Advances in the science of quality measurement

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What’s different right now?

Everyone is paying attention:
Patients, payers, providers
Quality and comparative effectiveness are linked.

![Bar chart showing adjusted mortality rates for different categories of pancreatic resections.]

- Pancreatic resection
  - <1: 16.3%
  - 1-2: 14.6%
  - 3-5: 11.0%
  - 6-16: 7.2%
  - >16: 3.8%

![Diagram of digestive system with labels:
- Jejunum raised
- Duodenum, head of pancreas, bile ducts and gallbladder removed]
Measuring quality

Outcomes – “Gold standard”
• Everyone agrees they are important
• Strong track record in cardiac surgery
  – NY, PA, CA report cards
• Other specialties pushing forward
  – CMS Hospital Compare (acute myocardial infarction, pneumonia, congestive heart failure)
“Calculus of Quality”

Observed Outcome = Quality of Care

Not that simple!
“Calculus of Quality”

Observed Outcome = Severity of Illness + Quality of Care + Random Error

- Overemphasized
- Oversimplified
- Underemphasized
Analogy

**Medicine:**
Which hospitals/surgeons are the best?

**Baseball:**
Which players should teams sign?
Why rethink the status quo?
$226 million
vs.
$40 million
GOOD with numbers? Fascinated by data? The sound you hear is opportunity knocking.

Mo Zhou was snapped up by I.B.M. last summer, as a freshly minted Yale M.B.A., to join the technology company’s fast-growing ranks of data consultants. They help businesses make sense of an explosion of data — Web traffic and social network comments, as well as software and sensors that monitor shipments, suppliers and customers — to guide decisions, trim costs and lift sales. “I’ve always had a love of numbers,” says Ms. Zhou, whose job as a data analyst suits her skills.
Roadmap

• Understanding the root causes of variation in surgical outcomes
  – Exploring the “Calculus of quality”
• Strategies for improving outcomes measurement in surgery
• Developing better approaches
  – Empirically weighted composite measures
Rethinking the “Calculus of quality”

Observed Outcome = Severity of Illness + Quality of Care + Random Error
Why adjust for patient risk?
Logit = \ln\left(\frac{P}{1-P}\right) = a + bX
Hospital mortality with cardiac surgery
New York State data, 2001-2

Correlation = 0.95

Hospital outcome comparisons confounded by patient factors:

1. Patient risk factors must be associated with outcomes
2. These risk factors must vary across hospitals
Hospital complication rates for colon resection, ACS-NSQIP, 2007

Implications

Clinical registries collect >180 variables for risk-adjustment

Can we decrease the burden of data collection?
More efficient risk-adjustment

• **Easier data collection:** Continue to look for automated data collection
  – Electronic medical records
  – Hybrid administrative/clinical datasets

• **Collect less data:** Streamline risk-adjustment by including only the most important variables without compromising risk-adjustment
Hospital-level correlation morbidity rates (5-variable vs. 20 variable model)

Dimick et al. J Am Coll Surg 2010
Rethinking the “Calculus of quality”

\[
\text{Observed Outcome} = \text{Severity of Illness} + \text{Quality of Care} + \text{Random Error}
\]
Back to baseball

Perfect batting averages

- 2007 10 major league players “1.0”
- But lifetime performance of these players was average
- They had only 3 or fewer at-bats during the season
Random error

• Surgical outcomes vary by chance
  – Compounded by any factor that reduces numerator or denominator

• Type I errors
  - Good or bad outcomes attributed to quality, when really just chance
  - “The Zero Mortality Paradox”

• Type II errors
  – Chance obscures true differences in quality
  – “Big Problems with Small Samples”
The Zero Mortality Paradox in Surgery

Justin B Dimick, MD, MPH, H Gilbert Welch, MD, MPH

BACKGROUND: Patients considering where to have surgery may reasonably believe that their chances of survival are highest at hospitals whose reported operative mortality is zero. We sought to determine if hospitals with zero mortality over 3 years also have lower than average mortality in the subsequent year.

