volume hospitals and evaluated the effects of a patient's "exposure" to a hospital's cardiac management style to see if this was associated with variations in outcomes across hospitals. Hospital management style was assessed in terms of rates of appropriate initial ED assessment, prescription of evidence-based medications at discharge, and early interventional therapy. Cardiac management style was attributed to the index hospital, even if the patient was transferred, as this hospital was deemed to represent the "system" within which the patient received care. All measures were first evaluated on individual patients and then aggregated to the hospital level to estimate a hospital's propensity to provide particular types of care. Because patients were assigned the management intensity of their hospital of admission, we avoided survival bias that might be present when analyzing patient-level exposures.[26]

Study Cohort

The cohort consisted of Ontario residents hospitalized with first (index) admission for AMI to an Ontario acute care hospital between April 1, 2000, and March 31, 2006 (N = 118,598), restricting to adult residents aged 20 to 100 with a stay of at least 3 days who were not admitted for AMI during the previous year (N = 111,353; 167 hospitals). For patients who were transferred, we created an episode of care beginning at index admission and ending at the final discharge, using a 12-hour rule to determine transfers, to distinguish transfers from readmissions. To ensure stability of the hospital measures, we further restricted the study to hospitals with >50 AMI admissions in 2000 and 2006 and included all their AMI admissions over the 6-year period. This resulted in a final study cohort of 98,115 AMI patients admitted to 77 hospitals.

Patient Follow-up and Outcomes

Patients were followed for 1 year after date of index admission for survival and 6 months for readmissions. The primary outcomes were 30-day mortality, 1-year mortality, AMI readmission or death within 6 months, and major cardiac event, defined as readmission for AMI, angina, congestive heart failure, or death within 6 months, as recommended by the Canadian AMI quality indicator panel.[11] Readmissions were analyzed as a combined end point with mortality as mortality was high, and the factors causing mortality were likely an exacerbation of those causing readmission. We ascertained cardiac catheterization, coronary revascularization (coronary artery bypass graft [CABG] or PCI) within 30 days of admission, and same-day PCI (because we could not determine timing more finely).

Hospital Cardiac Management Markers

Hospital interventional management intensity, measured as 30-day rate of cardiac catheterization (CATH), was defined as number of AMI patients receiving cardiac catheterization within 30 days of admission divided by the number admitted to the hospital, similarly to previous work.[5] This is a marker of intent to treat invasively since cardiac revascularization, through CABG or PCI, is always preceded by coronary angiography. Primary PCI is limited to a minority of Ontario hospitals so it could not be used as the marker of interventional management. Although timing of reperfusion therapy and PCI to appropriate patients are ACC/AHA AMI performance measures,[9] and would have been more suitable hospital markers of invasive care, these could not be determined using administrative data; however, both are strongly correlated with 30-day CATH and revascularization rates at the hospital level in Ontario and elsewhere.[27,28] Restricting to patients who survived discharge changed this marker very slightly (r = 0.995).

Hospital medical management intensity, measured as rate of discharge statin prescriptions (STATIN), was defined as the number of AMI patients filling a statin prescription within 30 days of discharge divided by the number discharged alive, among patients age 65 and older. These data were available only for elderly patients but hospital prescription rates to younger and older patients are highly correlated. In addition, a recent ACC/AHA report has included prescription of statin therapy at discharge as an AMI performance measure.[9] There was little variation in discharge beta-blocker or ACE inhibitor prescription rates across hospitals (additional AMI performance measures) so an aggregate measure of medical intensity would provide less ability to discriminate hospital performance.

Triage is a key process that occurs immediately upon ED arrival whereby patient priority and acuity are determined. All Ontario EDs use a common triage tool, the

Canadian Triage and Acuity Scale (CTAS), and common training programs for triage nurses. Patients whose assessments raise a suspicion of acute coronary syndrome are recommended to be assigned a high-acuity triage score of resuscitation or emergent.[29] Appropriate triage is important since key investigations such as electrocardiograms and key treatments such as aspirin may be administered directly at triage, and patients may be sent more rapidly for reperfusion therapy. Hospital rate of high-acuity triage was measured as number of AMI patients receiving a high-acuity ED triage score divided by the number of patients admitted through the ED.

Interventional and medical management rates and high-acuity ED triage rates were derived separately for each hospital in each study year. Rates were categorized into terciles of low, medium, and high intensity based on hospital study population. Study patients were assigned to the tercile of intensity in their index hospital during the year they were admitted.

Hospital AMI volume, attending physician specialty and mean annual AMI volume were computed as in previous work.[30]

Data Sources

Patient records were linked using unique, anonymized, encrypted identifiers across multiple Ontario health administrative databases containing information on all publicly insured, medically necessary hospital and physician services. These included the Discharge Abstract Database for hospital admissions, procedures, and transfers that includes the most responsible diagnosis (MRD) for patient length of stay, secondary diagnosis codes, comorbidities present upon admission, complications occurring during the hospital stay, and attending physician identifier; the National Ambulatory Care Reporting System (NACRS) that includes the CTAS triage score for ED visits; the Ontario Health Insurance Plan (OHIP) for physician billings for outpatient visits that includes patient diagnosis codes and procedures, and location of visit; the Ontario Drug Benefits Database (ODBD) for outpatient drug prescriptions for those over age 65 years; and the Registered Persons Database (RPDB) for patient demographic information and deaths. AMI cohort membership was determined using the MRD, excluding complications; comorbidities were identified using secondary Discharge Abstract Database diagnosis fields. International Classification of Diseases ninth revision (ICD-9 before April 1, 2002) and 10th revision-Canada (ICD-10-CA, thereafter) diagnosis codes, and Canadian Classification of Procedures (CCP before April 1, 2002), and Canadian Classification of Interventions (CCI, thereafter) procedure codes are in the Appendix. Neighborhood income was derived from Statistics Canada 2001 census estimates.

