Relationship Between Annual Volume of Patients Treated by Admitting Physician and Mortality After Acute Myocardial Infarction

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PHYSICIAN VOLUME IS A WELL-ESTABLISHED DETERMINANT OF OUTCOMES AFTER INVASIVE CARDIAC PROCEDURES. PREVIOUS STUDIES HAVE DEMONSTRATED AN INVERSE RELATIONSHIP BETWEEN ANNUAL SURGEON VOLUME OF CORONARY ARTERY BYPASS GRAFT (CABG) PROCEDURES AND IN-HOSPITAL MORTALITY AND BETWEEN ANNUAL CARDIOLOGIST VOLUME OF PERCUTANEOUS CORONARY INTERVENTIONS (PCIs) PROCEDURES AND COMPLICATION RATES AFTER THE PROCEDURE.1-3 THESE ASSOCIATIONS HAVE LED TO DEVELOPMENT OF AMERICAN HEART ASSOCIATION/AMERICAN COLLEGE OF CARDIOLOGY GUIDELINES THAT RECOMMEND A MINIMUM ANNUAL VOLUME OF PROCEDURES THAT SHOULD BE PERFORMED BY CARDIAC SURGEONS AND INVASIVE CARDIOLOGISTS.4,5

The contribution of physician experience to survival after an acute myocardial infarction (AMI) is less well understood. Treatment of AMI is complex and requires considerable acumen and clinical skills. Patients with AMI can present with a wide variety of clinical manifestations and may develop a number of complications that require immediate recognition and treatment. Optimal treatment for AMI patients has undergone rapid change during the past 2 decades, with new advances occurring frequently.3 Whether physicians who only occasionally treat AMI patients can provide care comparable with those who treat AMI patients more frequently remains uncertain. Therefore, we conducted a population-based study to evaluate the relationship between annual volume of AMI patients treated by admitting physicians and mortality after an AMI.

METHODS

Data Sources
We obtained information from the Ontario Myocardial Infarction Database (OMID), which links together information from several health care administrative databases in Ontario, as described previously.6 All 139,397 patients admitted to Ontario hospitals with an AMI between April 1, 1992, and March 31, 1998, were identified based on a “most responsible diagnosis” of AMI, (International Classification of Diseases, 9th Revision, Canadian Classification of Health Interventions).6

Context Acute myocardial infarction (AMI) is a common condition that is treated by physicians with varying levels of clinical experience, but whether the level of experience affects outcome remains uncertain.

Objective To evaluate the relationship between the average annual volume of cases treated by admitting physicians and mortality after AMI.


Main Outcome Measures Mortality risk rates for 30 days and 1 year post-AMI, adjusted by physician volume and patient, physician, and hospital characteristics.

Results The 30-day mortality rate was 13.5% and the 1-year mortality rate was 21.8%. A strong inverse relationship between the average annual volume of AMI cases treated by the admitting physician and mortality after an AMI was observed. The 30-day risk-adjusted mortality rate was 15.3% for physicians who treated 5 or fewer AMI cases per year (lowest quartile) compared with 11.8% for physicians who treated more than 24 AMI cases annually (highest quartile; P<.001). The 1-year risk-adjusted mortality rate was 24.2% for physicians who treated 5 or fewer AMI cases per year (lowest quartile) compared with 19.6% for physicians who treated more than 24 AMI cases annually (highest quartile; P<.001).

Conclusion Patients with AMI who are treated by high-volume admitting physicians are more likely to survive at 30 days and 1 year.

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cases, 9th Revision code 410) in the Canadian Institute for Health Information (CIHI) hospital discharge database.\textsuperscript{7} Patients were excluded from the study if they were younger than 20 years or older than 105 years, were not Ontario residents or had an invalid Ontario health card number, were admitted as transfers from another acute care institution or to a noncardiac surgical service, had an AMI coded as an in-hospital complication, were discharged alive with a length of stay of less than 3 days, or were admitted with an AMI in the year before the index admission. A total of 108,308 patients met these criteria. The rationale for these inclusion and exclusion criteria are described in detail elsewhere.\textsuperscript{6} Previous multicenter chart audits have demonstrated a high accuracy rate of AMI coding in this cohort.\textsuperscript{6,8} The CIHI database was, in turn, linked to the Ontario Registered Persons Database, which contains information on the vital status of all Ontario residents.