STUDY DESIGN: We obtained national Medicare data on five operations with high operative mortality (> 4.0%): coronary artery bypass grafting, abdominal aortic aneurysm repair, and resections for colon, lung, and pancreatic cancer. For each procedure, we defined zero mortality hospitals as those with no inpatient or 30-day deaths during the 3-year period 1997 to 1999. To determine whether these hospitals actually have lower mortality than other hospitals, we compared their mortality during the next year (2000) with the mortality at all other hospitals.

RESULTS: For four procedures, operative mortality in zero mortality hospitals in the subsequent year was no different than that in other hospitals: abdominal aortic aneurysm repair (6.3% zero mortality hospitals versus 5.8% other hospitals; (adjusted relative risk [RR] = 1.09; 95% CI 0.92 to 1.29); lobectomy for lung cancer (5.1% versus 5.3%; RR = 0.96; 95% CI 0.80 to 1.15); colon cancer resection (6.0% versus 6.6%; RR = 0.91; 95% CI 0.80 to 1.03); and coronary artery bypass surgery (4.0% versus 5.0%; RR = 0.81; 95% CI 0.61 to 1.04). In the case of pancreatic cancer resection, zero mortality hospitals had substantially higher mortality than other hospitals (11.2% versus 8.7%; RR = 1.29; 95% CI 1.04 to 1.59).

CONCLUSIONS: Paradoxically, hospitals with a history of zero mortality subsequently experience mortality rates that are the same or higher than those of other hospitals. Patients considering surgery should not consider a reported mortality of zero as being a reliable indicator of future performance. (J Am Coll Surg 2008;206:13–16. © 2008 by the American College of Surgeons)
Type I errors: The Zero Mortality Paradox

Subsequent Mortality Rates (2000)

Historical Mortality Rates (1997-1999)

Zero Mortality Hospitals

All Other Hospitals

RR=1.29
(95%CI: 1.04-1.59)
Surgical Mortality as an Indicator of Hospital Quality
The Problem With Small Sample Size

Justin B. Dinick, MD
H. Gilbert Welch, MD, MPH
John D. Birkmeyer, MD

PATIENTS AND POLICY MAKERS INCREASINGLY USE RATES OF SURGICAL MORTALITY TO ASSESS HOSPITAL PERFORMANCE. NEW YORK AND PENNSYLVANIA HAVE LONG-STANDING SYSTEMS FOR TRACKING AND PUBLICLY REPORTING RISK-ADJUSTED MORTALITY RATES AFTER CARDIAC SURGERY. CALIFORNIA AND NEW JERSEY HAVE MORE RECENTLY ADOPTED THIS APPROACH. THE LEAPFROG GROUP, A LARGE COALITION OF EMPLOYERS AND PURCHASERS, HAS MADE SURGICAL MORTALITY RATES ONE OF THE CRITERIA FOR “EVIDENCE-BASED REFERRAL” FOR CARDIAC PROCEDURES. AS PART OF ITS BROADER EFFORTS TO DEVELOP A CORE SET OF QUALITY INDICATORS, THE AGENCY FOR HEALTHCARE RESEARCH AND QUALITY (AHRQ) HAS RECENTLY ENDORSED THE USE OF SURGICAL MORTALITY RATES FOR 7 SURGICAL PROCEDURES INCLUDING REPAIR OF ABDOMINAL AORTIC ANEURYSM, ESOPHAGEAL RESECTION, AND HIP REPLACEMENT.

However, there are 2 reasons to question whether rates of surgical mortality can reliably detect quality problems. First, the targeted operations are infre-

CONTEXT Surgical mortality rates are increasingly used to measure hospital quality. It is not clear, however, how many hospitals have sufficient caseloads to reliably identify quality problems.

OBJECTIVE To determine whether the 7 operations for which mortality has been advocated as a quality indicator by the Agency for Healthcare Research and Quality (coronary artery bypass graft [CABG] surgery, repair of abdominal aortic aneurysm, pancreatic resection, esophageal resection, pediatric heart surgery, craniotomy, hip replacement) are performed frequently enough to reliably identify hospitals with increased mortality rates.