Statistical Analysis

All analyses used patient as the unit of analysis and the hospital cardiac management markers as the primary exposure variables. This allowed us to control for individual risk factors and permitted inferences to individual patient outcomes, although exposures were measured at the hospital level. We developed a baseline severity index by using logistic regression models to predict 30-day mortality, incorporating all baseline patient characteristics and comorbidities (shock, congestive heart failure, cancer, cerebrovascular disease, cardiac dysrhythmia, diabetes with complications, acute renal failure, chronic renal failure, pulmonary edema) comprising the Ontario AMI mortality prediction model (c-statistic, 0.78).[31] Mean predicted mortality was used as the summary measure of patient AMI severity, as in previous work.[5]

Cox proportional hazards models were used to assess rates of mortality, AMI readmissions or death, and major cardiac events across the 3 hospital management markers, censoring at the end of follow-up.[32] All models controlled for baseline patient characteristics including age group (20–49, 50–64, 65–74, 75–84, 85+ years), sex, and their interactions, median neighborhood income quintiles, AMI comorbidities, history of AMI, CABG, and PCI in the previous 10 years, and hospital AMI volume and teaching status.

The hospital management markers were evaluated by including all 3 markers jointly in the models to assess their independent effects on outcomes. We assessed interactions between hospital interventional and medical management markers, as in previous work.[5]

As patients admitted to the same hospital are likely to be treated similarly, they may have correlated outcomes, leading to underestimation of the standard errors. We used survival models that account for clustering by hospital by including a working correlation matrix in the estimation procedure to adjust the standard errors appropriately.[33] Model fit and proportionality of hazards were assessed using residual analyses.[34] Analyses were performed using the STATA procedure, STCOX.[35]

RESULTS

From 2000 to 2006, rates of 30-day cardiac catheterization and revascularization, and discharge statin prescriptions doubled; rates of same-day PCI tripled. Thirty-day mortality decreased by 12% (adjusted relative rate [aRR] = 0.88, 95% confidence interval [CI], 0.83–0.94), 1-year mortality decreased by 5% (aRR = 0.95, 95% CI, 0.90–0.99), AMI readmission or death within 6 months decreased by 17% (aRR = 0.83, 95% CI, 0.79–0.87), and major cardiac event within 6 months decreased by 27% (aRR = 0.73, 95% CI, 0.70–0.76).

Variations in risk-adjusted outcomes across hospitals were high. During 2005 to 2006, the latest years of the study, outcomes varied more than 2-fold across hospitals. Specifically, the fifth to 95th percentile range for hospital 30-day mortality rate was 7% to 17%, 1-year mortality was 13% to 29%, AMI readmission or death within 6 months was 14% to 28%, and major cardiac event within 6 months was 18% to 36% (Table 1). Thirty-day cardiac catheterization rates varied 2.3-fold (35% to 80%), discharge statin prescribing rates varied 1.6-fold (57%–90%), and high-acuity ED triage rates varied 2-fold (43%–88%) across hospitals. Hospital interventional and medical management intensity were correlated (r = 0.66), and hospitals generally remained in the same intensity tercile over time.

TABLE 1. Variations in Hospital Cardiac Management and Outcome Rates Among 77 High-Volume Ontario Hospitals During 2005–2006 (Last 2 yr of Study)*

	Q5	Q25	Median	Q75	Q95	Ratio Q95/Q5
Cardiac catheterization rate–30 d	35.0	52.9	61.5	66.0	80.3	2.3
Discharge statin rate–30 d	56.6	65.1	73.2	78.5	89.7	1.6
High-acuity ED triage score, %†	43.0	61.3	71.1	80.6	87.7	2.0
Inhospital mortality, %†	6.3	8.9	10.9	13.0	15.5	2.5
Mortality–30 d, %†	7.2	10.0	11.5	13.8	16.9	2.3
Mortality–1 yr, %†	13.2	17.0	20.3	23.8	28.9	2.2
AMI readmissions/death–6 mo, %†	13.8	17.4	19.8	23.8	27.5	2.0
Major cardiac events–6 mo, %†	18.2	21.8	25.8	29.4	35.6	2.0

*These rates apply to 2005–2006 and are lower than the overall 2000–2006 rates used in the analysis, since rates decreased over time.

†Outcome rates are risk-adjusted using hierarchical models incorporating comorbidities from the Ontario AMI mortality prediction model.

Although there were small differences in some risk factors, mean predicted 30-day mortality, the summary measure of baseline AMI patient severity, was similar across hospital management intensity groups (Table 2). High management intensity hospitals had higher AMI volumes and were more likely to be teaching hospitals, have onsite CATH labs and cardiac surgery capability, and assign a high-acuity ED triage score. The attending physician was more likely to be a cardiologist and see a high volume of AMI patients.

