AHRQ Quality Indicators

Pediatric Quality Indicators Composite Measure Workgroup

Final Report

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AHRQuality Indicators

Agency for Healthcare Research and Quality Quality Indicators (AHRQ QI)

Pediatric Quality Indicators (PDI) Composite Measure Workgroup Final Report March 2008

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1. Introduction

Many users of the AHRQ Quality Indicators (AHRQ QI) have expressed interest in the development of one or more composite measures. In particular, the National Healthcare Quality Report and the National Healthcare Disparities Report[1] staff asked the AHRQ QI program to develop composite measures for use in these reports. A composite measure for the Prevention Quality Indicators was developed initially.[2] The goal of the development effort was to develop a composite measure that might be used to monitor performance over time or across regions and populations using a methodology that applied at the national, regional, State, or provider/area level. This report describes the construction of a composite measure for the Pediatric Quality Indicators (PDIs): *Pediatric Patient Safety for Selected Indicators*.

To assist in the development of a composite measure methodology, the AHRQ QI Composite Measure Workgroup held several conference calls to discuss important issues and considerations and to provide feedback on preliminary results. To maintain the focus on the general composite measure methodology, the Workgroup did not consider the merits of including individual indicators in the composites. Rather, all available Pediatric Quality Indicators that met the conceptual criteria were included. The members of the AHRQ QI Composite Measure Workgroup are listed in Appendix A.

This report is very technical in nature. To facilitate future use of the composite, the AHRQ QI program plans to develop more accessible explanatory narrative on the composite measures as part of the reporting template initiative.

For more information on the Pediatric Quality Indicators, including selection criteria, coding, and specifications, see the Pediatric Quality Indicators technical report and the Pediatric Quality Indicators Technical Specifications, available on the AHRQ QI Web site (http://qualityindicators.ahrq.gov).[3]

2. Reasons for Composite Measures

Before considering alternative approaches to composite measures, one might consider why composite measures are potentially useful and for what purpose.

2.1. Benefits of Composite Measures

Composite measures have several potential benefits over individual indicators:

- *Summarize quality across multiple indicators*. There are 13 provider-level PDIs for various types of quality and adverse events, making it difficult to formulate general statements about overall trends or differences in quality and patient safety.

[1] The most recent National Healthcare Quality Report and National Healthcare Disparities Report may be found at http://www.ahrq.gov/qual/measurix.htm.
[2] A report describing the composite measure for the Prevention Quality Indicators can be found at: http://www.qualityindicators.ahrq.gov/downloads/technical/AHRQ QI PQI Composite Report Final.pdf.
[3] Guide: http://www.qualityindicators.ahrq.gov/downloads/pdi/pdi_measures_v31.pdf; Technical Specifications: http://www.qualityindicators.ahrq.gov/downloads/pdi/pdi_technical%20specs_v31.pdf.

- *Improve ability to detect quality differences*. Combining information from multiple indicators may result in greater discrimination in performance than is evident from individual indicators.

- *Identify important domains and drivers of quality*. To the extent that certain indicators track together, or track with certain process or structural characteristics of providers, one may identify the important domains and drivers of quality and patient safety.

- *Prioritize action for quality improvement*. Individual indicators that contribute a larger share to the composite may be targets for quality improvement activity.

- *Make current decisions about future (unknown) health care needs*. Depending on how the component indicators are weighted, composites may reflect the likely health outcomes for an individual or population.

- *Avoid cognitive "shortcuts."* Research suggests that individuals faced with too many factors in making a decision take cognitive shortcuts that might not be in their best interest. Composites may help to ensure that decisions are made appropriately.

2.2. Concerns About Composite Measures

Despite these benefits, there are concerns about using composite measures, depending on how the composite measure is constructed:

- *Can mask important differences and relationships among components*. Composite measures might mask the fact that two components are inversely related, or an "average" provider might be high on one component and low on another.

- *May not be actionable*. It might not be clear what action a provider should take given high or low performance on a composite measure.

- *May not identify which parts of the health care system contribute most to quality*. To the extent that the composite is not connected to the interventions important for the component measures, it might be difficult to know how the composite contributes to improving quality and patient safety.

- *Can detract from the impact and credibility of reports*. The composite measure might not reflect the evidence base of the component indicators.

2.3. Potential Uses of Composite Measures

Composite measures have many potential uses:

- *Consumers* might use composite measures to select a hospital or health plan either before or after a health event.

- *Providers* might use composite measures to identify the domains and drivers of quality and patient safety.

- *Purchasers* might use composite measures to select hospitals or health plans in order to improve the health of employees.

- *Policymakers* might use composite measures to set policy priorities in order to improve the health of a population.

