Background—Previous comparisons of acute myocardial infarction (AMI) treatment between the United States and Canada are limited because they compared selected patients from randomized trials, used administrative data that lacked clinical detail, or did not consider regional differences in AMI treatment.

Methods and Results—We compared medication use, invasive cardiac procedure use, and 30-day risk-standardized mortality rates of 38,886 fee-for-service Medicare beneficiaries hospitalized with AMI in the United States and 5634 similarly aged patients in Ontario, Canada, from 1998 and 2001. Baseline characteristics and illness severity across the US regions and Ontario were not substantially different. Cardiac catheterization use in AMI patients was significantly higher in the United States compared with Ontario (38.7% versus 16.8%, \(P<0.001\)), but significant regional variations existed, in which the northeastern United States had significantly lower utilization rates (25.6%) compared with other US regions. \(\beta\)-Blocker use among ideal candidates was highest in the northeastern United States (77.6% versus 69.7% in the United States as a whole, \(P<0.001\)) and angiotensin-converting enzyme inhibitor use was highest in Ontario (69.1% versus 58.2% in the United States, \(P<0.001\)). Risk-standardized mortality rates at 30 days were not substantially different across the regions.

Conclusions—Previous studies have suggested a clear divergence in invasive cardiac therapy for AMI patients between the United States and Canada on the basis of health care financing and structural differences. Our findings of similar treatment patterns in the northeastern United States and Ontario suggest that regional practices may have a greater impact on treatment patterns than the respective health care delivery systems. (Circulation. 2007;115:196-203.)

Key Words: outcomes ■ myocardial infarction ■ heart catheterization
early 1990s, which predate many recent advances in medical and interventional therapies.\textsuperscript{4–7} As a result, differences in processes of care and outcomes for AMI patients in the United States and Canada remain incompletely understood.

Implicit in these cross-country comparisons is the assumption that the observed differences in processes of care are driven by organizational differences between the 2 health care systems. None of these national comparison studies have considered whether local regional variations in AMI treatment patterns may play a role, however. Indeed, evidence has demonstrated tremendous regional variation in the utilization of medical therapy and cardiac invasive procedures within the United States.\textsuperscript{13–17} Therefore, it is possible that the discrepancy in cardiac procedure rates between the United States and Canada may reflect regional differences in practice patterns rather than national differences in the respective healthcare delivery systems.

Our first objective was to compare contemporary AMI treatment patterns and outcomes between the United States and Canada with clinically abstracted data from cohorts that are representative of routine clinical practice. Furthermore, we aimed to explore whether differences in AMI treatment between the United States and Canada were consistent across each US region.

### Methods

#### National Heart Care Project

The National Heart Care Project is an initiative of the Centers for Medicare and Medicaid Services designed to improve the quality of care for Medicare beneficiaries hospitalized with AMI in the United States.\textsuperscript{18} A random sample of Medicare beneficiaries hospitalized from March 1998 to April 1999 and from March 2000 to April 2001 with a principal discharge diagnosis of AMI (International Classification of Diseases, 9th Revision, Clinical Modification; code 410) was identified.\textsuperscript{19}

#### Enhanced Feedback for Effective Cardiac Treatment Project

The Enhanced Feedback for Effective Cardiac Treatment (EFFECT) project is an ongoing initiative to improve the care of cardiovascular patients in Ontario, Canada.\textsuperscript{20,21} Patients hospitalized with a most responsible diagnosis of AMI from April 1, 1999, to March 31, 2001, were identified randomly from each of the 103 participating hospitals with the Canadian Institute for Health Information hospital discharge database (International Classification of Diseases, 9th Revision, Clinical Modification, code 410). A “most responsible diagnosis” is the condition most responsible for the length of a patient’s hospital stay. This term has been demonstrated to be essentially equivalent for AMI patients to “principal diagnosis,” commonly used in the United States to describe the discharge diagnosis responsible for the hospital admission.\textsuperscript{4}

#### Study Sample

Because the data sets in the United States and Ontario were constructed independently, we restricted both AMI cohorts in an identical fashion to ensure comparability. We excluded patients who were <65 years or >105 years of age, who had invalid social security numbers (or Ontario health card numbers), who were transferred into a care center from another acute care institution, who had been hospitalized with an AMI in the previous year, or had left bundle-branch block on ECG.

We only included patients who had a confirmed AMI defined as either (1) creatine kinase–MB fraction >0.05, (2) elevation of troponin I or T above the upper limit of normal at a given hospital, or (3) 2 of the following: presence of chest pain, a 2-fold elevation of creatine kinase, or ST-segment elevation on ECG.