### Admitting Physician Characteristics

The admitting physician for each AMI patient was determined by linking the OMID cohort to the Ontario Health Insurance Plan (OHIP) database, which contains information on physician claims for all fee-for-service billings in Ontario. Ninety-five percent of Ontario physicians bill OHIP for their services, while the remainder have an alternate form of payment (eg, salary). The latter are either specialists who typically do not manage AMI cases (eg, psychiatrists or laboratory physicians) or family physicians whose office practice is remunerated by salary or capitation but whose inpatient practice is usually fee-for-service and, hence, captured in this study.

Physician billing codes for each patient were analyzed and the admitting physician was identified as the physician who submitted a claim for services rendered on the admission date. Billing codes for emergency department physicians were not included in determining the admitting physician. In the event that 2 or more physicians submitted claims on the admission date, the admitting physician was defined as the physician who submitted the most claims for follow-up care during that hospitalization. In the event that no claims for service were submitted for the day of admission, this process was repeated for the day following admission. A unique admitting physician was identified for 98,194 patients, representing the final study cohort. Once the admitting physician for each patient was identified, additional characteristics of that physician were identified by linkage to the Corporate Providers Database of the Ontario Ministry of Health and the Southam Medical Database. These data sources provided information on the self-reported specialty, medical school of graduation, age, and sex of the physician. The total annual billings (in Canadian dollars) and the percentage of claims billed for in-hospital compared with outpatient work were also calculated for each physician. All patient health card numbers and physician billing numbers were scrambled to maintain patient and physician confidentiality.

### Specialty Classification of Physicians

All physicians in the study were classified into 4 groups: cardiologists, general internists, family physicians, or other specialists. Cardiologists in Canada undergo 2 to 3 years of specialist training after completing 3 years of core internal medicine training. General internists in Canada are required to undertake 4 years of general internal medicine training. Family physicians (including general practitioners) in Canada complete either 1 or 2 years of postgraduate training after completing medical school. Physicians in the other specialty group were predominantly physicians in other specialties of internal medicine (eg, pulmonology, nephrology, hematology). In Ontario, most AMI care in teaching and large community hospitals is provided by cardiologists and internists, whereas in most smaller community hospitals, family physicians are usually the attending physicians because of a relative lack of specialists. Family physicians often cover inpatient wards on a rotating basis or admit their own patients to the hospital. There were 195 acute care hospitals in Ontario in 1996, serving a population of 11.1 million residents.

### Patient Severity Adjustment

To control for variations in patient severity at admission, we used the Ontario AMI mortality prediction rules. These rules are based on logistic regression models that predict 30-day and 1-year mortality after an AMI. \textit{International Classification of Diseases, 9th Revision} codes were used to identify the prevalence of 9 clinical risk factors in the 15 secondary diagnostic fields of the CIHI database in addition to the age and sex of the patient. These variables included severity of cardiac disease (eg, congestive heart failure, cardiogenic shock, and arrhythmia) and comorbid conditions (eg, cancer, diabetes mellitus, renal failure). The predictive models showed good predictive power, with areas under the receiver operating characteristic curve of 0.78 for 30-day mortality and 0.79 for 1-year mortality. Their development and validation are described in detail elsewhere.\textsuperscript{9}

We also adjusted for socioeconomic status by linking the first 3 digits of the postal code (Forward Sortation Area) to 1996 census data from Statistics Canada, a central database that contained information on the median annual personal income of the neighborhood where each patient resided, as described previously.\textsuperscript{10}

### Use of Cardiac Procedures and Secondary Prevention Medications

Information on rates of invasive cardiac procedure use (eg, cardiac catheterization, PCI, and CABG surgery) within 1 year of the index AMI were obtained by linkage to the OHIP physician services and CIHI hospital discharge databases.\textsuperscript{6} Data on use of various secondary prevention medications in 48,383 elderly AMI survivors were obtained by linkage to the Ont-
Ontario Drug Benefit (ODB) program database.\(^{11}\) The ODB program is a government-funded drug benefit program that covers outpatient drug costs for all Ontario residents aged 65 years or older. Some patients may have elected to purchase aspirin over the counter rather than receive it through the ODB program.

