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Risk-Adjusted Indices for Measuring the Quality of Inpatient Care

M. Thane Forthman, DHA; Robert S. Gold, MD; Henry G. Dove, PhD; Richard D. Henderson, MBA

This article describes a risk-adjustment method for profiling hospitals and physicians on key measures of clinical quality using readily available administrative data. By comparing actual and expected rates of mortality, complications, readmissions, and patient safety events, this method enables providers to identify both favorable and adverse outcomes performance.

Key words: *risk-adjustment, risk-adjusted complications index, risk-adjusted mortality index, risk-adjusted patient safety index, risk-adjusted readmissions index*

Over the past decade, the health care industry has witnessed an unparalleled disclosure of hospital-specific comparative outcomes information to the public. Clearly, there has been a growing consensus among a broad array of federal, state, association, business, and consumer stakeholders around the importance of public reporting of hospital quality measures, including those that measure clinical outcomes and the patient's perception of care. Many initiatives designed to increase accountability for and public awareness of differences in the quality of hospital services have been developed across the country. Specifically, in 1997, the Joint Commission on Accreditation of Health Care Organizations (JCAHO) announced the ORYX initiative, which integrated clinical outcomes and other performance measurement data into the hospital accreditation process as part of the JCAHO's Agenda for Change.[1] By design, the ORYX initiative includes many of the same quality measures launched by the Centers for Medicare & Medicaid Services (CMS) Ninth Scope of Work. The Ninth Scope of Work quality indicators are being collected by state quality improvement organizations to improve the quality of care for beneficiaries by ensuring that care meets professionally recognized standards of medical care. Given the importance of the Medicare program to hospitals, hospitals are becoming increasingly accountable to

Author Affiliations: *Comparion Medical Analytics, Inc., Greenville, SC (Dr. Forthman and Mr. Henderson); Documentation, Coding, and Billing Accuracy, Inc., Atlanta, GA (Dr. Gold); Casemix Consulting, LLC, Hamden, CT (Dr. Dove); Department of Health Policy and Administration, Yale University, New Haven, CT (Dr. Dove)*

Correspondence: *M. Thane Forthman, DHA, Comparion Medical Analytics, Inc.(email:tfort@comparionanalytics.com)*

federal quality standards. In 2003, the CMS instituted a pay-for-performance pilot program to reward hospitals with exemplary quality performance and penalize those with substandard performance.[2] Furthermore, the Agency for Healthcare Research and Quality (AHRQ) is now required to report to Congress on the state of the nation's health care quality. A report of these findings is now released annually to the public in the form of a "National Health Care Quality Report." The intent of the report is to measure safety, effectiveness, timeliness, and patient centeredness. In 1999, the National Quality Forum was created in response to the national quality improvement agenda proposed by the President's Advisory Commission on Consumer Protection and Quality. The National Quality Forum was founded to develop and implement a national strategy for health care quality measurement and reporting. The CMS is supporting National Quality Forum to develop quality indicators that can be reported and measured at a national level. The American Hospital Association, the Federation of American Hospitals, and the Association of American Medical Colleges have also embarked on a national initiative to collect and report hospital quality performance information on a voluntary basis.[3] The CMS, along with the JCAHO, and the AHRQ support the initiative as the beginning of an ongoing effort to make hospital performance information more accessible to consumers, payers, and providers of care. From an employer's perspective, increased accountability and public awareness have been established with the formation of the Leapfrog Group, founded in 2000 by the Business Round Table, a national association of Fortune 500 companies representing 150 public and private organizations that provide health benefits to more than 34 million consumers across all 50 states. The Business Round Table launched the Leapfrog initiative to address patient safety and quality issues in the US health care system and to recognize health plans and hospitals that implement the Leapfrog's quality standards.[4] As with the other national initiatives, the JCAHO and the CMS are working with the Leapfrog group to consistently accomplish these objectives. Other organizations such as CareChex, HealthGrades, WebMD, and Consumer Reports have joined the campaign through the release of hospital report cards and various awards designed to recognize providers who achieve commendable levels of quality performance.[5] Similarly US News & World Report[5] and Modern Healthcare,[6] as well as other media organizations, continue to promote public awareness through the publication of annual hospital rankings.

It would be difficult to imagine that a more pervasive culmination of efforts could exist to press the issue of publicly available hospital quality reporting. However, with all this reporting activity, it is imperative to recognize that since significant differences in demographic and clinical risk factors exist among patients treated across providers, a medically meaningful and statistically reliable risk adjustment tool is needed to make accurate comparisons of clinical outcomes. As Localio et al state,

> Organizations seeking to compare the quality of hospitals and physicians through outcome data need to recognize that simplistic methods applicable to large samples fail when applied to the outcomes of typical patients such as those admitted for pneumonia. Although these comparisons are much in demand, careful attention must be paid to their statistical methods to ensure validity and fairness.[7(p126)]

Although the usefulness and validity of the various quality measures deployed across the industry may vary, they nonetheless point to a growing desire for the public to make more informed choices regarding the selection of health care providers. In fact, a recent study performed by GE Healthcare indicates that one of the most important trends that should be considered in a hospital's strategy development is that quality reporting is shifting from value-add to essential. In this study, Vachon maintains,

> Metrics around quality and performance will drive everything that matters in health care going forward, from payer reimbursement and consumer choice to investment strategies that deliver results. Consumers and payers want to get the best care possible for their dollar, and the

current economic crisis has only added greater urgency to their efforts.[8]

Given the foregoing, the purpose of this article is 2-fold: first, to describe a risk-adjustment method for validly assessing clinical outcomes across providers and, second, to demonstrate how this method can be used by providers to identify adverse events in order to improve quality and to document favorable outcomes for promotion to purchasers and consumers. A description of how each of the risk-adjustment models was constructed and validated is presented in the next section.

