Background—The goal of this study was to determine the relationship between all-cause, risk-adjusted, in-hospital mortality after coronary artery bypass graft surgery and the proportion of preventable in-hospital deaths as a measure of quality of care at an institution level.

Methods and Results—We conducted a retrospective analysis of 347 randomly selected in-hospital deaths after isolated coronary artery bypass graft surgery at 9 institutions in Ontario over the period of 1998 to 2003. Nurse-abstracted chart summaries were reviewed by 2 experienced cardiac surgeons who were blinded to patient, surgeon, and hospital and used a standardized implicit tool to identify preventable death. A third reviewer reassessed all cases in which the first 2 reviewers disagreed. Rates of preventable deaths were estimated for each hospital and compared with all-cause mortality rates. A structured adverse event audit completed by each surgeon-reviewer was used to identify quality improvement opportunities for the preventable deaths. A total of 111 of 347 deaths (32%) were judged preventable despite a low risk-adjusted mortality range (1.3% to 3.1%) across hospitals. No significant correlation was found between all-cause, risk-adjusted in-hospital mortality rates and the proportion of preventable deaths at the hospital level (Spearman coefficient, \(-0.42; P=0.26\)). A large proportion of preventable deaths were related to problems in the operating room (86%) and intensive care unit (61%). Many deaths were associated with deviations in perioperative care (32% based on concurrence of 2 reviewers, and another 42% in cases in which 1 reviewer reached that opinion).

Conclusions—Approximately one third of in-hospital coronary artery bypass graft death rates were judged preventable by surgeon reviewers. All-cause risk-adjusted mortality rates are convenient measures of institutional quality of care but were not correlated with preventable mortality in our jurisdiction. Providers should conduct detailed adverse event audits to drive meaningful improvements in quality. (Circulation. 2008;117:2969-2976.)

Key Words: coronary artery bypass surgery ■ health policy ■ hospital mortality ■ quality of health care

In recent years, hospital report cards have become popular as a tool for promoting improvements in quality of care. These reports commonly monitor outcomes such as in-hospital mortality that are salient to patients and providers, are readily measured, and can be compared at the physician or institution level through the use of risk adjustment methodology.1,2 On the basis of comparisons to average performance in a peer group, providers are then identified as statistical outliers. This paradigm, however, has 2 basic problems. First, it is never clear how many of the deaths associated with an outlying provider are preventable. Second, compared with a handful of outlier providers, the total number of preventable deaths may actually be much higher if cumulated across the majority of nonoutlier hospitals or providers. The latter concern underpins arguments that quality of care is best enhanced...
by dealing with all institutions rather than isolating and addressing outliers.

**Editorial p 2963**

**Clinical Perspective p 2976**

Assessing the preventability of adverse events is not a new concept. Hospital morbidity and mortality rates have long been used as internal mechanisms to evaluate adverse events but have been criticized for lack of rigor. Moreover, critics have suggested that these rounds often ignore available evidence and best practices, in part because physicians are ineffective at self-audit owing to lack of insight, fear of embarrassment, or reluctance to admit errors. More structured reviews have therefore been initiated that aim to determine the preventability of adverse events by identifying problems with processes of care and then judging whether these problems contributed to the poor outcome. For example, preventable death rates have been defined as the fraction of the all-cause mortality that could have been avoided if optimal care had been delivered. Implicit standardized chart reviews have been used to identify preventable death, a UK medical review form, a US medical review form, and a form developed for identifying cause of death in patients undergoing CABG. This implicit review tool was modified by use of a consensus-based approach from previous templates applied in adverse event audits, eg, a nationwide project in Canada identifying preventable adverse events, a UK medical review form, a US medical review form, and a form developed for identifying cause of death in patients undergoing CABG. Our tool was uniquely sequenced to follow the clinical path of a patient using standardized checklists to help identify problems in each of the major phases of care: preoperative, operative, intensive care unit, and ward care.