DESIGN AND SETTING The US national average mortality rates and hospital caseloads of the 7 operations were determined using the 2000 Nationwide Inpatient Sample (NIS), and sample size calculations were performed to determine the minimum caseload necessary to reliably detect increased mortality rates in poorly performing hospitals. A 3-year hospital caseload was used for the baseline analysis, and poor performance was defined as a mortality rate double the national average.

MAIN OUTCOME MEASURE Proportion of hospitals in the United States that performed more than the minimum caseload for each operation.

RESULTS The national average mortality rates for the 7 procedures examined ranged from 0.3% for hip replacement to 10.7% for craniotomy. Minimum hospital caseloads necessary to detect a doubling of the mortality rate were 64 cases for craniotomy, 77 for esophageal resection, 86 for pancreatic resection, 138 for pediatric heart surgery, 195 for repair of abdominal aortic aneurysm, 219 for CABG surgery, and 2668 for hip replacement. For only 1 operation did the majority of hospitals exceed the minimum caseload, with 90% of hospitals performing CABG surgery having a caseload of 219 or higher. For the remaining operations, only a small proportion of hospitals met the minimum caseload: craniotomy (33%), pediatric heart surgery (25%), repair of abdominal aortic aneurysm (8%), pancreatic resection (2%), esophageal resection (1%), and hip replacement (<1%).

CONCLUSION Except for CABG surgery, the operations for which surgical mortality has been advocated as a quality indicator are not performed frequently enough to judge hospital quality.
What proportion of hospitals perform enough cases to reliably measure quality using mortality rates?

- Coronary bypass surgery: 90%
- Craniotomy: 33%
- Pediatric heart surgery: 25%
- Repair of abdominal aneurysm: 8%
- Pancreatic resection: 2%
- Esophageal resection: 1%
- Hip replacement: 1%

Type II errors: Big problems with small samples

Dimick et al. JAMA 2004
Techniques for dealing with random error ("statistical noise")

- Reliability adjustment
  - Use advanced modeling techniques to filter out statistical noise
    - Hierarchical/empirical Bayes models
    - Analogous to increasing signal to noise ratio in cellphones
Back to baseball

Carl Morris, PhD, Chair of Statistics at Harvard: “I’ve been thinking about advanced ideas in baseball analysis.”

“We ask whether Ty Cobb was a ‘true’ 0.400 hitter for a single season”

After adjusting for “noise”, the answer is no, his best year was 0.392
Ranking Hospitals on Surgical Mortality: The Importance of Reliability Adjustment

Justin B. Dimick, Douglas O. Staiger, and John D. Birkmeyer

Objective. We examined the implications of reliability adjustment on hospital mortality with surgery.

Data Source. We used national Medicare data [2003–2006] for three surgical procedures: coronary artery bypass grafting (CABG), abdominal aortic aneurysm (AAA) repair, and pancreatic resection.

Study Design. We conducted an observational study to evaluate the impact of reliability adjustment on hospital mortality rankings. Using hierarchical modeling, we adjusted hospital mortality for reliability using empirical Bayes techniques. We assessed the implication of this adjustment on the apparent variation across hospitals and the ability of historical hospital mortality rates [2003–2004] to forecast future mortality (2005–2006).

Principal Findings. The net effect of reliability adjustment was to greatly diminish apparent variation for all three operations. Reliability adjustment was also particularly important for identifying hospitals with the lowest future mortality. Without reliability adjustment, hospitals in the “best” quintile [2003–2004] with pancreatic resection had a mortality of 7.6 percent in 2005–2006; with reliability adjustment, the “best” hospital quintile had a mortality of 2.7 percent in 2005–2006. For AAA repair, reliability adjustment also improved the ability to identify hospitals with lower future mortality. For CABG, the benefits of reliability adjustment were limited to the lowest volume hospitals.