RISK-ADJUSTED QUALITY OF CARE MEASURES

It is not possible, either conceptually or technically, to construct an all-inclusive index to measure the quality of inpatient care. However, Comparion has constructed separate risk-adjusted indices that validly measure 4 important components of quality—rates of mortality, complications, readmissions, and patient safety events. The specific indices developed by Comparion are the risk-adjusted mortality index (RAMI), the risk-adjusted complications index (RACI), the risk-adjusted readmissions index (RARI), and the risk-adjusted patient safety index (RAPSI). The RAMI, RACI, and RARI are based on the earlier research performed at the Commission on Professional and Hospital Activities through funding provided by the CMS (formerly Health Care Financing Administration).[9-12] The RAPSI is based on recent patient safety research completed by Stanford University under subcontract with AHRQ.[13]

The risk models rely on readily available administrative data that can be used to assess risk factors relating to the patient's diagnoses (principal and secondary), surgical procedures, age, gender, and complications and comorbidities (CCs). Work by Iezzoni and colleagues[14] has shown that risk adjustment methods that rely solely on this type of administrative data perform quite well when compared with methods that require additional record abstracting.

However, risk adjustment should not be confused with severity adjustment. Although numerous severity measures exist, which account for some patient clinical characteristics, most have been constructed to measure a patient's increased need for resource consumption in order to assess utilization outcomes such as charges, costs, and length of stay. Moreover, severity narrowly implies that patients have some degree of severity associated with their principal diagnosis and that this degree defines their risk level. Yet, in reality, a patient may be in general good health but still at risk for a particular adverse outcome because of age, sex, comorbidity, health behavior, or other characteristics unrelated to the severity of their principal diagnosis.[15] Risk adjustment, on the other hand, accounts for the wide range of patient characteristics that may increase the probability for adverse clinical outcomes for a given patient. Figure 1 demonstrates the need for risk adjustment even after severity of illness has been accounted for using Medicare Severity Diagnosis Related Groups (MS-DRGs). This finding is consistent with the research performed at Harvard Medical School and Beth Israel Deaconess Medical Center that concluded that even severity adjustment methods such as All Payer Refined Diagnosis-Related Groups, Disease Staging, and MedisGroups did not adequately explain differences in death rates across hospitals.[16]

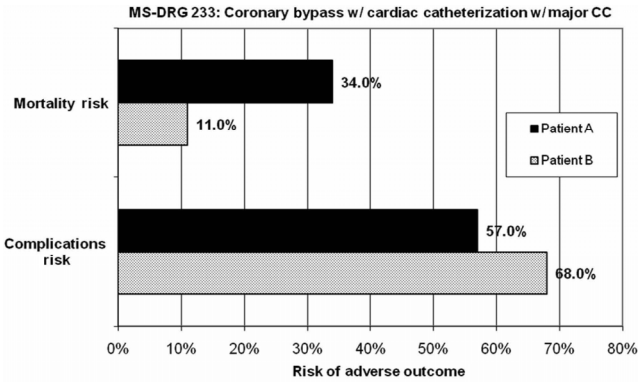

Figure 1. Differences in risk of adverse outcomes within the same medicare severity diagnosis-related groups (MS-DRG).

Risk-adjustment methodology

Risk factors for calculating the mortality model, complications model, readmissions model, and patient safety model were independently applied within clusters of MS-DRGs using binary logistic regression. The predictive variables for mortality, complications, and readmissions include the patient's age, gender, the number of major chronic conditions, and the number of other significant comorbidities. The list of major chronic conditions covers 1229 diagnosis codes and represents illnesses such as emphysema, diabetes, and cancer. The list of other significant comorbidities encompasses 1374 diagnosis codes and comprises illnesses such as acute appendicitis, bacterial pneumonia, and encephalitis.

The risk factors for predicting the occurrence of patient safety events include MS-DRG cluster, age, gender, and number of AHRQ-specified comorbidities. The 1254 comorbidities identified by AHRQ to significantly increase the risk of patient safety events include conditions such as aortic valve disorders, endocarditis, and congestive heart failure. A summary of the predictive variables used for each of the aforementioned risk models is displayed in Table 1.

Logistic regression was selected since each of the outcomes to be predicted (ie, death, presence of a complication, and readmission) could only be classified into 1 of 2 categories (either they occurred or they did not occur). The logistic regression model estimated the risk of each outcome for each patient at risk using a nationally representative database composed of 27 million discharges from general, acute, and nonfederal hospitals across 39 states. The database was nationally representative with respect to hospital bed size, teaching status, urban/rural designation, and geographic location. This risk estimate for each outcome was accomplished by weighting patient records using the beta coefficients associated with the corresponding predictive variables in the regression model and the intercept term. This produced the overall probability value for each outcome based on the normative experience of patients with similar clinical characteristics.