Evidence of preventability was scored on a 7-point Likert scale (ie, an increasing Likert scale score represented an increasing strength of preventability), which was then broken for our primary analysis into a binary outcome with boundaries as follows: (1) Preventability ratings of “none,” “slight,” “modest,” and “<50 to 50” were treated as an unpreventable event; (2) “50 to 50 but close call,” “strong,” and “certain” were treated as preventable events. These interpretations were predefined, and surgeon-reviewers were aware of the interpretive rubric in advance of reviewing. We also instructed reviewers that the preventability of the death could be judged only from facts available within the chart from the same hospital admission as CABG surgery. For this reason, we instructed reviewers that issues relating to care could be reliably judged only once the surgeon had accepted the patient (called the decision to operate as documented in the chart). Reviewers were advised that the preventable death was defined as a death that could have been avoided if optimal care had been delivered to the patient. We defined optimal care as the best possible care that could be delivered if current resources were operating at peak performance (ie, staff, equipment) in accordance with the best available evidence at the date of the particular patient admission. Reviewers were required to provide a list of quality-of-care problems that contributed to deaths judged as preventable and potential solutions to these problems. We encouraged reviewers to minimize hindsight bias by asking them after each problem listed to reflect on the question, “Would this still be a problem if the patient had not died?”

We instructed surgeon-reviewers to judge appropriateness of the decision to operate using the American College of Cardiology/American Heart Association class 1 or 2A indications for CABG surgery as a framework. Our reviewers understood that these indications should be applied in the context of a patient’s unique operability as assessed by anatomy, clinical status, and comorbidities.

For those cases in which disagreement arose on the appropriateness of the decision to operate and/or whether the death was preventable, a third surgeon-reviewer reviewed both primary physician reviews and the original chart data to provide a final judgment.

**Chart Review Methodology**

Hospital charts of each in-hospital death were reviewed by trained nurse-abstractors for baseline demographic and clinical data using a standardized database. The nurse-abstractors were experienced in carrying out chart reviews for cardiovascular disease. A 2-day training session was completed by each nurse-abstractor, and each nurse was required to complete 10 training charts with review and feedback from the principal investigator (V.G.).

The nurse-abstracted chart summary and relevant photocopied portions of the chart were reviewed by 2 cardiac surgeons blinded to the identity of the patient, attending surgeon, and hospital. The cardiac surgeons were experienced staff surgeons and/or division chiefs chosen from each of the participating hospitals. Each surgeon-reviewer was trained to apply a standardized implicit tool to identify preventable deaths. Training included a 1-day session, 2 teleconferences, and completion of 10 training charts with review and feedback. Each primary surgeon-reviewer was randomly assigned cases that originated from hospitals other than their home institution. Most primary surgeon-reviewers completed between 70 and 90 cases during the study.

This implicit review tool was modified by use of a consensus-based approach from previous templates applied in adverse event audits, eg, a nationwide project in Canada identifying preventable adverse events, a UK medical review form, a US medical review form, and a form developed for identifying cause of death in patients undergoing CABG. Our tool was uniquely sequenced to follow the clinical path of a patient using standardized checklists to help identify problems in each of the major phases of care: preoperative, operative, intensive care unit, and ward care.

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For those cases in which disagreement arose on the appropriateness of the decision to operate and/or whether the death was preventable, a third surgeon-reviewer reviewed both primary physician reviews and the original chart data to provide a final judgment.

**Methods**

**Target Population, Study Design, and Sampling Strategy**

Each cardiac surgery unit in Ontario agreed to participate in the study, and ethics approval was obtained from each hospital separately.

We identified patients undergoing isolated coronary artery bypass graft (CABG) surgery in Ontario between April 2000 and March 2002 using both a well-established surgical registry (Cardiac Care Network of Ontario) and hospital discharge abstract data (Canadian Institutes of Health Information). We randomly sampled up to 40 in-hospital postoperative deaths for 8 hospitals and 27 consecutive deaths at a single hospital. We instructed surgeon-reviewers to judge appropriateness of the decision to operate as documented in the chart. Reviewers were advised that the preventable death was defined as a death that could have been avoided if optimal care had been delivered to the patient. We defined optimal care as the best possible care that could be delivered if current resources were operating at peak performance (ie, staff, equipment) in accordance with the best available evidence at the date of the patient’s particular admission. Reviewers were required to provide a list of quality-of-care problems that contributed to deaths judged as preventable and potential solutions to these problems. We encouraged reviewers to minimize hindsight bias by asking them after each problem listed to reflect on the question, “Would this still be a problem if the patient had not died?”