Conclusion. Reliability adjustment results in more stable estimates of mortality that better forecast future performance. This statistical technique is crucial for helping patients select the best hospitals for specific procedures, particularly uncommon ones, and should be used for public reporting of hospital mortality.

Key Words. Quality, surgery, hospital, mortality, hierarchical
Impact of reliability adjustment on hospital mortality rates

Risk-adjusted mortality rates (%)

Observed mortality rates

Mortality rates after filtering out the statistical noise

Pancreatic Cancer Resection

After adjusting for reliability

Dimick et al. Health Services Research 2010
Are reliability adjusted mortality rates better at predicting future performance?

Pancreatic cancer resection

<table>
<thead>
<tr>
<th>Hospital Rankings (Quintiles) (2003-04)</th>
<th>Risk-adjusted mortality, % (2005-06)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not adjusted for reliability</td>
<td>1          2          3          4          5</td>
</tr>
<tr>
<td>1           2          3          4          5</td>
<td></td>
</tr>
<tr>
<td>Adjusted for reliability</td>
<td>1          2          3          4          5</td>
</tr>
<tr>
<td>1           2          3          4          5</td>
<td></td>
</tr>
</tbody>
</table>

Dimick et al. Health Services Research 2010
Rethinking the “Calculus of quality”

Observed Outcome = Severity of Illness + Quality of Care + Random Error
“Calculus of quality”

\[
\text{Observed Outcome} = \text{Severity of Illness} + \text{Process of Care} + \text{Random Error}
\]

\[
\left( \text{Measurable} + \text{Unmeasurable} \right)
\]

- Discrete aspects of perioperative care
- Patient selection
- Technical proficiency
Process measures in surgery

- Most focus on measurable aspects of perioperative care
- Medicare’s Surgical Care Improvement Project (SCIP)
  - Prophylaxis of complications (e.g., wound infection and venous thrombosis)
- Subset of measures publicly reported on CMS’ Hospital Compare website (www.hospitalcompare.hhs.gov)
Process of care compliance in Medicare’s Hospital Compare

Lauren Nicholas, PhD et al. Archives of Surgery 2010
Process compliance and risk-adjusted mortality, National Medicare population, 2005-06

Hospitals ranked on process compliance

Lauren Nicholas, PhD et al. Archives of Surgery, 2010
Process of care is oversimplified

- Existing processes do not explain the wide variations in surgical outcomes
- Most relate to secondary outcomes or extremely rare complications
High leverage indicators/processes: Back to baseball

Using sabermetrics to better understand what makes a good major league baseball player

**Status quo:** Foot speed, fielding ability, raw power (dramatically overpriced)

**Sabermetrics:** “plate discipline” (e.g., on base percentage) was the greatest indicator of future success
Identifying high leverage processes of care

• Continue to investigate new process measures
  – Randomized trials and linkage of process to outcome within clinical registries
• Develop better tools to measure important but currently unmeasurable processes
  – What happens in the operating room?
• Use tools of clinical epidemiology to identify the clinical mechanisms that lead to bad outcomes
Variation in Hospital Mortality Associated with Inpatient Surgery

Amir A. Ghaferi, M.D., John D. Birkmeyer, M.D., and Justin B. Dimick, M.D., M.P.H.

ABSTRACT

BACKGROUND
Hospital mortality that is associated with inpatient surgery varies widely. Reducing rates of postoperative complications, the current focus of payers and regulators, may be one approach to reducing mortality. However, effective management of complications once they have occurred may be equally important.

METHODS
We studied 84,730 patients who had undergone inpatient general and vascular surgery from 2005 through 2007, using data from the American College of Surgeons National Surgical Quality Improvement Program. We first ranked hospitals according to their risk-adjusted overall rate of death and divided them into five groups. For hospitals in each overall mortality quintile, we then assessed the incidence of overall and major complications and the rate of death among patients with major complications.
Explaining variations in surgical mortality rates

Hypothesis #1: High mortality hospitals have higher complication rates.