**Physician and Hospital AMI Volume**

The average annual volume of AMI cases treated was determined for each admitting physician by dividing the total number of AMI cases treated during the 6-year study period by the number of years the physician actually treated 1 or more AMI patients. The average annual volume of AMI cases treated was also calculated for each hospital in Ontario. Hospitals were classified as low (\(\leq 33\) AMI cases per year), medium (34–99 cases per year), or high (\(\geq 100\) cases per year) volume.

**Statistical Analyses**

The final cohort of 98194 patients was divided into 4 approximately equally sized physician volume quartiles, with approximately 25,000 patients in each quartile. This corresponded to average annual physician volumes of 1 to 5, 6 to 13, 14 to 24, and more than 24 AMI cases treated per year. Univariate analyses of patient and physician characteristics were conducted within each of these physician volume quartiles. Risk-adjusted mortality rates by physician volume were determined by dividing the observed mortality rates by the expected mortality rates predicted from the Ontario AMI mortality prediction rules and multiplying this ratio by the average mortality rate during the 6-year study period. The risk-adjusted mortality rate can be interpreted as the mortality rate that would be expected if the case mix were identical in different physician volume groups. To determine if there was a threshold effect for physician volume, 30-day and 1-year risk-adjusted mortality rates with 95% confidence intervals (CIs) were also calculated by decile of physician volume.

Multivariable analyses of the physician volume effect were also conducted using random effects hierarchical logistic regression models that adjusted for patient characteristics (eg, age, sex, predicted 30-day mortality, socioeconomic status), other physician characteristics (eg, specialty, age, sex), and hospital characteristics (eg, hospital volume and teaching status, availability of on-site revascularization facilities). These multilevel models were fit using the software package MLwiN\(^{12}\) and took into account the hierarchical nature of the data, with patients clustered within physicians and physicians clustered within hospitals. Backward stepwise regression analyses were conducted to identify the significant independent predictors of 30-day mortality at the \(P<.05\) level. Prespecified interaction terms between each physician volume quartile and specialty were included in these models. The discrimination and calibration of these models was determined.\(^{13,14}\)

A propensity score analysis was also conducted in which care by a low-volume physician was the exposure.\(^{15}\) A logistic regression model was used to de-

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**Table 1. Baseline Characteristics by Quartile of Admitting Physician AMI Volume**