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For those cases in which disagreement arose on the appropriateness of the decision to operate and/or whether the death was preventable, a third surgeon-reviewer reviewed both primary physician reviews and the original chart data to provide a final judgment.
Data Analysis

The statistical analyses were conducted with SAS software (version 8.2, SAS Institute Inc, Cary, NC). Inter-rater reliability between the first 2 primary death reviewers was assessed with a standard κ statistic. The κ statistic was interpreted as follows: 0 = none, 0 to 0.2 = slight, 0.2 to 0.4 = fair, 0.4 to 0.6 = moderate, 0.6 to 0.8 = substantial, and 0.8 to 1.0 = almost perfect.

A logistic model predicting in-hospital mortality was constructed using patient demographics and cardiac risk factors for patients undergoing isolated CABG in Ontario to calculate predicted mortality risk as described previously. Correlations were assessed with the Spearman rank correlation coefficient between all-cause risk-adjusted mortality and preventability of death or quality-of-care problems identified at each hospital. Risk-adjusted mortality was calculated using the observed mortality divided by the predicted mortality rate for a particular hospital multiplied by the average crude provincial mortality rate.

A logistic model was created from the 347-patient data set to determine the predictors of preventable versus nonpreventable deaths. An initial univariate selection of candidate predictor variables (ie, preoperative risk factors commonly used to adjust CABG mortality) was conducted in which variables that were statistically significant at the 0.3 level were retained for consideration in a model derived with backwards variable elimination. The significance level of 0.3 was selected to exclude potential predictors from consideration for inclusion in the final model. As a sensitivity analysis, we also estimated the same logistic regression model using generalized estimating equation methods (with the assumption that the structure of the working correlation matrix was exchangeable) to ensure that accounting for the clustering of patients within surgical center did not significantly change the estimates obtained.

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

Results

Figure 1 illustrates the results of the physician review. Fifty-two deaths occurred that both reviewers judged preventable. Another 114 deaths occurred that 1 of 2 reviewers judged preventable, and 59 of them were judged preventable by a third reviewer. Thus, 111 of 347 deaths (32%) reviewed were deemed preventable. As a sensitivity analysis, we averaged the preventability ratings of the first 2 reviewers and determined that the mean Likert rating for those cases deemed as preventable at 4.9 (95% CI, 4.71 to 5.07) was significantly different from those deemed as nonpreventable at 2.6 (95% CI, 2.43 to 2.69). Based on 2 reviews, the top 5 root causes of death after isolated CABG surgery were sudden death and/or ventricular arrhythmia (28%; 35% preventable); intraoperative and/or postoperative cardiac ischemia and/or cardiac infarction and/or cardiac failure (20%; 43% preventable); multiorgan failure (21%; 24% preventable); neurological injury, including coma and/or stroke (11%; 31% preventable); and respiratory failure (7%; 22% preventable).

More than 1 preventable cause could be identified for a given death. The majority of the deaths were attributed to problems that occurred in the operating room (86%) or postoperative intensive care unit (61%), with a minority occurring on the ward (15%; see Figure 1).

A small minority of deaths were attributed to problems in the timing of surgery (4% of deaths on both surgeon reviews [double review], 15% of deaths on 1 of the 2 surgeon reviews [single review]) and/or the initial decision to operate (2% double review, 12% single review; see Table 1). A larger minority of deaths were assessed as showing deviations in perioperative care (32% double review, 42% single review; see Table 1). As measured by κ statistics, mild to moderate agreement between reviewers was present on deviations in care and preventability of death (Table 1). The narrow institutional range of risk-adjusted mortality (1.3 to 3.1%);
Figure 2) notwithstanding, we found no significant correlation between all-cause, risk-adjusted mortality rates and the proportion of preventable deaths across the 9 hospitals (Figure 2). From the hospital-specific rates of preventable deaths and institutional volumes in the index period (fiscal year 2000 to 2001), we estimate that as many as 107 potentially preventable CABG-related deaths occurred in Ontario (calculated by multiplying the risk-adjusted all-cause mortality rate in fiscal 2000 to 2001 by the preventable death proportion and CABG volumes at each hospital in those years).