Patients admitted to high management intensity hospitals were more likely to receive evidence-based medications at discharge and interventional care (Table 3). Those discharged alive were more likely to see a cardiologist within 6 weeks and to have shared ambulatory care, defined as having at least 1 office visit within 4 weeks of discharge with a primary care physician and within 6 weeks with a cardiologist.

Adjusted mortality and readmissions were lower in high intensity medical and interventional hospitals; however, interactive effects were found between the 2 cardiac management styles ($P < 0.001$). There was a clear gradient in improved survival and nonfatal outcomes in hospitals from lowest (upper left) to highest (bottom right) combined intensity of management style (Tables 4–7). Patients admitted to hospitals with the highest versus lowest rates of combined medical and interventional management had lower rates of 30-day mortality (aRR = 0.84; 95% CI, 0.78–0.91), 1-year mortality (aRR = 0.86; 95% CI, 0.81–0.91), AMI readmission or death (aRR = 0.74; 95% CI, 0.69–0.78), and major cardiac events (aRR = 0.65; 95% CI, 0.61–0.68) (Tables 4–7).

After risk adjustment, patients admitted to hospitals with the highest rates of appropriate initial ED assessment (high-acuity triage rate >70%) had lower rates of 30-day mortality (aRR = 0.93; 95% CI, 0.88–0.98) and 1-year mortality (aRR = 0.96; 95% CI, 0.93–1.00). There was a trend to lower AMI readmissions or death (aRR = 0.97; 95% CI, 0.93–1.003) but no effect on major cardiac events (Tables 4–7).

For all markers, results changed negligibly when we adjusted for attending physician volume (as it was correlated with hospital volume) or for year of admission (as it was unrelated to patient risk and therefore, not a confounder) or when we included hospitals with at least 20 AMI admissions per year.

DISCUSSION

We conducted a population-based cohort study of AMI patients admitted to high-volume Ontario hospitals to assess whether hospital cardiac management was associated with better outcomes. There has been a dramatic increase in provision of evidence-based care and declining rates of mortality and readmissions over this time period in Canada as in the United States,[15] demonstrating that hospital quality improvement efforts seem to be paying off. High performing hospitals tended to provide more evidence-based medical therapies and more interventional therapies and had more appropriate initial ED assessment. Readmissions were extremely sensitive to care processes and quality, having important implications for quality of life and hospital resource use. This study has moved beyond volume-outcome associations to link hospital cardiac management practice directly to outcomes.

Risk-adjusted variations in AMI outcomes across these hospitals were high but similar to those in US hospitals.[36] Although risk adjustment might be improved by using chart data, previous work has shown high concordance between Ontario hospital risk-adjusted mortality rates, using chart and administrative data.[21]

Strengths of the study are that it was a large, population-based cohort study that evaluated the effects of hospital cardiac management in usual practice. We are the first to evaluate the association between hospital management and readmissions, and are also the first to explore initial ED assessment as a hospital marker of improved AMI outcomes. Given the importance of rapid, and even prehospital, identification of AMI to administer evidence-based treatments in a timely fashion, we showed that quality of initial ED assessment is an important and novel indicator of quality of care. Uniform use of a single triage scale, CTAS, and a common triage training program across all Ontario EDs offered a unique opportunity to explore this marker at a population level.

The association of higher intensity medical and interventional therapies with better outcomes are consistent with randomized trial evidence that statin therapy reduces reinfarct and that cardiac revascularization improves angina and reduces cardiac admissions.[1–3] The 3 hospital cardiac management intensity markers are indicators for better evidence-based care. They are also associated with availability of or access to cardiac technology and more experienced specialists, both of which facilitate timelier use of PCI to eligible patients in the acute AMI phase. These hospitals triaged patients more appropriately in the ED, suggesting that AMI was identified more rapidly and reperfusion therapies initiated sooner.[37] Patients received more comprehensive ambulatory care which is associated with lower long-term mortality, higher

TABLE 2. Select Baseline Characteristics of AMI Patients, According to Hospital Cardiac Catheterization (CATH) Intensity, Hospital Discharge Statin Intensity and Rate, Hospital Discharge Statin Rate and High-Acuity ED Triage Rate