The clustering of MS-DRGs was necessary because many of the risk factors associated with an increased risk of death or complications for a clinical condition were used as the basis for MS-DRG patient classification (eg, presence or absence of CCs and discharge status). For instance, simple pneumonia and pleurisy are assigned to MS-DRGs 193-195 on the basis of the designation of "with major CC, with CC, or without CC." Similarly, MS-DRGs 280-285 represent acute myocardial infarction cases, but the MS-DRG assignments vary by discharge status (alive or expired) and are further stratified on the basis of the presence or absence of CCs. Consequently, MS-DRGs were combined into clinically related clusters to

Table 1

SUMMARY OF PREDICTIVE VARIABLES BY RISK MODEL

Predictive Variables	Mortality Model	Complications Model	Readmissions Model	Patient Safety Model
Demographic				
Age	✓	✓	✓	✓
Gender	✓	✓	✓	✓
Clinical				
Medicare Severity Diagnosis-Related Groups cluster	✓	✓	✓	✓
No. of major chronic conditions	✓	✓	✓	✓
No. of other significant comorbidities	✓	✓	✓	
No. of Agency for Healthcare Research and Quality-specified comorbidities				✓

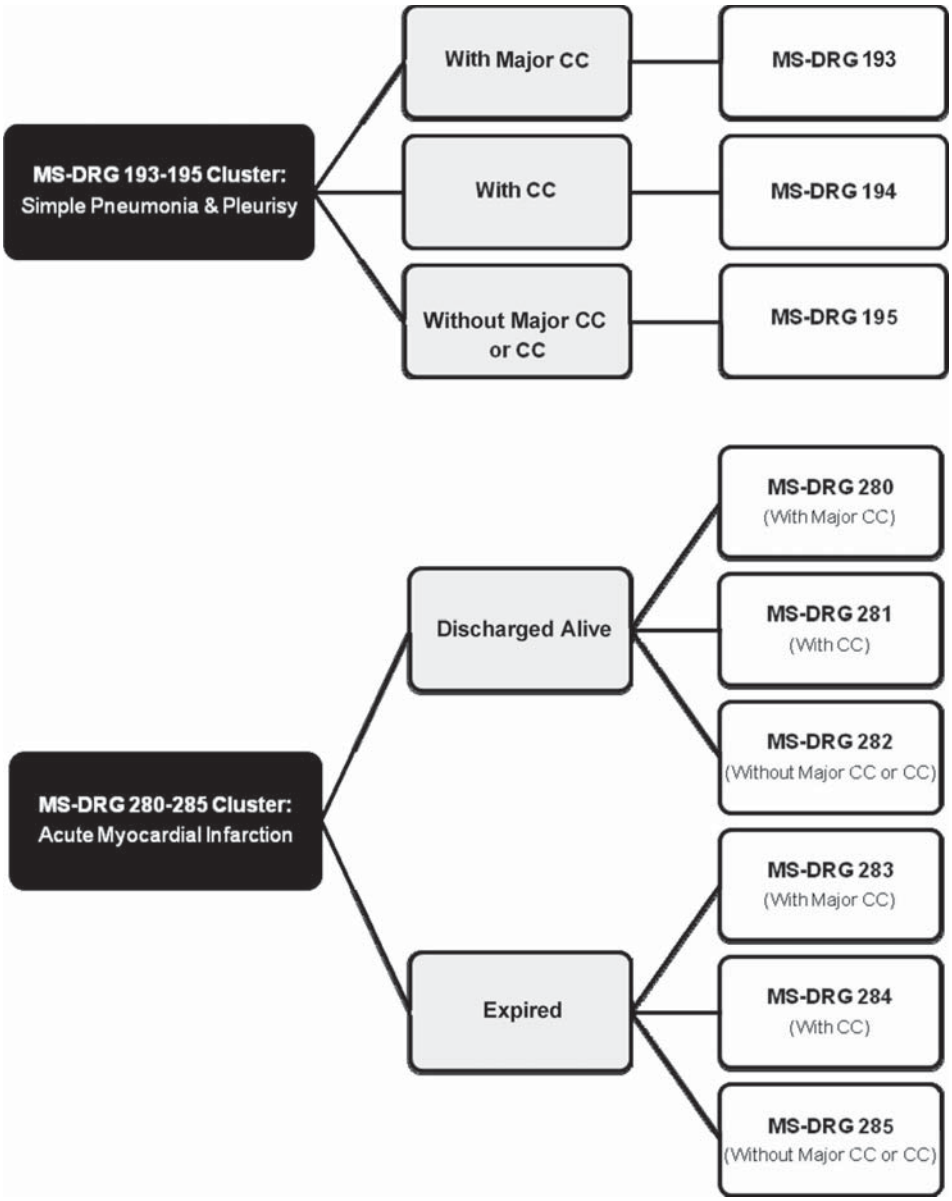

Figure 2. Structure of specific medicare severity diagnosis-related groups (MS-DRG) clusters. "CC" indicates complications and comorbidities.

determine how CCs and other factors were associated with an increased risk of adverse outcomes within each disease category. The clustering process was applied across all MS-DRGs that resulted in 746 distinct clinical categories. For ease of analysis, once the models were applied to the MS-DRG clusters, most of the results were unbundled and summarized at the individual MS-DRG level. The method used to cluster MS-DRGs was essentially the same as the CMS "adjacent" diagnosis related group (DRG) methodology developed by the Health Systems Management Group at Yale University to combine DRGs "with and without CCs."[17] The actual structure of specific MS-DRG clusters is shown in Figure 2.