<table>
<thead>
<tr>
<th>Physician Volume Quartile, AMI Cases per Year</th>
<th>1-5</th>
<th>6-13</th>
<th>14-24</th>
<th>&gt;24</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. (% of patients)</td>
<td>27494 (28.0)</td>
<td>20896 (21.3)</td>
<td>24730 (25.2)</td>
<td>25074 (25.5)</td>
</tr>
<tr>
<td>Age, mean (median), y</td>
<td>68.8 (70)</td>
<td>66.6 (68)</td>
<td>66.6 (68)</td>
<td>66.0 (67)</td>
</tr>
<tr>
<td>Female, %</td>
<td>39.0</td>
<td>35.5</td>
<td>35.1</td>
<td>34.5</td>
</tr>
<tr>
<td>Median neighborhood personal annual income, Can $</td>
<td>19542</td>
<td>20140</td>
<td>20102</td>
<td>20041</td>
</tr>
<tr>
<td>Clinical status at admission, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac dysrhythmias</td>
<td>13.5</td>
<td>14.2</td>
<td>14.5</td>
<td>14.7</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>2.2</td>
<td>4.2</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>22.5</td>
<td>19.3</td>
<td>19.1</td>
<td>19.7</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>1.4</td>
<td>1.2</td>
<td>1.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Cancer</td>
<td>2.6</td>
<td>2.0</td>
<td>2.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Stroke</td>
<td>4.9</td>
<td>3.9</td>
<td>3.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Diabetes with complications</td>
<td>2.4</td>
<td>1.8</td>
<td>1.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Renal failure</td>
<td>1.8</td>
<td>1.4</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Acute</td>
<td>2.6</td>
<td>2.1</td>
<td>2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Predicted mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-Day</td>
<td>14.7</td>
<td>13.0</td>
<td>13.2</td>
<td>12.9</td>
</tr>
<tr>
<td>1-Year</td>
<td>23.9</td>
<td>21.1</td>
<td>21.2</td>
<td>20.9</td>
</tr>
<tr>
<td><strong>Physician Characteristics, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family physician</td>
<td>76.5</td>
<td>25.3</td>
<td>4.6</td>
<td>0</td>
</tr>
<tr>
<td>General internist</td>
<td>9.6</td>
<td>30.3</td>
<td>35.8</td>
<td>20.6</td>
</tr>
<tr>
<td>Cardiologist</td>
<td>3.4</td>
<td>24.7</td>
<td>44.4</td>
<td>73.4</td>
</tr>
<tr>
<td>Other</td>
<td>10.6</td>
<td>19.7</td>
<td>15.2</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Hospital Characteristics, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching hospital</td>
<td>9.5</td>
<td>18.3</td>
<td>19.9</td>
<td>23.4</td>
</tr>
<tr>
<td>Rural hospital</td>
<td>6.6</td>
<td>4.1</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Hospital AMI volume (cases per year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low ((\leq 33))</td>
<td>19.5</td>
<td>5.4</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Medium (34–99)</td>
<td>34.1</td>
<td>20.8</td>
<td>18.4</td>
<td>10.7</td>
</tr>
<tr>
<td>High ((\geq 100))</td>
<td>46.4</td>
<td>73.9</td>
<td>80.7</td>
<td>80.3</td>
</tr>
<tr>
<td>Catheterization/revascularization facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>89.1</td>
<td>83.2</td>
<td>88.4</td>
<td>80.1</td>
</tr>
<tr>
<td>Both</td>
<td>7.2</td>
<td>13.0</td>
<td>9.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Catheterization only</td>
<td>3.7</td>
<td>3.8</td>
<td>2.1</td>
<td>5.4</td>
</tr>
</tbody>
</table>

*AMI indicates acute myocardial infarction. The unit of analysis in this table is the patient.
PHYSICIAN VOLUME AND MORTALITY AFTER AMI

terminate the probability of having been treated by a low-volume physician, using the variables from the Ontario AMI mortality prediction rules as covariates. Patients were stratified into quintiles according to their propensity of having been treated by a low-volume physician. The effect of having been treated by a low-volume physician as opposed to a non–low-volume physician was estimated across quintiles. All traditional statistical analyses were conducted using SAS version 8 software (SAS Institute Inc, Cary, NC).

RESULTS

The final cohort of 98,194 patients was divided into 4 quartiles of physician AMI volume (TABLE 1). The characteristics of 4 quartiles with the exception of low-volume physicians (≤5 AMI cases per year), whose patients were slightly older on average than those in the other quartiles. Patients of low-volume physicians were also more likely to be admitted to low- or medium-volume hospitals, although almost half (46.4%) of these patients were admitted to high-volume hospitals. In contrast, patients of high-volume physicians (>24 AMI cases per year) were predominantly admitted to high-volume hospitals.

The characteristics of admitting physicians by physician volume quartile are shown in TABLE 2. The median age of the physicians was similar across the quartiles; however, the proportion of high-volume physicians was lower at the extremes of age (ie, <35 and ≥65 years). The vast majority of physicians (n=4455) were in the low-volume category. They were more likely to be family physicians (76.5%), with the highest relative proportion of female physicians (17.0%) in the low-volume category. High-volume physicians were predominantly cardiologists. The total amount of clinical work (measured by total billings) was similar across volume quartiles, although the proportion of in-hospital work was greatest among higher-volume physicians.