	CATH Intensity			Statin Intensity			High-Acuity ED Triage Rate		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Median intensity (interquartile range)	25.0 (2.9–34.9)	43.9 (35.0–54.9)	62.5 (55.0–87.5)	36.1 (8.9–44.9)	55.6 (45.0–64.9)	73.5 (65.0–90.6)	37.3 (30.7–43.4)	60.5 (56.3–64.9)	78.0 (73.5–84.4)
Patient characteristics									
Cohort members, N	26,266	39,411	32,438	25,783	39,225	33,107	24,304	39,386	34,425
AMI severity (predicted 30-d mortality)	0.122 ± 0.124	0.127 ± 0.131	0.119 ± 0.129	0.119 ± 0.124	0.123 ± 0.128	0.126 ± 0.132	0.125 ± 0.129	0.124 ± 0.129	0.120 ± 0.128
Age ≥65	16,816 (64.0%)	24,934 (63.3%)	19,239 (59.3%)	16,007 (62.1%)	24,485 (62.4%)	20,497 (61.9%)	15,414 (63.4%)	24,692 (62.7%)	20,883 (60.7%)
Female	9997 (38.1%)	14,987 (38.0%)	11,688 (36.0%)	9565 (37.1%)	14,803 (37.7%)	12,304 (37.2%)	9323 (38.4%)	14,822 (37.6%)	12,527 (36.4%)
High income (quintile 4 or 5)	8687 (33.1%)	13,429 (34.1%)	12,167 (37.5%)	9107 (35.3%)	13,647 (34.8%)	11,529 (34.8%)	7848 (32.3%)	13,341 (33.9%)	13,094 (38.0%)
History of AMI in last 10 yr	3025 (11.5%)	3953 (10.0%)	2590 (8.0%)	3124 (12.1%)	3847 (9.8%)	2597 (7.8%)	2658 (10.9%)	3884 (9.9%)	3026 (8.8%)
History of congestive heart failure	5595 (21.3%)	8458 (21.5%)	6096 (18.8%)	5360 (20.8%)	8260 (21.1%)	6529 (19.7%)	5273 (21.7%)	8260 (21.0%)	6616 (19.2%)
History of diabetes complications	948 (3.6%)	1635 (4.1%)	1404 (4.3%)	839 (3.3%)	1652 (4.2%)	1496 (4.5%)	1086 (4.5%)	1571 (4.0%)	1330 (3.9%)
History of chronic renal failure	1118 (4.3%)	2279 (5.8%)	2029 (6.3%)	1016 (3.9%)	2127 (5.4%)	2283 (6.9%)	1244 (5.1%)	2239 (5.7%)	1943 (5.6%)
Hospital characteristics									
High-volume teaching hospital (>200 AMI patients)	1935 (7.4%)	8308 (21.1%)	10,045 (31.0%)	2881 (11.2%)	6176 (15.7%)	11,231 (33.9%)	3060 (12.6%)	11,515 (29.2%)	5713 (16.6%)
Onsite CATH lab	1298 (4.9%)	10,824 (27.5%)	19,230 (59.3%)	5956 (23.1%)	11,247 (28.7%)	14,149 (42.7%)	5182 (21.3%)	13,228 (33.6%)	12,942 (37.6%)
Onsite CABG capability	337 (1.3%)	6083 (15.4%)	13,629 (42.0%)	3868 (15.0%)	5560 (14.2%)	10,621 (32.1%)	1010 (4.2%)	10,055 (25.5%)	8984 (26.1%)
High-acuity ED triage score	11,589 (54.4%)	20,309 (58.7%)	21,030 (69.2%)	10,823 (57.0%)	20,856 (58.9%)	21,249 (66.5%)	7654 (36.7%)	21,024 (60.7%)	24,250 (78.8%)
Attending physician characteristics									
High annual AMI volume (>24 patients)	9551 (36.4%)	17,078 (43.3%)	16,191 (49.9%)	10,787 (41.8%)	17,360 (44.3%)	14,673 (44.3%)	9838 (40.5%)	16,390 (41.6%)	16,592 (48.2%)
Cardiology	4673 (17.8%)	13,966 (35.4%)	20,037 (61.8%)	7288 (28.3%)	13,630 (34.7%)	17,758 (53.6%)	6838 (28.1%)	14,065 (35.7%)	17,773 (51.6%)

TABLE 3. Selected Therapies and Outcomes for AMI Cohort, According to Hospital Cardiac Catheterization Rate, Hospital Discharge Statin Catheterization (CATH) Intensity, Hospital Discharge Statin Intensity and Rate and High-Acuity ED Triage Rate