Hospital facility characteristics such as ownership type, bed size, teaching status, residency training program status, rural or urban designation, and occupancy level were not used in the regression models since these characteristics do not adjust for a *patient's* legitimate clinical risk.[18] Instead, they represent the institutional risk associated with being admitted to a particular type of facility. The importance of excluding hospital characteristics cannot be overstated since the inclusion of these characteristics would grossly distort each of the risk models by lowering and raising the standard of care across hospitals when the demographic and clinical characteristics of the patients are the same. Furthermore, since institutional risk is one of the residual variables that should be carefully evaluated by purchasers and providers, the use of hospital characteristics is counterintuitive and therefore lacks face validity with employers, payers, and the medical community at large.[11]

Risk-adjusted mortality index

The RAMI was developed to measure to what extent a provider's inpatient mortality rate is higher or lower than expected for specific diagnoses and procedures given the risk factors of the patient population, where an index of 1.00 indicates that the actual mortality rate equals the expected rate. The RAMI model excludes all patients with do-not-resuscitate and palliative care codes as well as all MS-DRG clusters with fewer than 300 cases nationally (because of insufficient statistical power). In addition, complications of care were excluded as risk factors so the patient's illness level at the time of admission could be measured to assess the risk of the patient's primary medical problem and related comorbidities prior to medical intervention. Clinicians designated 48 postsurgical and 110 postobstetrical conditions on the CMS major CC and CC list to be complications of care or iatrogenic events. This list includes problems such as accidental operative laceration, postoperative infection, and obstetrical shock.

Risk-adjusted complications index

The RACI was developed to identify the extent to which a provider's postsurgical and postobstetrical complication rates during a hospital stay are higher or lower than expected for particular diagnoses and procedures, given the risk factors of the patient population, where an index of 1.00 indicates that the actual complication rate is equal to the expected rate. The RACI model excludes newborns, all cases that died, all cases that were transferred to other short-term hospitals, and MS-DRG clusters with less than 300 cases nationally. A list of the postsurgical and postobstetrical complications screened by the RACI is displayed in Table 2.

Risk-adjusted readmissions index

The risk-adjusted readmissions index was developed to measure the extent to which a provider's actual readmission rate is higher or lower than expected for specific diagnoses and procedures, given the risk factors of the patient population, where an index of 1.00 indicates that the actual readmission rate is equal to the expected rate. Importantly, the RARI measures only unanticipated readmissions to the same hospital within 30 days of discharge. Since the purpose of the readmissions model is to identify adverse outcomes, certain types of readmissions were excluded such as readmissions that would ordinarily be either scheduled (eg, chemotherapy) or unavoidable (eg, multiple admissions for AIDS patients and cancer patients). In addition, cases that were transferred to another short-term hospital, cases that died during the first admission, and newborns were excluded from the model. Moreover, a case was considered a readmission only if the patient's subsequent hospital stay was in the same MS-DRG or related service line as the first admission. Lastly, MS-DRG clusters with fewer than 300 cases nationally were excluded from analysis.

Risk-adjusted patient safety index

The risk-adjusted patient safety index was developed to identify the extent to which a provider's actual rate of patient safety events during a hospital stay for particular diagnoses and procedures is higher or lower than expected, given the risk factors of the patient population, where an index of 1.00 indicates the actual rate of patient safety events equals the

Table 2

LIST OF POSTSURGICAL AND POSTOBSTETRICAL COMPLICATIONS

Postsurgical complications

1. Accidental cut in medical care necrotizing endocarditis (NEC)
2. Accidental cut in medical care not otherwise specified (NOS)
3. Accidental cut/hemorrhage in infusion
4. Accidental cut/hemorrhage in injection
5. Accidental cut/hemorrhage in surgery
6. Accidental cut/hemorrhage with catheterization
7. Accidental cut/hemorrhage with enema
8. Accidental cut/hemorrhage with heart catheter
9. Accidental cut/hemorrhage with scope exam
10. Accidental cut/hemorrhage, perfusion NEC
11. Accidental operative laceration
12. Accidental puncture or laceration during a procedure
13. Cataract fragment from cataract surgery
14. Complications due to cardiac device, implant, or graft
15. Complications due to renal dialysis device, graft
16. Complications due to vascular access device, implant, graft
17. Disruption external wound
18. Disruption internal wound
19. Emphysema resulting from procedure
20. Foreign body accidentally left in during procedure
21. Hematoma complication procedural
22. Hemorrhage complication procedural
23. Iatrogenic cardiovascular infarction/hemorrhage
24. Iatrogenic pulmonary embolism/infarction
25. Iatrogenic pneumothorax
26. Infected postoperative seroma
27. Nonhealing surgical wound
28. Other specific complication procedural NEC
29. Other postoperative infection
30. Other respiratory complications
31. Persistent postoperative fistula
32. Postoperative complication NOS
33. Postoperative reaction to foreign substance accidentally left in
34. Postoperative shock
35. Postoperative wound disruption
36. Postoperative respiratory failure
37. Reaction – other vascular device/graft
38. Seroma complicating procedure
39. Surgical complication—hypertension
40. Surgical complication—body system NEC
41. Surgical complication—digestive
42. Surgical complication—nervous system
43. Surgical complication—peripheral vascular system
44. Surgical complication—respiratory
45. Surgical complication—urinary tract
46. Surgical complication—heart
47. Vascular complications of medical care
48. Ventilator associated pneumonia