Hypothesis #2: High mortality hospitals are not as effective in “rescuing” patients once they develop a complication.
Mechanisms underlying variation, colectomy in ACS-NSQIP hospitals, 2005-2006

Amir Ghaferi, MD, Research Fellow, University of Michigan, New England Journal of Medicine, 2009
Summary of “Calculus of quality”

Observed = Severity of Illness + Process of Care + Random Error

Overemphasized:
Adjusting for patient severity is not the whole battle. Needs to be streamlined.

Oversimplified:
We need to identify high leverage processes of care using tools of clinical epidemiology.

Underemphasized:
We need to explicitly deal with random error. Develop better measures that adjust for reliability.
Towards better measures

\[
\text{Observed Outcome} = \text{Severity of Illness} + \text{Process of Care} + \text{Random Error}
\]
Towards better measures

Observed Outcome = Severity of Illness + Process of Care + Random Error

Structure

Outcomes from other conditions
Empirically-derived composite measures

- Combine multiple domains of quality (structure, process, outcome) into a single quality score
- **Empirically** weight input measures
  - Rather than arbitrary or equal weighting
- Filter our statistical “noise” using empirical Bayes techniques
- Global indicator of performance, helps make sense of multiple conflicting measures
## Example of the importance of individual measures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Individual quality measures</th>
<th>Proportion of hospital level variation explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary artery bypass surgery</td>
<td>Mortality</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Mortality with aortic valve surgery</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Mortality with mitral valve surgery</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Mortality with percutaneous coronary interventions</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Hospital volume</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>Hospital volume with other operations</td>
<td>11%</td>
</tr>
</tbody>
</table>

Dimick et al. *Health Services Research* 2012 (In press)
Forecasting future risk-adjusted mortality:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>3-star</th>
<th>2-star</th>
<th>1-star</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percutaneous coronary interventions</td>
<td>2.4</td>
<td>3.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Coronary artery bypass</td>
<td>2.7</td>
<td>3.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>4.4</td>
<td>6.3</td>
<td>9.2</td>
</tr>
<tr>
<td>Esophageal cancer resection</td>
<td>4.5</td>
<td>6.1</td>
<td>10.2</td>
</tr>
<tr>
<td>Pancreatic cancer resection</td>
<td>6.2</td>
<td>10.1</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Risk-adjusted mortality (%) in 2007-08

Hospital rankings based on 2005-06 composite

Dimick et al. *Health Services Research* 2012 (In press)
Comparison to individual quality indicators:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Hospital volume</th>
<th>Risk-adjusted mortality</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coronary artery bypass grafting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary artery bypass grafting</td>
<td>1.46 (1.35 to 1.59)</td>
<td>1.61 (1.48 to 1.75)</td>
<td>2.10 (1.93 to 2.28)</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>1.65 (1.49 to 2.34)</td>
<td>1.52 (1.38 to 1.69)</td>
<td>2.10 (1.89 to 2.34)</td>
</tr>
<tr>
<td>Percutaneous coronary interventions</td>
<td>1.43 (1.36 to 1.51)</td>
<td>1.45 (1.38 to 1.52)</td>
<td>1.81 (1.72 to 1.91)</td>
</tr>
<tr>
<td>Pancreatic cancer resection</td>
<td>2.41 (1.63 to 3.58)</td>
<td>1.44 (1.06 to 1.94)</td>
<td>3.29 (2.27 to 4.77)</td>
</tr>
<tr>
<td>Esophageal cancer resection</td>
<td>2.58 (1.76 to 3.79)</td>
<td>1.25 (0.95 to 1.65)</td>
<td>3.91 (2.74 to 5.58)</td>
</tr>
</tbody>
</table>
### Comparison to individual quality indicators:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Hospital volume</th>
<th>Risk-adjusted mortality</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary artery bypass grafting</td>
<td>14%</td>
<td>27%</td>
<td>54%</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>18%</td>
<td>12%</td>
<td>47%</td>
</tr>
<tr>
<td>Percutaneous coronary interventions</td>
<td>16%</td>
<td>15%</td>
<td>45%</td>
</tr>
<tr>
<td>Pancreatic cancer resection</td>
<td>59%</td>
<td>7%</td>
<td>98%</td>
</tr>
<tr>
<td>Esophageal cancer resection</td>
<td>60%</td>
<td>8%</td>
<td>92%</td>
</tr>
</tbody>
</table>
What Is the Best Way to Estimate Hospital Quality Outcomes? A Simulation Approach