	CATH Intensity			Statin Intensity			High-Acuity ED Triage Rate		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Selected cardiac therapies									
Cardiac catheterization within 30 d	6515 (24.8%)	17,496 (44.4%)	20,727 (63.9%)	8442 (32.7%)	17,214 (43.9%)	19,082 (57.6%)	9151 (37.7%)	17,764 (45.1%)	17,823 (51.8%)
CABG or PCI within 30 d	4039 (15.4%)	10,784 (27.4%)	13,811 (42.6%)	5153 (20.0%)	10,757 (27.4%)	12,724 (38.4%)	5593 (23.0%)	11,266 (28.6%)	11,775 (34.2%)
PCI (24 h)	306 (1.2%)	2406 (6.1%)	7098 (21.9%)	1093 (4.2%)	2567 (6.5%)	6150 (18.6%)	762 (3.1%)	4027 (10.2%)	5021 (14.6%)
Discharge drug prescriptions within 30 d (among patients ≥65 yr, alive at discharge)									
Patients ≥65 yr, alive at discharge (N)	14,100	20,825	16,375	13,394	20,615	17,291	12,784	20,804	17,712
ACE inhibitors	8860 (62.8%)	13,319 (64.0%)	10,559 (64.5%)	8291 (61.9%)	12,992 (63.0%)	11,455 (66.2%)	8178 (64.0%)	13,319 (64.0%)	11,241 (63.5%)
Beta blockers	9212 (65.3%)	14,423 (69.3%)	11,734 (71.7%)	8629 (64.4%)	14,017 (68.0%)	12,723 (73.6%)	8510 (66.6%)	14,441 (69.4%)	12,418 (70.1%)
Statins	6062 (43.0%)	11,686 (56.1%)	11,201 (68.4%)	4719 (35.2%)	11,411 (55.4%)	12,819 (74.1%)	6396 (50.0%)	11,944 (57.4%)	10,609 (59.9%)
Outcomes									
Death within 30 d	3305 (12.6%)	4971 (12.6%)	3482 (10.7%)	3189 (12.4%)	4736 (12.1%)	3833 (11.6%)	3171 (13.0%)	4750 (12.1%)	3837 (11.1%)
Death within 1 yr	5698 (21.7%)	8588 (21.8%)	6059 (18.7%)	5427 (21.0%)	8255 (21.0%)	6663 (20.1%)	5344 (22.0%)	8314 (21.1%)	6687 (19.4%)
AMI readmission or death (6 mo)	6236 (23.7%)	8854 (22.5%)	6023 (18.6%)	5945 (23.1%)	8607 (21.9%)	6561 (19.8%)	5598 (23.0%)	8655 (22.0%)	6860 (19.9%)
Major cardiac event (6 mo)	8662 (33.0%)	11,552 (29.3%)	7898 (24.3%)	8326 (32.3%)	11,386 (29.0%)	8400 (25.4%)	7458 (30.7%)	11,364 (28.9%)	9290 (27.0%)
Postdischarge ambulatory care (among patients alive at discharge)									
Patients alive at discharge (N) patients	23,251	34,816	29,189	22,856	34,879	29,521	21,385	35,003	30,868
Office visit to GP/FP within 4 wk	15,560 (66.9%)	23,558 (67.7%)	20,573 (70.5%)	15,551 (68.0%)	23,611 (67.7%)	20,529 (69.5%)	13,969 (65.3%)	23,904 (68.3%)	21,818 (70.7%)
Office visit to cardiologist within 6 wk	4272 (18.4%)	9888 (28.4%)	8880 (30.4%)	4918 (21.5%)	9115 (26.1%)	9007 (30.5%)	5346 (25.0%)	8778 (25.1%)	8916 (28.9%)
Office visit to GP/FP and cardiologist (shared care)	2845 (12.2%)	6889 (19.8%)	6659 (22.8%)	3490 (15.3%)	6303 (18.1%)	6600 (22.4%)	3535 (16.5%)	6227 (17.8%)	6631 (21.5%)

TABLE 4. Adjusted 30-d Relative Mortality Rate by Combined Hospital CATH and Statin Intensity and by High-Acuity ED Triage Rate*

	CATH Intensity			High-Acuity ED Triage Rate	
	<35%	35–55%	>55%		
Statin intensity <45%	1.00 (reference)	0.95 (0.85, 1.05)	0.81 (0.64, 1.02)	<50%	1.00 (reference)
Statin intensity 45–65%	0.88 (0.80, 0.97)	0.93 (0.85, 1.02)	0.87 (0.78, 0.97)	50–70%	0.97 (0.92, 1.01)
Statin intensity >65%	0.84 (0.73, 0.98)	0.91 (0.81, 1.03)	0.84 (0.78, 0.91)	>70%	0.93 (0.88, 0.98)

*The 3 hospital markers are jointly adjusted for all patient and hospital factors.

TABLE 5. Adjusted 1-yr Relative Mortality Rate, by Combined Hospital CATH and Statin Intensity and by High-Acuity ED Triage Rate*

	CATH Intensity			High-Acuity ED Triage Rate	
	<35%	35–55%	>55%		
Statin intensity <45%	1.00 (reference)	0.96 (0.89, 1.04)	0.85 (0.68, 1.06)	<50%	1.00 (reference)
Statin intensity 45–65%	0.93 (0.88, 0.98)	0.95 (0.89, 1.02)	0.90 (0.83, 0.98)	50–70%	0.99 (0.96, 1.03)
Statin intensity >65%	0.87 (0.77, 0.98)	0.94 (0.88, 1.00)	0.86 (0.81, 0.91)	>70%	0.96 (0.93, 1.00)

*The 3 hospital markers are jointly adjusted for all patient and hospital factors.

TABLE 6. Adjusted 6-mo Relative AMI Readmission Rate by Combined Hospital CATH and Statin Intensity and by High-Acuity ED Triage Rate*

	CATH Intensity			High-Acuity ED Triage Rate	
	<35%	35–55%	>55%		
Statin intensity <45%	1.00 (reference)	0.91 (0.84, 0.97)	0.81 (0.72, 0.91)	<50%	1.00 (reference)
Statin intensity 45–65%	0.89 (0.85, 0.94)	0.88 (0.84, 0.93)	0.81 (0.75, 0.86)	50–70%	1.02 (0.98, 1.05)
Statin intensity >65%	0.82 (0.74, 0.90)	0.84 (0.79, 0.89)	0.74 (0.69, 0.78)	>70%	0.97 (0.93, 1.003)

*The 3 hospital markers are jointly adjusted for all patient and hospital factors.