#### Census Regions

We divided the US cohort into 4 census regions (northeastern, southern, midwestern, and western United States) based on the state in which the patients were hospitalized.\textsuperscript{22} These regions were chosen a priori such that the sample sizes of AMI patients in each region would be comparable to the Ontario cohort.

#### Process of Care and Mortality

Patients were identified as eligible for discharge medications if they had survived to hospital discharge and were not transferred out to another acute care hospital. We identified ideal candidates for aspirin, \( \beta \)-blockers, and angiotensin-converting enzyme inhibitors at discharge by exclusion of eligible patients who had contraindications to therapy. We harmonized the definition of “ideal” so that data elements common to both databases could be used in an identical fashion.\textsuperscript{19,23}

We assessed mortality after hospital admission by linking the clinical data sets to the Medicare enrollment database and billing records in the United States, and the Ontario Registered Persons Database in Canada, which contains information on the vital status of all Ontario residents.\textsuperscript{24,25} Risk-standardized mortality rates at 30 days were chosen as our primary mortality outcome and risk-standardized mortality rates at 1 year and 3 years were chosen as secondary outcomes.

#### Statistical Analysis

Because of national privacy laws that restrict the combination of individual patient information, analyses of US and Canadian data were performed separately. We compared demographics, clinical characteristics, and therapies between the entire US and Ontario cohorts. We also compared these characteristics across geographic regions with \( \chi^2 \) tests for categorical variables and \( F \) tests with 4 degrees of freedom for continuous variables. We considered probability values of <0.001 as statistically significant in order to reduce type I error due to multiple comparisons performed in the present study. We acknowledge that because of the large number of patients in our cohorts, it is possible that small differences may be detected as statistically significant, and we therefore carefully considered clinically important results. We also examined the relationship between regional cardiac catheterization rates and availability of cardiac facilities by linear regression. An \( R^2 \) statistic was calculated to assess the strength of association and Studentized residuals were used to assess potential outliers.

To account for differences in baseline risk in comparisons of mortality rates, we first calculated mortality risk scores for each national cohort from the in-hospital prediction risk score from the Global Registry of Acute Coronary Events (GRACE) study.\textsuperscript{26} We then calculated direct standardized mortality rates of patients hospitalized in the United States (or different regions in the United States) from the risk score distribution in the Canadian cohort as the standard. This method allowed estimation of mortality rates that would be expected in the US cohort if it were to have the same risk distribution as the Canadian cohort, which thus enabled us to adjust for differences in baseline risk without combining our data sets.

Statistical analyses were conducted with SAS version 9.1 software (SAS Institute Inc, Cary, NC), and direct standardized mortality calculation was performed with STATA statistical software (Version 8.0; STATA Corp, College Station, TX).

The authors had full access to the data and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

#### Results

The US study cohort included 38,886 patients and the Canadian cohort included 5634 patients who were hospital-
Regional Variations in Medical Therapy and Cardiac Procedure Use

Among ideal candidates, β-blocker use was highest in the northeastern United States, angiotensin-converting enzyme inhibitor use was highest in Ontario, and early reperfusion therapy use was highest in the western United States (Table 3). Cardiac catheterization rates were significantly higher in the United States compared with Ontario (Table 3). We observed substantial regional differences in cardiac catheterization use in the United States, however. When cardiac catheterization rates in each US region were compared with rates in Ontario, the rates in the northeastern United States were more similar to Ontario than other regions of the United States. Similar utilization patterns of percutaneous coronary intervention and coronary artery bypass surgery were observed, with the northeastern United States being more similar to Ontario than other regions of the United States (Table 3). On the other hand, physicians in the northeastern United States and Ontario were more likely to evaluate ischemia noninvasively after AMI and had the highest utilization rates of stress tests during hospitalization (Table 3).

Table 4 shows the demographic and admission characteristics of AMI patients who received cardiac catheterization during hospitalization. AMI patients hospitalized in different regions had similar age, clinical characteristics, and mean GRACE risk score. In addition, patients who received cardiac catheterization in the northeastern United States and Ontario, areas of lower utilization of cardiac catheterization, had similar demographic and admission characteristics compared with other regions with higher utilization rates.

There was a strong association between the use of cardiac catheterization and the availability of cardiac-invasive facilities ($R^2=0.81$) (Figure 1). Observed rates of cardiac catheterization were below the best-fit line of expected rates in the northeastern United States and higher than expected in the western United States. None of the regions were considered outliers as all regions had Studentized residuals within the expected range of $-2$ to $2$.