Postobstetrical complications

1. Acute renal failure, delivered with postpartum
2. Acute renal failure, postpartum
3. Amniotic embolism, postpartum
4. Amniotic embolism, delivered
5. Amniotic embolism, delivered with postpartum
6. Cerebrovascular disorder, delivered with postpartum
7. Cerebrovascular disorder, postpartum
8. Central nervous system complication in delivery, postpartum
9. Central nervous system complication labor/delivery, delivered
10. Central nervous system complication, delivered with postpartum
11. Complicated delivery NEC, delivered with postpartum
12. Complicated delivery NEC, postpartum
13. Complicated delivery NOS, delivered with postpartum
14. Complicated delivery NOS, postpartum
15. Complicated labor/delivery NOS, delivered
16. Complication of anesthesia NOS, delivered
17. Complication of anesthesia NOS, delivered with postpartum
18. Complication of anesthesia, postpartum
19. Complication of anesthesia, postpartum
20. Complication of anesthesia NEC, delivered
21. Complication of anesthesia NEC, delivered with postpartum
22. Damage to pelvic joint, delivered
23. Damage to pelvic joint, postpartum
24. Damage to pelvic joint, unspecified
25. Deep vein thrombosis, postpartum
26. Delivery with 3-degree laceration, delivered
27. Delivery with 3-degree laceration, postpartum
28. Deliver with 3-degree laceration, unspecified
29. Delivery with 4-degree laceration, delivered
30. Delivery with 4-degree laceration, postpartum
31. Delivery with 4-degree laceration, unspecified

(*continues*)

Table 2

LIST OF POSTSURGICAL AND POSTOBSTETRICAL COMPLICATIONS (*Continued*)

Postobstetrical complications (*continued*)	
32. Delayed postpartum hemorrhage, delivered with P/P	73. Obstetrical surgical complication, delivered with postpartum
33. Delayed postpartum hemorrhage, postpartum	74. Obstetrical trauma NEC, antepartum
34. Disrupted C-section wound, delivered with postpartum	75. Obstetrical trauma NEC, delivered
35. Disrupted C-section wound, postpartum	76. Obstetrical trauma NEC, delivered with postpartum
36. Disrupted C-section wound, unspecified	77. Obstetrical trauma NEC, postpartum
37. Disrupted perineum, delivered with postpartum	78. Obstetrical trauma NEC, unspecified
38. Disruption perineum, postpartum	79. Obstetrical trauma NOS, antepartum
39. Heart complication in delivery, delivered	80. Obstetrical trauma NOS, delivered
40. Heart complication, delivered with postpartum	81. Obstetrical trauma NOS, delivered with postpartum
41. Heart complication, postpartum	82. Obstetrical trauma NOS, postpartum
42. High vaginal laceration, delivered	83. Obstetrical trauma NOS, unspecified
43. High vaginal laceration, postpartum	84. Other obstetrical complications, delivered
44. High vaginal laceration, unspecified	85. Other obstetrical complications, delivered with postpartum
45. Injury, pelvic organ NEC, postpartum	86. Other obstetrical surgical complications, postpartum
46. Inversed uterus, postpartum	87. Postpartum coagulation deficiency, delivered with postpartum
47. Laceration of cervix, delivered	88. Perineal laceration NOS, postpartum
48. Laceration of cervix, postpartum	89. Perineal trauma NEC, postpartum
49. Laceration of cervix, unspecified	90. Perineal trauma NOS, postpartum
50. Major puerperal infection, delivered with postpartum	91. Postpartum coagulation deficit, postpartum
51. Major puerperal infection, postpartum	92. Postpartum hemorrhage NEC, delivered with postpartum
52. Major puerperal infection, unspecified	93. Postpartum hemorrhage NEC, postpartum
53. Maternal hypotension syndrome, delivered	94. Puerperal cerebrovascular disorder, delivered
54. Maternal hypotension syndrome, delivered with postpartum	95. Pulmonary complication in delivery, delivered
55. Maternal hypotension syndrome, postpartum	96. Pulmonary complication, postpartum
56. Obstetrical air embolism, delivered	97. Pulmonary complication, delivered with postpartum
57. Obstetrical air embolism, delivered with postpartum	98. Pulmonary embolism NEC, delivered
58. Obstetrical air embolism, postpartum	99. Pulmonary embolism NEC, delivered with postpartum
59. Obstetrical injury, pelvic organ NEC, delivered	100. Pulmonary embolism NEC, postpartum
60. Obstetrical injury, pelvic organ NEC, unspecified	101. Pulmonary embolism NOS, delivered
61. Obstetrical perineal laceration NOS, delivered	102. Pulmonary embolism NOS, delivered with postpartum
62. Obstetrical perineal laceration NOS, unspecified	103. Pulmonary embolism NOS, postpartum
63. Obstetrical perineal trauma NEC, delivered	104. Rupture uterus NOS, delivered
64. Obstetrical perineal trauma NEC, unspecified	105. Third-stage hemorrhage, delivered with postpartum
65. Obstetrical perineal trauma NOS, delivered	106. Third-stage hemorrhage, postpartum
66. Obstetrical perineal trauma NOS, unspecified	107. Thrombosis NEC, delivered
67. Obstetrical pyemic embolism, delivered	108. Thrombosis NEC, delivered with postpartum
68. Obstetrical pyemic embolism, delivered with postpartum	109. Thrombosis NEC, postpartum
69. Obstetrical pyemic embolism, postpartum	110. Thrombosis postpartum, delivered with postpartum
70. Obstetrical shock, delivered	
71. Obstetrical shock, delivered with postpartum	
72. Obstetrical shock, postpartum	