TABLE 7. Adjusted 6-mo Relative Major Cardiac Event Rate by Combined Hospital CATH and Statin Intensity and by High-Acuity ED Triage Rate*

	CATH Intensity			High-Acuity ED Triage Rate	
	<35%	35–55%	>55%		
Statin intensity <45%	1.00 (reference)	0.86 (0.81, 0.91)	0.74 (0.69, 0.79)	<50%	1.00 (reference)
Statin intensity 45–65%	0.84 (0.81, 0.88)	0.80 (0.76, 0.84)	0.74 (0.69, 0.79)	50–70%	1.02 (0.99, 1.05)
Statin intensity >65%	0.75 (0.68, 0.83)	0.73 (0.69, 0.77)	0.65 (0.61, 0.68)	>70%	1.00 (0.97, 1.03)

*The 3 hospital markers are jointly adjusted for all patient and hospital factors.

rates of rehabilitation, and higher compliance with medications.[38,39] Thus, practice patterns within the "system of care" consisting of the initial hospital of admission and the associated network of inhospital and community physicians caring for these patients, are important determinants of outcomes.

The association between hospital management style and readmissions was striking. Readmissions appear to be more sensitive than mortality to hospital quality and processes of care and to comprehensive ambulatory care. Given the implications with respect to higher quality of life and lower use of hospital resources, this has important clinical and fiscal consequences. A recent study has highlighted the high rate of potentially preventable readmissions and correspondingly high costs to US Medicare patients, underscoring the US National Quality Forum's adoption of readmission as a hospital performance measure.[40]

This study shows that better hospital management is associated with improved patient outcomes, particularly readmissions. These findings could stimulate efforts to implement system strategies to reduce excess mortality and avoidable readmissions. These include standardized admission and discharge orders, care pathways, discharge planning, real-time audit and data feedback, continuous quality improvement, and integration of care across hospital and ambulatory sectors, which have been shown to improve survival and quality of care.[41–44] In jurisdictions with lower supply of cardiac specialty services, access to rapid revascularization could be increased through implementation of or better use of regionalized cardiac networks, such as the Ontario Cardiac Care Network, rather than through increasing local cardiac catheterization laboratory supply. Timelier AMI diagnosis for ambulance patients could be achieved through use of prehospital ECGs.[8] AMI diagnosis and management could be improved by better training of ED triage nurses in use of the common triage scale.

Several limitations should be considered. In observational studies, comparisons of exposed and unexposed groups may be biased due to unobserved selection bias.[26] We attempted to reduce potential unmeasured illness confounding by studying incident AMI patients who are likely to have similar baseline severity across hospitals, as shown in previous work.[5] Lower intensity hospitals did not appear to treat disproportionately sicker patients, because mean baseline AMI severity was similar across hospital management marker groups. Although admission severity would be determined with greater accuracy using clinical detail from medical charts, previous work has shown high concordance between risk-adjusted hospital outcomes, using chart and administrative data.[21] We further attempted to reduce uncontrolled confounding by studying only patients admitted to larger hospitals. Health administrative data do not have sufficient information to determine severity, infarction type and location of AMI, appropriateness of interventional and medical therapies, presence and timing of reperfusion and primary PCI, or processes of care such as smoking cessation counseling and cardiac rehabilitation referral, to provide better insight into how high performing hospitals achieved better outcomes.

Canadian hospitals do not collect data on core AMI process measures so we could not refine our hospital cardiac management markers to better reflect evidence-based care. Canadian data distinguish between comorbidities present at admission and complications, leading to improved admission severity coding.[45] Recent studies confirmed the validity and reliability of Ontario administrative data, especially the MRD field used to identify the cohorts.[46–48]

Because process measures explain a small proportion of the variation in hospital mortality rates,[49,50] provide a narrow perspective on overall quality, and are not routinely collected or reported in some jurisdictions, some have advocated using outcomes as a more direct measure of performance, especially in high-volume hospitals.[11,23–25] In the face of unwarranted variations in mortality and readmissions across larger Ontario hospitals and given the potential for even greater improvement in lower volume hospitals with typically poorer outcomes, there is a need for better data on hospital process measures and for public reporting on quality indicators and outcomes with a view to hospital accountability for quality and costs.

Given the constraints of geography, patient preferences, and resources, many AMI patients cannot be admitted to high performing hospitals. In the face of huge variations in outcomes across hospitals, there is a need for better data on hospital process measures and public accountability for outcomes and costs. A systems-minded approach to improving care that focuses on the interface between ED, inhospital, and ambulatory care would permit all hospitals to reduce resource use and provide better outcomes.