Chart reviewers identified quality improvement opportunities in both preventable deaths and nonpreventable deaths. A higher rate of quality improvement opportunities was identified for preventable deaths in the areas of communication, credentialing, education measures, quality assurance programs, enhanced resources, and retraining (Table 2). Concrete examples of suggested improvements identified by physician-reviewers are listed in Table 2.

Preventable deaths were more likely to occur in patients with a lower predicted operative risk (Figure 3). We developed a multivariable logistic regression model to predict the occurrence of a preventable death. The factors in the multivariable model are listed in Table 3 and include factors that may be protective against preventable death such as older age, left main disease, 3-vessel coronary disease, emergent status, and diabetes. A number of these factors also are risk factors for increased operative mortality, illustrating that deaths among lower-risk patients were more likely to be judged preventable (Figure 3). The only factor that increased the risk of a preventable death was female sex (see Table 3). The discrimination of this model was assessed with the area under the receiver-operating characteristics curve, which was equal to 0.67. The goodness of fit of the model was assessed with the Hosmer-Lemeshow statistic, which was equal to 0.91, indicating acceptable model fit.

![Figure 2. Correlation of risk-adjusted all-cause hospital mortality rates vs preventable death judgments through implicit review.](http://circ.ahajournals.org/)

**Table 1. Quality-of-Care Problems Identified on Independent Cardiac Surgeon Reviews of Isolated CABG Deaths (n=347)**

<table>
<thead>
<tr>
<th>Review Section</th>
<th>Double MD Review, % (n)</th>
<th>Single MD Review, % (n)</th>
<th>(\kappa) (95% CI)*</th>
<th>Crude Agreement, %</th>
<th>Post Third Review Total, % (n)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inappropriate timing of surgery</td>
<td>4 (14)</td>
<td>15 (52)</td>
<td>0.26 (0.11–0.40)</td>
<td>85</td>
<td>8 (27)</td>
</tr>
<tr>
<td>A reasonable surgeon would not repeat surgery</td>
<td>2 (7)</td>
<td>12 (42)</td>
<td>0.17 (0.01–0.33)</td>
<td>89</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Significant deviation in perioperative management from the accepted norm</td>
<td>32 (112)</td>
<td>42 (146)</td>
<td>0.16 (0.05–0.26)</td>
<td>58</td>
<td>...</td>
</tr>
<tr>
<td>Evidence of preventability</td>
<td>15 (52)</td>
<td>33 (115)</td>
<td>0.24 (0.13–0.34)</td>
<td>67</td>
<td>32 (111)</td>
</tr>
</tbody>
</table>

Double MD Review indicates the proportion of deaths in which both reviewers agreed there was a problem; Single MD Review, proportion of deaths in which only 1 of 2 reviewers identified a problem; and Post Third Review Total, result obtained after those cases in which a problem was only identified by a single MD review were reviewed by an independent reviewer who made a final judgment.

*\(\kappa\) Value is the degree of agreement beyond chance and is interpreted as follows: 0 = none, 0 to 0.2 = slight, 0.2 to 0.4 = fair, 0.4 to 0.6 = moderate, 0.6 to 0.8 = substantial, and 0.8 to 1.0 = almost perfect.19,25
Table 2. Percentage of General Areas for Improvement Identified by Physician Review for Preventable Versus Nonpreventable Deaths on Single Review (n=694 Physician Single Reviews)