expected rate. Given that AHRQ's patient safety indicator (PSI) methodology is limited to only evaluating an individual PSI occurrence (eg, PSI 6: Iatrogenic Pneumothorax) across a broad range of unrelated MS-DRG clusters aggregately, a notable benefit of RAPSI is that it allows for the global screening of all PSIs at risk at the individual MS-DRG level as well as the clinical category level (eg, cardiac care, orthopedic care). Without the use of the RAPSI methodology, important evaluations of this type are not possible.

The RAPSI model excludes the following AHRQ PSIs due to inconsistent coding practices among hospitals or the prevalence of false positives: complications of anesthesia, accidental puncture and laceration, transfusion reaction, and death in low mortality DRGs. The model also excludes MS-DRG clusters with fewer than 300 cases nationally. A list of the 16 patient safety events screened by RAPSI is provided in Table 3 and includes adverse events such as iatrogenic pneumothorax, postoperative respiratory failure, and postoperative sepsis.

Table 3

LIST OF PATIENT SAFETY EVENTS SCREENED BY THE RISK-ADJUSTED PATIENT SAFETY INDEX

1. Failure to rescue
2. Decubitus ulcer
3. Foreign body left in during procedure
4. Iatrogenic pneumothorax
5. Selected infections due to medical care
6. Postoperative hip fracture
7. Postoperative hemorrhage or hematoma
8. Postoperative physiologic and metabolic derangements
9. Postoperative respiratory failure
10. Postoperative pulmonary embolism or deep-vein thrombosis
11. Postoperative sepsis
12. Postoperative wound dehiscence in abdominopelvic surgical patients
13. Birth trauma—injury to neonate
14. Obstetric trauma—vaginal delivery with instrument
15. Obstetric trauma—vaginal delivery without instrument
16. Obstetric trauma—cesarean delivery

Validation of the risk models

Significant effort was taken to construct medically meaningful and statistically reliable models for risk-adjusting comparisons of mortality, complications, readmissions, and patient safety events. A summary of the steps taken to ensure the validity of each of the risk models is as follows.

1. Only demographic and clinical characteristics of patients were used as predictive variables in each of the risk models.
2. Risk factors were modeled for RAMI, RACI, RARI, and RAPSI, using a large, representative database that covered all payer classifications and case types except neonates.
3. Statistical analysis was performed on each of the models using an *R*-square (R^2) and C-statistic. Specifically, the R^2 was calculated by comparing observed rates to predicted rates across an independent data set that was not used to fit the models. The resultant R^2 values for the models were shown to be 0.94 for RAMI, 0.93 for RACI, 0.97 for RARI, and 0.93 for RAPSI; where 1.0 would indicate a perfect linear relationship between observed and predicted rates. Models with R^2 values greater than 0.50 are generally considered to have good predictive power. Although R^2 values are commonly reported for dichotomous data, they are referred to as pseudo-R^2s since the statistic was specifically designed to identify the amount of variation explained using continuous data. Hence, the findings derived from pseudo-R^2s can be less reliable for determining the actual predicative capability of dichotomous models. Consequently, a C-statistic was calculated from the receiver-operator characteristic curve to determine the extent to which each model correctly predicted their respective dichotomous outcome, where a C-statistic of 0.50 or less indicates poor predictive power. The resultant C-statistics yielded 0.87 for RAMI, 0.68 for RACI, 0.59 for RARI, and 0.54 for RAPSI.

A summary of the statistical measures used for validating each model's predictive capability is provided in Table 4. An overview of the various outcome

Table 4

SUMMARY OF *R*-SQUARES AND *C*-STATISTICS BY RISK MODEL[a]

Category by Statistic	Mortality Model	Complications Model	Readmissions Model	Patient Safety Model
Overall				
R^2	0.94	0.93	0.97	0.93
C-statistic	0.87	0.68	0.59	0.54
Medical				
R^2	0.93	...	0.96	0.90
C-statistic	0.83	...	0.57	0.59
Surgical				
R^2	0.94	0.93	0.98	0.94
C-statistic	0.89	0.68	0.59	0.63

[a]Ellipses indicate not available (complications model only reports on postsurgical and postobstetrical cases).

analyses that can be performed using the risk models is discussed in the next section.

CLINICAL QUALITY ANALYSIS

There are various databases available for conducting valid comparisons of provider outcomes (for both hospitals and physicians). The databases rely on patient discharge abstracts and include the following.

- Centers for Medicare & Medicaid Services Medicare Provider Analysis and Review files, which represent all Medicare discharges from short-term, general, nonfederal US hospitals.
- Public domain all payer statewide databases that include Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Iowa, Louisiana, Maine, Maryland, Missouri, Massachusetts, Nevada, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, and Wyoming (certain restrictions may apply regarding data access and reporting in each state).
- Proprietary universal billing (UB) data from individual hospitals and consortia (including networks, alliances, and multihospital systems).