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REFERENCES

1. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. *Lancet*. 2003;361:13–20.
2. Mehta SR, Cannon CP, Fox KA, et al. Routine vs. selective invasive strategies in patients with acute coronary syndromes: a collaborative meta-analysis of randomized trials. *JAMA*. 2005;293:2908–2917.
3. Baigent C, Keech A, Kearney PM, et al. Efficacy and safety of cholesterol-lowering treatment: prospective meta-analysis of data from 90,056 participants in 14 randomised trials of statins. *Lancet*. 2005;366:1267–1278.
4. Ford ES, Ajani UA, Croft JB, et al. Explaining the decrease in U.S. deaths from coronary disease, 1980–2000. *N Engl J Med*. 2007;356:2388–2398.
5. Stukel TA, Lucas FL, Wennberg DE. Long-term outcomes of regional variations in intensity of invasive vs. medical management of Medicare patients with acute myocardial infarction. *JAMA*. 2005;293:1329–1337.
6. Rasmussen JN, Chong A, Alter DA. Relationship between adherence to evidence-based pharmacotherapy and long-term mortality after acute myocardial infarction. *JAMA*. 2007;297:177–186.
7. Setoguchi S, Glynn RJ, Avorn J, et al. Improvements in long-term mortality after myocardial infarction and increased use of cardiovascular drugs after discharge: a 10-year trend analysis. *J Am Coll Cardiol*. 2008;51:1247–1254.
8. Antman EM, Hand M, Armstrong PW, et al. 2007 Focused Update of the ACC/AHA 2004 Guidelines for the Management of Patients with ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration With the Canadian Cardiovascular Society endorsed by the American Academy of Family Physicians: 2007 Writing Group to Review New Evidence and Update the ACC/AHA 2004 Guidelines for the Management of Patients with ST-Elevation Myocardial Infarction, writing on Behalf of the 2004 Writing Committee. *Circulation*. 2008;117:296–329.
9. Krumholz HM, Anderson JL, Bachelder BL, et al. ACC/AHA 2008 performance measures for adults with ST-elevation and non-ST-elevation myocardial infarction. a report of the American College of Cardiology/American Heart Association Task Force on performance measures. *Circulation*. 2008;118:2596–2648.
10. Jha AK, Li Z, Orav EJ, et al. Care in U.S. hospitals—the Hospital Quality Alliance program. *N Engl J Med*. 2005;353:265–274.
11. Tu JV, Khalid L, Donovan LR, et al; for the Canadian Cardiovascular Outcomes Research Team/Canadian Cardiovascular Society Acute Myocardial Infarction Quality Indicator Panel. Indicators of quality of care for patients with acute myocardial infarction. *CMAJ*. 2008;179:909–915.
12. Royal College of Physicians. Myocardial Ischaemia National Audit Project (MINAP). Available at: http://www.rcplondon.ac.uk/CLINICAL-STANDARDS/ORGANISATION/PARTNERSHIP/Pages/MINAP-.aspx. Accessed November 4, 2008.
13. Alter DA, Stukel TA, Newman A. Proliferation of cardiac technology in Canada: a challenge to the sustainability of Medicare. *Circulation*. 2006;113:380–387.
14. Lucas FL, DeLorenzo MA, Siewers AE, et al. Temporal trends in the utilization of diagnostic testing and treatments for cardiovascular disease in the United States, 1993–2001. *Circulation*. 2006;113:374–379.
15. Fox KA, Steg PG, Eagle KA, et al. Decline in rates of death and heart failure in acute coronary syndromes, 1999–2006. *JAMA*. 2007;297:1892–1900.
16. Austin PC, Tu JV, Ko DT, et al. Use of evidence-based therapies after discharge among elderly patients with acute myocardial infarction. *CMAJ*. 2008;179:895–900.
17. Wennberg DE; Dartmouth Atlas of Cardiovascular Health Care Working Group. *The Dartmouth Atlas of Cardiovascular Health Care.* Chicago, IL: AHA Press; 1999.
18. Naylor CD, Baigrie RS, Goldman BS, et al. Assessment of priority for coronary revascularisation procedures. Revascularisation Panel and Consensus Methods Group. *Lancet*. 1990;335:1070–1073.