<table>
<thead>
<tr>
<th>Areas of Improvement</th>
<th>Preventable Death, % (n)</th>
<th>Nonpreventable, % (n)</th>
<th>Examples of MD-Identified Suggested Improvements (Root Cause of Death)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication*</td>
<td>23 (160)</td>
<td>14 (97)</td>
<td>1. Complex cases require a thorough discussion and coordination of strategy between surgeon, anesthetist, and perfusionist. All redo cases with patent grafts should have vascular access before sternotomy (other: intracardiac injury with sternotomy).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. The decision to remove an intraaortic balloon pump should be clearly delineated and the discussion, and consensus between the surgeon and intensivist should be documented (cardiac infarction/failure).</td>
</tr>
<tr>
<td>Credentialing*</td>
<td>12 (83)</td>
<td>3 (21)</td>
<td>1. Unit needs to review conversion rates and focus expertise; techniques for off-pump need to be reviewed and further documented in each operative record (cardiac infarction/failure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. If aorta is severely calcified, consider circulatory arrest for replacement of ascending aorta. Refer case to high-risk center (stroke).</td>
</tr>
<tr>
<td>Education*</td>
<td>29 (201)</td>
<td>21 (146)</td>
<td>1. Delayed recognition of sepsis; 2 full days between onset of sternal drainage, suspicion of sepsis, and definitive surgical treatment (sepsis).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Too much intravenous propanolol given to this patient with grade 3 left ventricular function, a tight left main lesion, and signs of heart failure, leading to an asystolic cardiac arrest (cardiac failure).</td>
</tr>
<tr>
<td>Quality assurance*</td>
<td>38 (264)</td>
<td>28 (194)</td>
<td>1. Ensure better intraoperative hemostasis before leaving the OR (intrathoracic bleeding).</td>
</tr>
<tr>
<td>Record keeping</td>
<td>4 (28)</td>
<td>5 (35)</td>
<td>1. Proper dictation of procedure and findings (intracardiac sternotomy).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Record bilateral arm blood pressure measurements in chart to determine whether left internal mammary artery use is okay (cardiac infarction/failure).</td>
</tr>
<tr>
<td>Resources*</td>
<td>24 (167)</td>
<td>17 (118)</td>
<td>1. Patient needed to be placed on a left ventricular assist device (cardiac failure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Invest resources to purchase flow probe systems (cardiac infarction/failure).</td>
</tr>
<tr>
<td>Retraining*</td>
<td>29 (201)</td>
<td>13 (90)</td>
<td>1. The angiogram should be reviewed in a rounds format with experienced surgeons (cardiac infarction/failure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. The technical aspects of the proximal construction (of grafts) should be reviewed in detail (aortic dissection).</td>
</tr>
<tr>
<td>System</td>
<td>15 (104)</td>
<td>16 (111)</td>
<td>1. Better system to triage very unstable patients in nontertiary centres, along with more prompt transfer policies (cardiac failure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Insist on a system with perhaps a second consultation to identify pros and cons of surgery (cardiac failure).</td>
</tr>
<tr>
<td>Other</td>
<td>5 (35)</td>
<td>5 (35)</td>
<td>1. Develop standard criteria for the use of atrial leads (cardiac failure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Develop care map for low-output syndrome (cardiac ischemia/failure).</td>
</tr>
</tbody>
</table>

OR indicates operating room.

*Only areas with a significant difference (P < 0.05) between proportions identified in preventable and nonpreventable deaths.

Discussion

This study has important implications for the measurement of quality of CABG care and for the assessment of quality of procedural interventions in general. In our jurisdiction, despite a decade of all-cause mortality report card feedback, some measurable lowering of provincial CABG mortality rates,23 and a low range of risk-adjusted mortality rates across hospitals, substantial room for improvement still existed, with 32% of deaths judged by experience surgeons as potentially preventable. Appropriateness of case selection and scheduling of surgery, the first hurdles of quality of care, were minor issues in our region. Instead, the audit indicated that opportunities for improvement primarily involved operating room care and postoperative intensive care unit management. All-cause mortality measures do not provide the level of detail required for targeted quality improvement. Indeed, we found that institution-level preventable mortality rates are not correlated with all-cause risk-adjusted mortality rates. Although interinstitutional comparisons of all-cause mortality rates are a convenient and commonly used performance measure in CABG quality reports, such comparisons may actually ignore quality-of-care problems that exist across hospitals in a region. In fact, our review indicated that in 74% of cases, deviations in care from the norm occurred that may or may not have been related to the outcome of death. This indicates that substantial room for improvement exists in the processes of care for CABG patients in our region.