Mortality Outcomes

The area under the receiver-operating characteristic curve of the GRACE mortality model was 0.76 for the US cohort and 0.80 for the Canadian cohort, which indicated good discriminative ability of the GRACE risk score within each cohort. Risk-standardized mortality rates at 30 days were not significantly different between the United States (17.3%; 95% CI, 17.0% to 17.7%) and Ontario (16.5%; 95% CI, 15.6% to 17.4%; $P=0.1$). Furthermore, 30-day standardized rates were not substantially different when compared across all geographic regions: northeastern United States (15.3%; 95% CI, 14.9% to 16.5%), southern United States (19.0%; 95% CI, 18.4% to 19.6%), midwestern United States (17.1%; 95% CI, 16.4% to 17.8%), western United States (16.4%; 95% CI, 15.7% to 17.1%), and Ontario (16.5%; 95% CI, 15.6% to 17.4%; $P=0.06$ across all 5 regions). At 1 year after AMI hospitalization, risk-standardized mortality rates were significantly lower in Ontario (27.7%; 95% CI, 26.7% to 28.8%) compared with the United States (31.9%; 95% CI, 31.5% to 32.3%; $P<0.001$). Similarly, risk-standardized mortality rates were also significantly lower at 3 years after AMI hospitalization (40.3%; 95% CI, 39.1% to 41.5% in Ontario versus 45.9%; 95% CI, 45.5% to 46.4% in the United States; $P<0.001$).

Discussion

To the best of our knowledge, the present study is the first United States–Canada comparison study that uses clinical data from population-representative samples to compare AMI treatment patterns and outcomes. Although we observed significantly higher overall utilization rates of cardiac invasive procedures in the United States compared with Canada, these differences varied substantially according to geographic regions in the United States. In fact, AMI treatment patterns were quite similar in the northeastern United States and Ontario, as both regions had relatively low rates of cardiac-invasive procedures but among the highest rates of medication use compared with other US regions. Less intensive use
of cardiac-invasive procedures in the northeastern United States and Ontario was not associated with poorer outcomes in the short and longer term after hospitalization compared with other US regions. This observation may imply that regions can deliver quality of care to AMI patients with similar mortality outcomes at lower cost. Our findings also suggest that, in addition to rules and regulations in each country, local regional practice patterns may also substantially influence treatment patterns. Future United States–Canada comparisons should perhaps include regional analyses, as it is possible that simple national comparisons may obscure important differences that exist between regions.

Cardiac-invasive procedures are highly dependent on the availability of resources. It is therefore not surprising to observe that lower utilization rates in the northeastern United States and Ontario were associated with a lower supply of cardiac-invasive facilities. It is well known that Canadian federal budget deficits during the 1990s created a strain on specialized services. Although Ontario continues to have the lowest utilization of cardiac catheterization, our observed rate of 16.8% during hospitalization is actually 2-fold higher than the rate of 6.3% at 30 days observed in 1991 to 1992.4 It has also been suggested that Canadian patients do not receive timely access to quality care. Our observation that Ontario had the fewest number of catheterization facilities in the northeastern United States and Ontario had the fewest number of catheterization facilities.
Although we cannot determine the optimal rate of cardiac catheterization after AMI, the less aggressive invasive approach observed in the northeastern United States and Ontario was not associated with worse short- or long-term survival after adjustment for patient and hospital factors. Findings from our study mirror those of other population-based studies, where increased invasive procedure utilization had no significant impact on mortality after AMI. A “paradox” has been observed, however, in which aggressive medical and interventional therapies are often applied to patients at relatively low risk of adverse outcomes. Finally, data suggest that invasive therapies need to be used in a timely fashion to optimize their benefits. Therefore, delays in the use of invasive therapies may have diminished the potential benefits of cardiac invasive procedures in clinical practice.

We chose risk-standardized mortality at 30 days as our primary outcome of interest because it is likely most reflective of in-hospital processes of care. Risk-standardized mortality rates were similar between the United States and Ontario at 30 days. However, we found that longer-term mortality at 1 year and at 3 years were lower in Ontario in secondary analyses. A phenomenon of better short-term survival rates in the United States followed by better intermediate-term survival rates in Canada has also been previously observed in other studies. We could not assess the possible reasons for this finding in our study, but a recent study that surveyed both countries found that US residents had more chronic conditions but were less likely to have a regular physician, more likely to have unmet health needs, and more likely to forgo needed medications because of cost. It is also possible that long-term survival after an AMI is more dependent on the general health status of patients and/or the quality of outpatient care (eg, primary care, medication adherence) than on the quality of in-hospital care, medication adherence) than on the quality of in-hospital process of care.