Application of the risk models for analysis of hospital outcomes is displayed in Table 5, using Medicare data from the CMS Medicare Provider Analysis and Review file. Actual and expected rates of mortality, complications, and patient safety events for coronary bypass with cardiac catheterization with major CC (MS-DRG 233) are shown, along with the respective risk-adjusted indices for each hospital (actual hospital names are available on the Medicare Provider Analysis and Review file but were omitted for the sake of a generalized example). The expected rates represent the national rates for patients with similar demographic and clinical characteristics as those of the hospital under analysis. The risk-adjusted indices were calculated by taking the actual rates for mortality, complications, and patient safety events for each hospital and dividing them by the expected rates generated from the respective regression models. Hence, an index greater than 1.0 indicates that the actual rate is higher than expected (eg, an index of 1.20 indicates that the actual rate is 20% higher than expected), whereas an index less than 1.0 indicates that the actual rate is lower than expected (eg, an index of 0.80 indicates that the actual rate is 20% lower than expected). A 95%confidence interval was also calculated for each index to determine whether the difference between a hospital's performance and the national norm was statistically significant or merely due to normal variation in the data.

The benchmarks were derived by ranking all hospitals in the national database from lowest to

Table 5

MORTALITY AND COMPLICATIONS COMPARISON BY PROVIDER FOR MS-DRG 233: CORONARY BYPASS WITH CARDIAC CATHETERIZATION WITH MAJOR CC[a]

Provider	Number of Cases	Actual Mortality Rate, %	Expected Mortality Rate, %	Risk-Adjusted Mortality Index*	Actual Complication Rate, %	Expected Complication Rate, %	Risk-Adjusted Complications Index (RACI)[b]	Effect of RACI Benchmark Variance on $	Actual Patient Safety Event Rate, %	Expected Patient Safety Event Rate, %	Risk-Adjusted Patient Safety Index Index (RAPSI)[b]
A	447	3.5	2.3	1.55	15.4	36.2	0.43[b]	$11,119	2.2	2.7	0.82
B	222	2.9	2.0	1.45	44.2	33.1	1.34[b]	$104,619	2.8	2.6	1.09
C	201	2.0	1.5	1.40	18.8	28.6	0.66[b]	$12,897	3.7	2.5	1.49
D	174	4.1	3.0	1.38	45.7	37.2	1.23[b]	$87,380	10.9	2.6	4.21[b]
E	86	2.4	1.2	1.93	13.3	26.9	0.49[b]	$14,898	6.6	2.4	2.73[b]
Peer group	1130	3.1	2.1	1.49	26.1	33.6	0.78	$178,879	5.1	2.6	1.98
Benchmark				0.78			0.59				0.63
National norm				1.00			1.00				1.00

[a]From Centers for Medicare & Medicaid Services Medicare Provider Analysis and Review file.
[b]Risk-adjusted index is statistically significant at a confidence level of 95%.

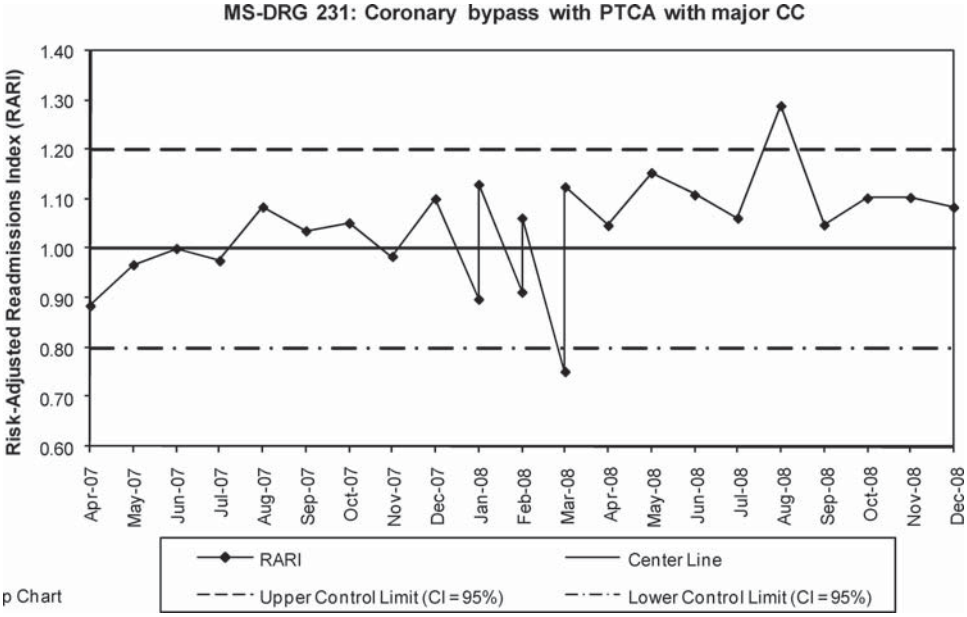

Figure 3. Control chart for hospital risk-adjusted readmissions index by month. "CC" indicates complications and comorbidities; RARI, risk-adjusted readmissions index.

highest on each risk-adjusted index and then identifying a cluster of providers that were performing at the 75th percentile. Thus, the benchmark represents providers whose performance is better than 75% of the providers in the database for the particular outcome.