Use of various secondary preventive medications in elderly AMI survivors is shown in TABLE 3 by physician volume quartile. Elderly patients of low-volume physicians were least likely to receive aspirin, β-blockers, or statins within 90 days of hospital discharge, compared with those of high-volume physicians (P<.001 for all comparisons). Patients of low-volume physicians were

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Table 2. Physician Characteristics by Quartile of Admitting Physician AMI Volume*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1-5</th>
<th>6-13</th>
<th>14-24</th>
<th>&gt;24</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of physicians</td>
<td>4455</td>
<td>526</td>
<td>257</td>
<td>136</td>
</tr>
<tr>
<td>Age, median (IQR), y</td>
<td>42 (35-51)</td>
<td>41 (35-48)</td>
<td>42 (37-51)</td>
<td>44 (40-52)</td>
</tr>
<tr>
<td>Physician age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;35</td>
<td>1099 (24.7)</td>
<td>127 (24.1)</td>
<td>39 (15.2)</td>
<td>14 (10.3)</td>
</tr>
<tr>
<td>35-44</td>
<td>1515 (34.0)</td>
<td>207 (39.4)</td>
<td>106 (41.3)</td>
<td>56 (41.2)</td>
</tr>
<tr>
<td>45-54</td>
<td>1044 (23.5)</td>
<td>115 (21.9)</td>
<td>66 (25.7)</td>
<td>43 (31.6)</td>
</tr>
<tr>
<td>55-64</td>
<td>491 (11.0)</td>
<td>57 (10.8)</td>
<td>35 (13.6)</td>
<td>19 (14.0)</td>
</tr>
<tr>
<td>&gt;65</td>
<td>303 (6.8)</td>
<td>20 (3.8)</td>
<td>11 (4.3)</td>
<td>4 (2.9)</td>
</tr>
<tr>
<td>Total annual billings, median, Can $†</td>
<td>175,832</td>
<td>157,665</td>
<td>175,073</td>
<td>195,745</td>
</tr>
<tr>
<td>Billings derived from hospital work, median (IQR), %</td>
<td>7.7 (4.3-13.6)</td>
<td>19.4 (9.5-36.4)</td>
<td>31.6 (20.7-42.4)</td>
<td>36.7 (27.7-46.5)</td>
</tr>
<tr>
<td>Female physicians</td>
<td>757 (17.0)</td>
<td>68 (12.9)</td>
<td>21 (8.2)</td>
<td>7 (5.2)</td>
</tr>
<tr>
<td>Foreign medical graduates</td>
<td>890 (20.0)</td>
<td>109 (20.7)</td>
<td>65 (25.3)</td>
<td>36 (26.5)</td>
</tr>
<tr>
<td>Rural physicians</td>
<td>453 (10.2)</td>
<td>40 (7.7)</td>
<td>9 (3.5)</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Family physicians</td>
<td>3406 (76.5)</td>
<td>163 (31.0)</td>
<td>13 (5.1)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>General internists</td>
<td>383 (8.6)</td>
<td>144 (27.4)</td>
<td>89 (34.6)</td>
<td>31 (22.8)</td>
</tr>
<tr>
<td>Specialists</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiologists</td>
<td>72 (1.6)</td>
<td>113 (21.5)</td>
<td>115 (44.8)</td>
<td>97 (71.3)</td>
</tr>
<tr>
<td>Other</td>
<td>594 (13.3)</td>
<td>106 (20.2)</td>
<td>40 (15.6)</td>
<td>8 (5.9)</td>
</tr>
</tbody>
</table>

*All data are number (percentage) unless otherwise specified. AMI indicates acute myocardial infarction; IQR, interquartile range.
†Excludes billings for diagnostic and therapeutic procedures.