### TABLE 3. Process of Care of AMI Patients in the United States and Ontario

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>United States (n=3886)</th>
<th>Northeastern United States (n=6655)</th>
<th>Southern United States (n=13187)</th>
<th>Midwestern United States (n=10213)</th>
<th>Western United States (n=8831)</th>
<th>Ontario, Canada (n=5634)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedures during hospitalization</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac catheterization</td>
<td>15 044 (38.7)</td>
<td>1702 (25.6)</td>
<td>5378 (40.8)</td>
<td>4202 (41.1)</td>
<td>3762 (42.6)</td>
<td>948 (16.8)</td>
</tr>
<tr>
<td>PCI</td>
<td>7099 (18.3)</td>
<td>700 (10.5)</td>
<td>2260 (17.1)</td>
<td>2199 (21.5)</td>
<td>1940 (22.0)</td>
<td>368 (6.5)</td>
</tr>
<tr>
<td>CABG</td>
<td>2489 (6.4)</td>
<td>231 (3.5)</td>
<td>904 (6.9)</td>
<td>784 (7.7)</td>
<td>570 (6.5)</td>
<td>223 (4.0)</td>
</tr>
<tr>
<td>Echocardiography</td>
<td>21 882 (56.3)</td>
<td>4450 (66.9)</td>
<td>7366 (55.9)</td>
<td>5548 (54.3)</td>
<td>4518 (51.2)</td>
<td>2462 (43.7)</td>
</tr>
<tr>
<td>Stress test</td>
<td>3718 (9.6)</td>
<td>1037 (15.6)</td>
<td>1025 (7.8)</td>
<td>833 (8.2)</td>
<td>823 (9.3)</td>
<td>669 (11.9)</td>
</tr>
<tr>
<td><strong>Medications for ideal candidates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin</td>
<td>19 668 (76.2)</td>
<td>3128 (74.9)</td>
<td>6350 (74.1)</td>
<td>5487 (77.8)</td>
<td>4703 (78.2)</td>
<td>3268 (77.7)</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>16 193 (62.7)</td>
<td>2969 (71.1)</td>
<td>5155 (60.1)</td>
<td>4521 (64.1)</td>
<td>3548 (59.0)</td>
<td>2788 (66.3)</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>8042 (52.6)</td>
<td>1452 (54.4)</td>
<td>2639 (50.6)</td>
<td>2201 (53.4)</td>
<td>1750 (53.1)</td>
<td>1281 (67.6)</td>
</tr>
<tr>
<td>Angiotensin receptor blockers</td>
<td>899 (5.9)</td>
<td>151 (5.7)</td>
<td>298 (5.7)</td>
<td>236 (5.7)</td>
<td>214 (6.5)</td>
<td>65 (3.4)</td>
</tr>
<tr>
<td>Lipid-lowering therapy</td>
<td>8192 (31.7)</td>
<td>1327 (31.8)</td>
<td>2571 (30.0)</td>
<td>2778 (32.3)</td>
<td>2016 (33.5)</td>
<td>1330 (36.1)</td>
</tr>
<tr>
<td><strong>Medications for ideal candidates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrombolysis</td>
<td>1326 (47.1)</td>
<td>271 (53.2)</td>
<td>410 (47.1)</td>
<td>254 (40.8)</td>
<td>391 (48.0)</td>
<td>859 (62.9)</td>
</tr>
<tr>
<td>Primary PCI</td>
<td>540 (19.2)</td>
<td>43 (8.4)</td>
<td>137 (15.7)</td>
<td>157 (25.2)</td>
<td>203 (24.9)</td>
<td>18 (1.3)</td>
</tr>
<tr>
<td>Reperfusion therapy</td>
<td>1781 (63.2)</td>
<td>310 (60.9)</td>
<td>519 (59.6)</td>
<td>391 (62.8)</td>
<td>561 (68.8)</td>
<td>870 (63.7)</td>
</tr>
<tr>
<td>Aspirin at discharge</td>
<td>10 457 (76.2)</td>
<td>1932 (78.1)</td>
<td>3333 (74.0)</td>
<td>2760 (76.5)</td>
<td>2423 (77.7)</td>
<td>3003 (79.5)</td>
</tr>
<tr>
<td>β-Blockers at discharge</td>
<td>7965 (68.7)</td>
<td>1324 (77.6)</td>
<td>2512 (63.8)</td>
<td>2323 (71.9)</td>
<td>1806 (67.5)</td>
<td>1811 (68.6)</td>
</tr>
<tr>
<td>ACE inhibitors at discharge</td>
<td>6381 (58.2)</td>
<td>1136 (60.9)</td>
<td>2091 (55.5)</td>
<td>1778 (59.5)</td>
<td>1376 (58.5)</td>
<td>1016 (69.1)</td>
</tr>
</tbody>
</table>