Our study also shows that preventable deaths are more likely to be identified in those patients with lower predicted operative risk. This suggests that one way to focus quality improvement efforts is to look most closely at deaths that are statistically “unexpected,” ie, occurring among those who were expected to have uncomplicated postoperative courses and excellent outcomes. However, this observation also may partly reflect an understandable risk heuristic, ie, that among patients deemed at higher
operative risk, an adverse outcome is more likely to be attributable to biology than to suboptimal care. This study builds on previous research on CABG quality of care and preventable mortality. The Veterans Administration undertook a review of 116 CABG surgery deaths for those institutions with mortality rates twice the mean mortality rate of all hospitals during 1981 to 1983. Its advisory committee identified a substantial number of cases in which suboptimal care, particularly operative care, contributed to adverse outcomes. A smaller study in New York State conducted by the state’s Peer Review Organization undertook blinded reviews of cardiac surgical deaths among patients operated on by board-certified specialists. The Peer Review Organization found that 18 of 40 deaths (45%) reviewed from high-outlier hospitals had a quality-of-care problem, whereas 1 of 23 deaths (4.4%) reviewed from low-outlier hospitals had a quality problem.

Our study adds to this work by evaluating preventable CABG deaths in a contemporary context in which hospital-specific outcome report cards had been in routine use for more than a decade. This study is the largest review of cardiac surgery deaths. Among the other advantages of this study are the use of risk adjustment for interinstitutional comparisons, multivariate delineation of predictors of preventable deaths, and a more extensive and consistent review across hospitals with a mixed implicit and explicit audit process undertaken by clinically expert reviewers. Work by the Northern New England Cardiovascular Disease Study Group has shown the value of a collaborative effort to assess quality of CABG using both process of care and outcomes measures. Measures of preventable mortality have been used to study quality of care in other clinical settings. An audit of 15,000 surgical charts in 28 Utah and Colorado hospitals from 1992 found that 45% of all adverse events were operative with 17% related to a quality-of-care problems. This study was limited by a brief review process conducted by physicians who were not necessarily experts in the specialty under review. A similar adverse event study across medical and surgical specialties conducted in Canada found that 51% of adverse events occurred during surgical admissions, and overall, 37% of these were preventable. The present project differed from these prior studies with its specific focus on CABG and reliance on experienced and expert auditors who would be able to identify and provide solutions to the problems identified with deaths they judged to be preventable.

Our study has a number of limitations. For example, the variability in risk-adjusted mortality rates across hospitals is

![Figure 3. Percentage of deaths judged preventable and/or inappropriate for surgery on primary surgeon review vs patient’s estimated risk of in-hospital death.](http://circ.ahajournals.org/)

### Table 3. Preoperative Patient Predictors of Preventable Death

<table>
<thead>
<tr>
<th>Patient Factor</th>
<th>Coefficient (P)</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.63 (0.10)</td>
<td>1.63 (0.10)</td>
</tr>
<tr>
<td>Age (continuous variable)</td>
<td>-0.027 (0.05)</td>
<td>0.97 (0.95–1.00)</td>
</tr>
<tr>
<td>Female Sex</td>
<td>0.38 (0.12)</td>
<td>1.47 (0.90–2.39)</td>
</tr>
<tr>
<td>Left main coronary disease</td>
<td>-0.39 (0.12)</td>
<td>0.67 (0.41–1.11)</td>
</tr>
<tr>
<td>3-Vessel coronary disease</td>
<td>-0.31 (0.27)</td>
<td>0.73 (0.42–1.27)</td>
</tr>
<tr>
<td>Emergent status (OR &lt; 24 h)</td>
<td>-0.98 (0.06)</td>
<td>0.38 (0.13–1.04)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>-0.96 (0.0003)</td>
<td>0.38 (0.22–0.65)</td>
</tr>
</tbody>
</table>

OR indicates operating room.