Table 3. Secondary Prevention Medication Use, Invasive Cardiac Procedures, and Outcomes After AMI by Annual Physician Volume Quartile*

<table>
<thead>
<tr>
<th>Physician Volume Quartile, AMI Cases per Year</th>
<th>1-5</th>
<th>6-13</th>
<th>14-24</th>
<th>&gt;24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary prevention medication rates at 90 days, %†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin</td>
<td>54.3‡</td>
<td>59.9‡</td>
<td>61.1§</td>
<td>62.5</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>42.8‡</td>
<td>50.8</td>
<td>52.3§</td>
<td>50.9</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>45.4</td>
<td>46.4§</td>
<td>46.0</td>
<td>44.8</td>
</tr>
<tr>
<td>HMG-CoA reductase inhibitors (statins)</td>
<td>10.3§</td>
<td>13.1§</td>
<td>14.3</td>
<td>14.8</td>
</tr>
<tr>
<td>Cardiac procedure rates at 1 year, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCI</td>
<td>6.1‡</td>
<td>8.6‡</td>
<td>8.6‡</td>
<td>9.9</td>
</tr>
<tr>
<td>CABG</td>
<td>8.1‡</td>
<td>9.5‡</td>
<td>10.2§</td>
<td>10.8</td>
</tr>
<tr>
<td>Outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-Day crude mortality, %</td>
<td>16.6†</td>
<td>12.9‡</td>
<td>12.8‡</td>
<td>11.3</td>
</tr>
<tr>
<td>30-Day risk-adjusted mortality, %</td>
<td>15.3†</td>
<td>13.4‡</td>
<td>13.1†</td>
<td>11.8</td>
</tr>
<tr>
<td>1-Year crude mortality, %</td>
<td>26.5†</td>
<td>20.9‡</td>
<td>20.6†</td>
<td>18.8</td>
</tr>
<tr>
<td>1-Year risk-adjusted mortality, %</td>
<td>24.2†</td>
<td>21.6‡</td>
<td>21.1†</td>
<td>19.6</td>
</tr>
<tr>
<td>Length of stay, median, d</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

*AMI indicates acute myocardial infarction; ACE, angiotensin-converting enzyme; HMG-CoA, 3-hydroxy-3-methylglutaryl coenzyme A; PCI, percutaneous coronary intervention; and CABG, coronary artery by-pass graft.
†The sample for these analyses was restricted to elderly (age ≥65 years) AMI survivors only. Some patients may have received aspirin over the counter rather than through the Ontario Drug Benefit Program.
‡P value <.001 compared with high-volume physicians.
§P value <.05 compared with high-volume physicians.
*See "Statistical Analysis" in the "Methods" section of the text for details about risk-adjusted mortality rate calculations.
also the least likely to receive invasive
cardiac procedures, including cardiac
catheterization, PCI, and CABG sur-
gery, within 1 year of their AMI
(P<.001).

The overall 30-day mortality rate in
the study cohort was 13.5% and the
1-year mortality rate was 21.8%. An in-
verse relationship was found between
admitting physician AMI volume and
verse relationship was found between
the study cohort was 13.5% and the
adjusted mortality rate was 24.2% amon-
glow-volume physicians to a low of
11.8% among high-volume physi-
cians (P<.001), while the 1-year risk-
adjusted mortality rate was 24.2%
among low-volume physicians com-
pared with 19.6% among high-
volume physicians (P<.001). Analy-
ses of the physician volume–mortality
relationship by decile of physician vol-
ume are shown in the Figure. A defini-
tive volume threshold where mortal-
ity rates plateaued did not appear to
exist, with mortality differences great-
est at the extremes of physician vol-
ume. The physician volume effect ex-
isted not only at 30 days but also
through 1 year of follow-up.

Based on the 11 variables listed in
Table 1, a logistic regression model was
used to generate propensity scores de-
scribing the probability that any given
patient would be cared for by a low-
volume physician. The χ² statistic of the
model was 0.56. After adjusting for the
propensity score among these pa-
tients, patients cared for by lower-
volume physicians had a higher rate of
death at 30 days (15.2% vs 12.6%; 95%
CI for difference, 2.2%-3.0%; P<.001)
and at 1 year (24.3% vs 20.6%; 95% CI
for difference, 3.2%-4.2%; P<.001).