Values are expressed as n (%). ACE indicates angiotensin-converting enzyme; PCI, percutaneous coronary intervention.

*P values compared characteristics between the entire US and Ontario cohorts. Tests of significance (not shown in table) across all 5 regions had P values <0.001 for all variables.

Because the northeastern United States does not face similar resource constraints compared to Ontario, it is more difficult to understand why the northeastern United States consistently performed fewer cardiac invasive procedures, had a smaller number of invasive facilities, and performed lower proportion of cardiac invasive procedures per facility than other US regions. We observed that patients who underwent cardiac catheterization had admission characteristics and similar GRACE risk scores, which indicated that illness severity was unlikely a major reason to explain variations in invasive procedures. Other possible reasons to explain procedural variations that we were unable to explore include differences in physician attitudes toward invasive treatment, patient preferences, and unmeasured regional characteristics.

Although we cannot determine the optimal rate of cardiac catheterization after AMI, the less aggressive invasive approach observed in the northeastern United States and Ontario was not associated with worse short- or long-term survival after adjustment for patient and hospital factors. Findings from our study mirror those of other population-based studies, where increased invasive procedure utilization had no significant impact on mortality after AMI. Several reasons may explain why benefits shown in randomized trials do not translate to the population level. First, evidence has suggested that there may only be marginal additional benefits of coronary interventions in patients who already receive optimal medical therapy. Second, the impact of any evidence-based cardiovascular therapy in the population is predominantly dependent on a patient’s baseline risk of future cardiovascular events (ie, greater benefits in higher-risk patients); a “paradox” has been observed, however, in which aggressive medical and interventional therapies are often applied to patients at relatively low risk of adverse outcomes. Finally, data suggest that invasive therapies need to be used in a timely fashion to optimize their benefits. Therefore, delays in the use of invasive therapies may have diminished the potential benefits of cardiac invasive procedures in clinical practice.
The use of cardiac catheterization in acute myocardial infarction and the proportion of patients hospitalized to a cardiac invasive facility in each region of the United States and Ontario, Canada.
a random sample of AMI patients representative of the entire province. However, we performed additional analyses by weighting the US sample based on the population in each state and found similar mortality results. Finally, we were unable to compare other nonfatal outcomes after AMI such as quality of life, left ventricular ejection fraction, or heart failure hospitalization because these data were not available.

In conclusion, despite marked differences between the American and the Canadian health care systems, the similarity of AMI treatment between the northeastern United States and Ontario suggests that local regional practice patterns play a substantial role in the influence of the delivery of care. Further exploration of factors that underlie these regional variations may provide insights to improve the quality of care for patients with AMI.

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Disclosures

None.

References

Clinical Perspective

Previous studies have suggested a clear divergence in cardiac invasive therapy for acute myocardial infarction patients between the United States and Canada on the basis of health care finance and structural differences. With clinical data from population-representative samples in the United States and Canada, we observed that acute myocardial infarction treatment patterns were actually quite similar in the northeastern United States and Ontario, as both regions had relatively low rates of cardiac-invasive procedures, whereas the rates of medication use compared with other US regions were among the highest. Less intensive use of cardiac-invasive procedures in the northeastern United States and Ontario was not associated with poorer mortality outcomes at short- and longer-term after hospitalization compared with other US regions. This observation may imply that regions can deliver quality of care to acute myocardial infarction patients with similar mortality outcomes at lower cost. Our findings also suggest that, in addition to rules and regulations in each country, local regional practice patterns may also play a substantial role in influencing how care is delivered to patients.
Regional Differences in Process of Care and Outcomes for Older Acute Myocardial Infarction Patients in the United States and Ontario, Canada

Dennis T. Ko, Harlan M. Krumholz, Yongfei Wang, JoAnne M. Foody, Fredrick A. Masoudi, Edward P. Havranek, John J. You, David A. Alter, Therese A. Stukel, Alice M. Newman, and Jack V. Tu

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