*Age is a continuous variable. The age odds ratio for 10-year increments is 0.77. We also repeated the model with age included as a dichotomous variable: age ≥70 years, which had an odds ratio of 0.55 (95% CI, 0.33 to 0.90). Left main coronary disease and 3-vessel disease (ie, right coronary artery system, left anterior descending artery system, and circumflex coronary artery system) indicate a coronary stenoses ≥50% in the respective territories; emergent status indicates a patient triaged to require surgery within 24 hours because of ongoing clinical (ongoing angina despite maximal nonsurgical treatment) and/or hemodynamic instability. Diabetes mellitus includes all patients requiring medical therapy to control their blood sugars (ie, insulin and/or oral hypoglycemics).
limited, presumably because of regionalization of CABG provision to high-volume centers and the existence of a long-standing quality improvement system. Conversely, this setting also is representative of the way that modern CABG surgery is organized in many jurisdictions. Furthermore, despite conducting this study in a setting with high-volume hospitals and long-standing outcome report cards, we found that a substantial proportion of the deaths were associated with quality-of-care problems.

A further limitation is imposed by the retrospective nature of the study. We relied on the accuracy and completeness of the blinded chart data provided to expert reviewers for identification of quality-of-care problems. We surmise, however, that more complete documentation would be unlikely to alter the results of our study. (If anything, better documentation might allow greater certainty in assessments and a higher preventable death rate).

A third limitation arises from the inevitable subjectivity of expert judgments. The interauditor agreement was low to moderate as measured by the κ statistic, a finding consistent with other studies that have carried out this type of review process. However, even our “low-end” estimate of preventable deaths of 15%, based on agreement between the first 2 reviewers, is clinically significant. A recent study suggests that adding a third review would have little effect on estimates of adverse event rates if the first 2 reviewers agree and the event rate is 15% to 30%. Therefore, our low-end estimate of 15% would be unlikely to change with a third review. Whether the “true” rate of preventable deaths is 15%, 32%, or somewhere in between, these findings highlight the importance of ongoing efforts to improve quality of care.

A further limitation arises from the potential for hindsight bias in that the surgeon-reviewers knew that all the reviewed charts were those of patients who had died. On the other hand, our audit tool was standardized with blended implicit and explicit elements; our surgeon-reviewers were committed and therefore well aware of the pitfalls of post hoc criticism. We would like to thank the following individuals for helping complete this project: Sharon Vanhinger (project coordinator), Nemir Alazzawi (database programmer), Jiming Fang (computer programmer), and our team of registered nurse-abstractors: Cathy Husser, Beverley Baxter, Beth Fry, Helena Tremblay, Alena Sarnecka, Ann Baker, JoAnn Donaldson, and Christine Archer.

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Disclosures
None.

References
In this study, we conducted a large, population-based, retrospective audit (using implicit review) of randomly selected deaths after cardiac surgery over a 2-year period in Ontario, Canada, and showed that 32% of the deaths were judged by experienced surgeons as being potentially preventable, even though the crude mortality rates were already fairly low (~2%). Our study showed that preventable deaths occurred at all hospitals in Ontario and that the relative proportions of deaths were similar, even though the risk-adjusted all-cause mortality rates varied significantly across hospitals. Our study has important implications for the field of quality improvement because it demonstrates that opportunities exist for improving death rates at all hospitals, even in a region with relatively high institutional volumes where institution-level cardiac surgery report cards have been published for more than a decade. Our results suggest that a need for quality improvement exists at all hospitals as opposed to only outlier hospitals, the traditional outcome from the report card approach. The findings of the study represent a significant paradigm shift in our thinking about how to improve quality with report cards. To the best of our knowledge, this study includes the largest and most comprehensive audit of cardiac surgical deaths that has ever been undertaken in any jurisdiction. Our identification that most deaths occur as a result of problems in the operating room suite and/or intensive care unit and the reasons why these deaths occurred should be of interest to all those interested in further lowering the death rates for these complex operations.

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Relationship Between Preventability of Death After Coronary Artery Bypass Graft Surgery and All-Cause Risk-Adjusted Mortality Rates

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