Multivariable analyses of physician
volume and specialty effects on 30-day
mortality are shown in Table 4. Be-
cause of a significant interaction
between physician volume and spe-
cialty, the overall effect of both factors
could not be expressed as a single
odds ratio (OR). Table 4 demonstrates
a consistent volume-outcome gradient
within each physician specialty after
adjustment for possible confounders.
It also shows that physician specialty
was not an independent predictor of
30-day mortality in most subgroups
after adjusting for physician volume.
The discrimination of this model was
good (χ² statistic=0.80), while the cali-
bration was poor (Hosmer-Lemeshow
χ² statistic=170; P<.001), likely secondary
to the large sample size.16 Low-volume
physicians in other specialties had the
highest adjusted OR (2.49; 95% CI,
1.92-3.24) for 30-day mortality. Low
hospital volume was not a significant
independent predictor of 30-day mor-
tality, with an OR of 0.96 (95% CI,
0.86-1.08) after adjustment for physi-
cian volume and other factors. Admis-
sion to a revascularization hospital
was also not a predictor of 30-day
mortality (OR, 1.12; 95% CI, 0.94-
1.35), but admission to a teaching
hospital was predictive of lower
30-day mortality (OR, 0.79; 95% CI,
0.68-0.92).

We also examined the association be-
 tween physician volume and outcome
during different points of the study.
Among patients cared for in 1992, the
adjusted 30-day mortality rates for pa-
tients in the lowest and highest quar-
tiles of physician volume were 15.8%
and 12.3%. Similarly, in 1996, the cor-
responding death rates were 15.2% and
10.5%.

Figure. Risk-Adjusted Acute Myocardial Infarction (AMI) Mortality Rates at 30 Days and 1 Year by Deciles of Annual Volume of AMI Patients Treated by Admitting Physician

Error bars indicate 95% confidence intervals for mortality rates.

Table 4. Adjusted Odds Ratios for 30-Day Mortality by Physician Volume Specialty of Admitting Physician

| Physician Volume Quartile, AMI Cases per Year | 1-5 | 6-13 | 14-24 | >24
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<td>Compared With High-Volume Physicians Within Same Specialty</td>
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| Cardiologists | 1.48 (1.17-1.86) | 1.22 (1.06-1.41) | 1.09 (0.97-1.23) | Referent
| General internists | 1.57 (1.30-1.90) | 1.27 (1.06-1.51) | 1.25 (1.05-1.48) | Referent
| Family physicians | 1.32 (0.98-1.78) | 1.26 (0.92-1.72) | Referent | †
| Other | 2.49 (1.92-3.24) | 1.00 (0.77-1.31) | 1.09 (0.82-1.44) | Referent
| Compared With Cardiologists Within Same Volume Category | | | | |
| Cardiologists | Referent | Referent | Referent | Referent
| General internists | 1.02 (0.80-1.30) | 0.99 (0.86-1.15) | 1.09 (0.96-1.24) | 0.95 (0.81-1.31)
| Family physicians | 0.78 (0.62-0.98) | 0.90 (0.77-1.06) | 0.88 (0.66-1.16) | †
| Other | 1.98 (1.66-2.51) | 0.96 (0.82-1.14) | 1.17 (0.99-1.38) | 1.17 (0.91-1.51)

*AMI indicates acute myocardial infarction. Odds ratios are adjusted for variations in patient age, sex, predicted 30-
day mortality, and socioeconomic status; physician specialty, volume, specialty-volume interaction, sex, and age;
hospital volume, teaching status, and cardiac procedural capacity. Data are odds ratios (95% confidence int-
ervals).
†There were no family physicians in the highest-volume quartile.
COMMENT

This study demonstrates a strong inverse association between average annual volume of AMI cases treated by admitting physicians and patient mortality after an AMI. Physicians who treated the most patients on an annual basis had the lowest 30-day and 1-year patient mortality rates, even after adjusting for potential confounders. The impact of physician volume on outcomes of AMI patients was comparable with the impact of physician volume on outcomes of invasive cardiac procedures. Our study suggests that “practice makes perfect” in treating AMI, a common condition treated by physicians with widely varying levels of clinical experience. The association between physician volume and mortality was robust and existed across physician specialties.