An analysis of Table 5 shows that all hospitals have mortality indices that are higher than expected nationally. However, these findings are not shown to be statistically significant. Consequently, the variation in mortality should be attributed to random variation rather than to poor quality of care. With regard to complications, hospitals A, C, and E have RACIs that are lower than expected nationally for bypass surgery, while RACIs for both hospital B and hospital D are higher than expected nationally. Each of these indices is shown to be statistically significant at a confidence level of 95%, which suggests that quality improvement opportunities exist since variation can be attributed to special causes. Comparison of all hospitals to the RACI benchmark reveals that providers A and E are performing better than the benchmark indicating that they are among the top performing providers in the nation. On the other hand, hospitals B and D are incurring more than $104 000 and $87 000, respectively, in additional resource consumption because of complication rates that are much higher than the benchmark. The opportunity for hospitals B and D to reduce their cost of care by improving their rates of complications demonstrates a well-known continuous quality improvement principle that better quality can actually cost less. Additional analysis reveals that hospitals D and E are shown to have rates of patient safety events that are significantly higher than expected nationally. Another important measure of quality is the hospital's readmission rate. Figure 3 displays a particular hospital's RARI performance using a control chart that reveals that readmissions were lower in March 2008 than expected, but higher in August 2008. The fact that the corresponding data points are outside the upper and lower control limits indicates that the observations are statistically significant. If possible, differences in the pattern of care should be evaluated between the 2 months to identify the special causes of variation and uncover the underlying processes

that led to a better than expected readmission rate in March.

CONCLUSION

This type of risk-adjusted approach to outcomes assessment allows purchasers to validly assess the relative performance of hospitals and physicians on important measures of quality. It also enables hospitals to identify and statistically validate adverse events, establish improvement priorities and objectives, develop quality improvement plans, assess compliance with pay-for-performance initiatives, and identify favorable outcomes for marketing to payers, employers, and consumers. In addition, it offers an effective process for monitoring new treatment protocols to ensure that cost containment does not compromise the quality of care.

REFERENCES

1. Braun BI, Koss RG, Loeb JM. Integrating performance measure data into the Joint Commission accreditation process. *Eval Health Prof.* 1999;3:283-297.
2. Darr K. The Centers for Medicare and Medicaid Services proposal to pay for performance. *Hosp Top.* 2003;2:30-32.
3. Tide rises on pay for performance with voluntary reporting initiative. *Healthc Financ Manag.* 2004;58(3):120-121.
4. Milstein A, Galvin RS, Delbanco SF, Salber P, Buck CR, Jr. Improving the safety of health care: the leapfrog initiative. *Eff Clin Pract.* 2000;3(6):313-316.
5. Comaro A. America's best hospitals. *US News World Rep.* 2003;28:46.
6. Burda D. They just do it better. *Mod Healthc.* 2003; 29(suppl):6.
7. Localio RA, Hamory BH, Sharp TJ, Weaver SL, TenHave TR, Landis JR. Comparing hospital mortality in adult patients with pneumonia: a case study of statistical methods in a managed care program. *Ann Intern Med.* 1995;122(2):125-131.
8. Vachon M. Six trends for your next strategy session agenda. *Healthc Executive.* 2009;24(3)(Suppl.):1.
9. DesHarnais SI, McMahon LF Jr, Wroblewski RT. Measuring outcomes of hospital care using multiple risk-adjusted indexes. *Health Serv Res.* 1991;26(4):425-445.
10. DesHarnais SI. Current uses of large data sets to assess the quality of providers: construction of risk-adjusted indexes of hospital performance. *Int J Technol Assess Health Care.* 1990;6:229-238.
11. DesHarnais SI, McMahon LF Jr, Wroblewski RT, Hogan AJ. Measuring hospital performance: the development and validation of risk-adjusted indexes of mortality, readmissions, and complications. *Med Care.* 1990;28(12):1127-1141.
12. DesHarnais SI, Chesney JD, Wroblewski RT, Fleming ST, McMahon LF Jr. The risk-adjusted mortality index: a new measure of hospital performance. *Med Care.* 1988;26(12):1129-1148.
13. Patient Safety Indicators Overview. *AHRQ Quality Indicators.*, Rockville, MD: Agency for Healthcare Research and Quality; 2006.
14. Iezzoni LI, Ash AS, Shwartz M, Daly J, Hughs JS, Mackiernan YD. Predicting who dies depends on how severity is measured: implications for evaluating patient outcomes. *Ann Intern Med.* 1995;123:763-770.
15. Pine M, Pine J. Standardization of terms and analytical methods for performance evaluation: achievable goal or impossible dream? *Manag Care Q.* 1995;3(3):11.
16. Iezzoni LI. The risk of risk adjustment. *J Am Med Assoc.* 1997;278(19):1600.
17. Edwards N, Honemann D, Burley D, Navarro M. Refinement of the Medicare diagnosis-related groups to incorporate a measure of severity. *Health Care Financ Rev.* 1994;16(2):48.
18. Iezzoni LI, ed. *Risk Adjustment for Measuring Health Care Outcomes.* Ann Arbor, MI: Health Administration Press; 1994;30–32, 200.