Andrew Ryan, James Burgess, Robert Strawderman, and Justin Dimick

Objective. To test the accuracy of alternative estimators of hospital mortality quality using a Monte Carlo simulation experiment.

Data Sources. Data are simulated to create an admission-level analytic dataset. The simulated data are validated by comparing distributional parameters (e.g., mean and standard deviation of 30-day mortality rate, hospital sample size) with the same parameters observed in Medicare data for acute myocardial infarction (AMI) inpatient admissions.

Study Design. We perform a Monte Carlo simulation experiment in which true quality is known to test the accuracy of the Observed-over-Expected estimator, the Risk Standardized Mortality Rate (RSMR), the Dimick and Staiger (DS) estimator, the Hierarchical Poisson estimator, and the Moving Average estimator using hospital 30-day mortality for AMI as the outcome. Estimator accuracy is evaluated for all hospitals and for small, medium, and large hospitals.

Data Extraction Methods. Data are simulated.

Principal Findings. Significant and substantial variation is observed in the accuracy of the tested outcome estimators. The DS estimator is the most accurate for all hospitals and for small hospitals using both accuracy criteria (root mean squared error and proportion of hospitals correctly classified into quintiles).

Conclusions. The mortality estimator currently in use by Medicare for public quality reporting, the RSMR, has been shown to be less accurate than the DS estimator, although the magnitude of the difference is not large. Pending testing and validation of our findings using current hospital data, CMS should reconsider the decision to publicly report mortality rates using the RSMR.

Key Words. Biostatistical methods, incentives in health care, hospitals, Medicare, patient outcomes/functional status/ADLs/IADLs, quality of care/patient safety (measurement)
Table 3: Evaluation of Estimator Accuracy for Acute Myocardial Infarction

<table>
<thead>
<tr>
<th>Estimator</th>
<th>Root Mean Squared Error</th>
<th>Proportion Correctly Classified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall</td>
<td>Small Hospitals</td>
</tr>
<tr>
<td>OE₁</td>
<td>.0968*</td>
<td>.1764*</td>
</tr>
<tr>
<td>RSMR₃</td>
<td>.0520*</td>
<td>.0794*</td>
</tr>
<tr>
<td>RSMR₂</td>
<td>.0539*</td>
<td>.0847*</td>
</tr>
<tr>
<td>RSMR₁</td>
<td>.0599*</td>
<td>.0947*</td>
</tr>
<tr>
<td>MA₃</td>
<td>.0611*</td>
<td>.1046*</td>
</tr>
<tr>
<td>MA₂</td>
<td>.0706*</td>
<td>.1260*</td>
</tr>
<tr>
<td>DS₃</td>
<td>.0466*</td>
<td>.0672</td>
</tr>
<tr>
<td>DS₂</td>
<td><strong>.0462</strong></td>
<td>.0680*</td>
</tr>
<tr>
<td>DS₁</td>
<td>.0498*</td>
<td>.0715*</td>
</tr>
<tr>
<td>Hierarchical</td>
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<td>.0814*</td>
</tr>
<tr>
<td>Poisson₃</td>
<td>.0529*</td>
<td>.0844*</td>
</tr>
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<td>Hierarchical</td>
<td>.0579*</td>
<td>.0918*</td>
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<tr>
<td>Poisson₂</td>
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<td>Hierarchical</td>
<td>.0579*</td>
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Towards better quality indicators: Composite measures

\[
\text{Observed Outcome} = \text{Severity of Illness} + \text{Process of Care} + \text{Random Error} + \text{Outcomes from other conditions}
\]