The results of our study are consistent with a previous study conducted using Pennsylvania hospital discharge data from 1993 that demonstrated an inverse association between physician volume and in-hospital mortality after an AMI. That study demonstrated that patients of low-volume physicians who treated 1 to 6 AMI patients per year had a 43% higher in-hospital mortality rate than high-volume physicians, defined as those who treated 24 or more AMI patients per year. Using a larger population-based sample of 98,194 patients and 5374 physicians during a 6-year period, we observed a similar effect on 30-day and 1-year risk-adjusted mortality, suggesting that the physician volume effect is a universal phenomenon that exists in different countries and is independent of the health care system. Physician volume was a stronger predictor of 30-day AMI mortality than was physician specialty in both our study and the Pennsylvania analysis.

Our analyses suggest that physician volume may explain the AMI survival benefit with cardiological care found in other studies. Our data do not allow us to precisely define a minimum annual volume of AMI cases that should be treated to optimize patient outcomes. There did not appear to be any volume threshold beyond which mortality rates leveled off (Figure). Nevertheless, our results do suggest that significant reductions in AMI mortality could be achieved by shifting the primary responsibility for treating more AMI patients to a smaller number of high-volume physicians. Hospitals that have low-volume physicians could consider designating a few physicians to handle all of their AMI cases or they could mandate that low-volume physicians work with high-volume physicians when treating AMI patients. This strategy may be more difficult to implement in small, rural hospitals, where only a few physicians are available to provide AMI care. Alternatively, educational strategies could be developed toward improving the knowledge and clinical expertise of low-volume physicians. For example, use of standardized care maps and admission orders might improve compliance with recommended treatment protocols (eg, aspirin, β-blockers) among low-volume physicians.

The inverse association between physician volume and mortality rates, even after adjusting for potential confounders, the impact of physician volume on outcomes of invasive cardiac procedures, and the association between physician volume and mortality were robust and existed across physician specialties. Physician volume was a strong predictor of 30-day AMI mortality, although low hospital volume was not a significant predictor of 30-day mortality in our analysis.

Our study has certain limitations. First, because our study relied on linked administrative databases, we were unable to adjust for all possible clinical factors that influence mortality after an AMI. Nevertheless, we did adjust for patient age, sex, comorbidities, socioeconomic status, and physician specialty as well as other physician and hospital characteristics, and we still found a consistent physician volume-outcome relationship. Second, there may have been undercoding of comorbid conditions in our administrative databases, which may have reduced the accuracy of our statistical regression models to adjust for factors that may affect the physician volume-outcome relationship. Third, we did not have information on in-hospital use of various therapies such as thrombolytics, aspirin, and β-blockers, which could partially explain the volume-outcome relationship. One recent study from Minnesota showed that low-volume physicians were the least likely to treat their AMI patients with aspirin and thrombolytics. High-volume physicians may also be better at recognizing an AMI and interpreting difficult electrocardiograms. They may be faster at making decisions regarding thrombolytics, choose more appropriate risk stratification tests, make more appropriate referral decisions, and be more skilled at treating complications such as cardiogenic shock and arrhythmia. These possible explanations will need to be investigated in future studies.

In summary, we found a significant inverse relationship between the average annual volume of patients treated by the admitting physician and mortality after an AMI. Increases in the annual volume of cases treated were associated with significant reductions in 30-day mortality that were sustained at 1 year of follow-up. These results have important policy implications for optimizing the quality of care for AMI patients. Although the exact mechanisms contributing to this complex phenomenon remain to be elucidated, our data suggest that shifting the care of more AMI patients to a smaller number of high-volume physicians could potentially result in a significant decrease in the number of AMI deaths that occur each year. Developing strategies to improve the clinical expertise of low-volume physicians might also lead to better patient outcomes.

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REFERENCES


Science and technology, and the various forms of art, all unite humanity in a single and interconnected system. As science progresses, the worldwide cooperation of scientists and technologists becomes more and more of a special and distinct intellectual community of friendship, in which, in place of antagonism, there is growing up a mutually advantageous sharing of work, a coordination of efforts, a common language for the exchange of information, and a solidarity, which are in many cases independent of the social and political differences of individual states.

—Zhores Aleksandrovich Medvedev (1925- )