19. Monaghan B, Morgan C, Shragge B, et al. Through the looking glass: the cardiac care network of Ontario 10 years later. *Hosp Q*. 2001;4:30–38.
20. Tu JV, Donovan LR, Austin PC, et al. Quality of cardiac care in Ontario: Phase 1. Report 2. Toronto: Institute for Clinical Evaluative Sciences. Available at: http://www.ccort.ca/PDF/CCORT_EFFECT_Phase1_Report2.pdf. Accessed January 12, 2007.
21. Austin PC, Tu JV. Comparing clinical data with administrative data for producing acute myocardial infarction report cards. *J R Stat Soc Ser A*. 2006;169:115–126.
22. Ko DT, Mamdani M, Alter DA. Lipid-lowering therapy with statins in high-risk elderly patients: the treatment-risk paradox. *JAMA*. 2004;291:1864–1870.
23. Birkmeyer JD, Dimick JB, Birkmeyer NJ. Measuring the quality of surgical care: structure, process, or outcomes? *J Am Coll Surg*. 2004;198:626–632.
24. Jha AK. Measuring hospital quality: what physicians do? How patients fare? Or both? *JAMA*. 2006;296:95–97.
25. Krumholz HM, Normand SL. Public reporting of 30-day mortality for patients hospitalized with acute myocardial infarction and heart failure. *Circulation*. 2008;118:1394–1397.
26. Stukel TA, Fisher ES, Wennberg DE, et al. Analysis of observational studies in the presence of treatment selection bias: effects of invasive cardiac management on AMI survival using propensity score and instrumental variable methods. *JAMA*. 2007;297:278–285.
27. Selby JV, Fireman BH, Lundstrom RJ, et al. Variation among hospitals in coronary-angiography practices and outcomes after myocardial infarction in a large health maintenance organization. *N Engl J Med*. 1996;335:1888–1896.
28. Alter DA, Naylor CD, Austin PC, et al. Long-term MI outcomes at hospitals with or without on-site revascularization. *JAMA*. 2001;285:2101–2108.
29. Beveridge B, Clarke B, Janes L, et al. Canadian Emergency Department Triage and Acuity Scale. Implementation guidelines. *Can J Emerg Med*. 1999;1(suppl 3):S2–S20.
30. Tu JV, Austin PC, Chan BT. Relationship between annual volume of patients treated by admitting physician and mortality after acute myocardial infarction. *JAMA*. 2001;285:3116–3122.
31. Tu JV, Austin PC, Walld R, et al. Development and validation of the Ontario acute myocardial infarction mortality prediction rules. *J Am Coll Cardiol*. 2001;37:992–997.
32. Hosmer DW, Lemeshow S. *Applied Survival Analysis: Regression Modeling of Time to Event Data*. New York, NY: Wiley; 1999.
33. Lin DY. Cox regression analysis of multivariate failure time data: the marginal approach. *Stat Med*. 1994;13:2233–2247.
34. Schoenfield D. Partial residuals for the proportional hazards regression model. *Biometrika*. 1982;69:239–241.
35. StataCorp. *Stata Statistical Software: Release 8.0.* College Station, TX: Stata Corporation; 2003.
36. Krumholz HM, Wang Y, Mattera JA, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. *Circulation*. 2006;113:1683–1692.
37. Atzema CL, Austin PC, Tu JV, et al. Emergency department triage of acute myocardial infarction patients and the effect on outcomes. *Ann Emerg Med*. 2009;53:736–745.
38. Ayanian JZ, Landrum MB, Guadagnoli E, et al. Specialty of ambulatory care physicians and mortality among elderly patients after myocardial infarction. *N Engl J Med*. 2002;347:1678–1686.
39. Smith SM, Allwright S, O'Dowd T. Effectiveness of shared care across the interface between primary and specialty care in chronic disease management. *Cochrane Database Syst Rev.* 2007:CD004910.
40. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009;360:1418–1428.
41. Eagle KA, Montoye CK, Riba AL, et al. Guideline-based standardized care is associated with substantially lower mortality in Medicare patients with acute myocardial infarction: the American College of Cardiology's Guidelines Applied in Practice (GAP) Projects in Michigan. *J Am Coll Cardiol*. 2005;46:1242–1248.
42. Bradley EH, Herrin J, Mattera JA, et al. Quality improvement efforts and hospital performance: rates of beta-blocker prescription after acute myocardial infarction. *Med Care*. 2005;43:282–292.
43. Bradley EH, Herrin J, Wang Y, et al. Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N Engl J Med*. 2006;355:2308–2320.
44. Kalla K, Christ G, Karnik R, et al. Implementation of guidelines improves the standard of care: the Viennese registry on reperfusion strategies in ST-elevation myocardial infarction (Vienna STEMI registry). *Circulation*. 2006;113:2398–2405.
45. Pine M, Jordan HS, Elixhauser A, et al. Enhancement of claims data to improve risk adjustment of hospital mortality. *JAMA*. 2007;297:71–76.
46. Tu JV, Austin PC, Naylor CD, et al. Acute myocardial infarction outcomes in Ontario. In: Naylor CD, Slaughter PM (eds.) *Cardiovascular Health and Services in Ontario: An ICES Atlas*. Toronto, ON: Institute for Clinical Evaluative Sciences; 1999:83–110.
47. Richards J, Brown A, Homan C. The data quality study of the Canadian discharge abstract database. Proceedings of Statistics Canada Symposium 2001: Achieving data quality in a statistical agency: a methodological perspective. Ottawa, ON: Statistics Canada. Available at www.cihi.ca/cihiweb/en/downloads/quality_dadconfpaper_e.pdf. Accessed January 12, 2007.
48. Juurlink D, Preyra C, Croxford R, et al. Canadian Institute for Health Information discharge abstract database: a validation study. Toronto: Institute for Clinical Evaluative Sciences. Available at: www.ices.on.ca/file/CIHI_DAD_Reabstractors_study.pdf. Accessed January 12, 2007.
49. Peterson ED, Roe MT, Mulgund J, et al. Association between hospital process performance and outcomes among patients with acute coronary syndromes. *JAMA*. 2006;295:1912–1920.
50. Bradley EH, Herrin J, Elbel B, et al. Hospital quality for acute myocardial infarction: correlation among process measures and relationship with short-term mortality. *JAMA*. 2006;296:72–78.

APPENDIX

TABLE A1. ICD-9/ICD-10-CA Diagnosis Codes and CCP/CCI Intervention Codes

Admission Diagnosis	ICD-9 Codes	ICD-10-CA Codes
Acute myocardial infarction	410.00–410.92 (excluding 410.x2)	I21.0–I21.9
Congestive heart failure	428.0, 428.1, 428.9	I50.0, I50.1, I50.9
Intervention	**CCP Codes**	**CCI Codes**
Cardiac catheterization	489.2–489.8, 499.6, 499.7	2.HZ.28, 3.IP.10, 3.IS.10
Percutaneous coronary intervention	48.02, 48.03, 48.09	1.IJ.26, 1.IJ.50, 1.IJ.55, 1.IJ.57
Coronary artery bypass graft	48.1–48.19, 48.2	1.IJ.76, 1.IJ.80

ICD indicates International Classification of Diseases; CCP, Canadian Classification of Procedures; CCI, Canadian Classification of Interventions.