3. Alternative Perspectives on Composite Measures

Two alternative perspectives on composite measures guide the development of a composite measure methodology:

- *Signaling perspective*, which seeks to guide decisionmaking by providing information that will result in actions leading to some intended result. The ultimate evaluation criterion for the composite measure is the usefulness of the measure for achieving the intended result. An example of a composite measure reflecting the signaling perspective is the Dow Jones Industrial Average used to guide decisionmaking on allocating investment resources.

- *Psychometric perspective*, which seeks to capture an underlying construct of quality based on multiple single indicators. The ultimate evaluation criterion for the composite measure is the extent to which the components reflect that construct. An example of a composite measure reflecting the psychometric perspective is the IQ test used to capture a construct labeled "intelligence."

The methodology used for the AHRQ QI composite measures reflects the signaling perspective, in that the primary intent of the measures is to guide decisionmaking in terms of where to allocate resources to improve quality rather than to capture an underlying construct of quality.

4. Methodology for the AHRQ QI Composite Measures

4.1. Composite Measure Development Criteria

This report describes the construction of a single composite measure for the PDI: *Pediatric Patient Safety for Selected Indicators*. Appendix B presents PDI composite tables (Tables 1-8). Table 1 shows the reference population, including the incidence rate for each adverse event.

The basic criteria used to guide the development of the methodology were:

- *Evidence based*. The composite measure should be based on indicator components that are important, reliable, valid, and minimally biased.

- *Conceptually coherent*. The components of the composite measure should be related to one another conceptually.

- *Empirically coherent*. The components of the composite measure should be related to one another empirically.

- *Intended use*. The composite measures should be constructed in a manner appropriate to the intended use, whether that is comparative reporting or quality improvement.

Applying these criteria to the PDIs, one could advocate for separate composites based on the type of adverse event (e.g., postoperative). However, in general, the component indicators apply to the same providers (see Table 2) and show at least some positive correlation with one another (see Table 3). Therefore, the initial composite includes all the provider-level indicators (see table below).[4] Future development might examine subcomposites for certain indicators.

AHRQ PDI Composite Measure

Pediatric Patient Safety for Selected Indicators	
PDI #01 Accidental Puncture or Laceration	PDI #09 Postop Respiratory Failure
PDI #02 Decubitus Ulcer	PDI #10 Postop Sepsis
PDI #05 Iatrogenic Pneumothorax	PDI #11 Postop Wound Dehiscence
PDI #08 Postop Hemorrhage or Hematoma	PDI #12 Selected Infections Due to Medical Care

4.2. AHRQ QI Composite Measure Methodology

The general methodology for the AHRQ QI composite measures might be described as constructing a "composite of composites." The first "composite" is the reliability-adjusted ratio, which is a weighted average of the risk-adjusted ratio and the reference population ratio, where the weight is determined empirically. The second "composite" is a weighted average of the component indicators, where the weights are selected based on the intended use of the composite measure. These weights might be determined empirically or based on nonempirical considerations.

4.3. Construction of AHRQ QI Composite Measure

The basic steps for computing the composite follow.

Step 1. Compute the risk-adjusted rate and confidence interval

The AHRQ QI risk-adjusted rate is computed based on a simple logistic regression model[5] for calculating a predicted value for each case. Then the predicted values among all the cases in the hospital are summed to compute the expected rate. The risk-adjusted rate is computed using indirect standardization as the observed rate (OR) divided by the expected rate (ER), with the result multiplied by the reference population rate: (RR) = (OR/ER × PR). The reference population used in this analysis includes the States participating in the Healthcare Cost &

[4] Foreign Body Left During Procedure (PDI #03) and Transfusion Reaction (PDI #13) are serious reportable events (i.e., "never events") and are reported as counts. Iatrogenic Pneumothorax in Neonates (PDI #04) is included in a new neonatal indicator set (release date in fiscal year 2008).
[5] Release 3.1 (fiscal year 2007) of the AHRQ QI software adopted a hierarchical modeling methodology for the risk adjustment, but the composite methodology remains the same.

Utilization Project (HCUP) for 2001-2003, consisting of 38 States and approximately 90 million discharges.[6]

Step 2. Scale the risk-adjusted rate using the reference population

Table 1 shows the reference population numerator, denominator, and rate for each PDI. The relative magnitudes of the rates vary from indicator to indicator. To combine the component indicators using a common scale, each indicator's risk-adjusted rate is divided by the reference population rate to yield a ratio. The components of the composite are therefore defined in terms of a ratio to the reference population rate for each indicator. The component indicators are scaled by the reference population rate so that each indicator reflects the degree of deviation from the overall average performance.

Step 3. Compute the reliability-adjusted ratio

The reliability-adjusted ratio (RAR) is computed as the weighted average of the risk-adjusted ratio and the reference population ratio, where the weights vary from 0 to 1, depending on the degree of reliability for the indicator and provider (or other unit of analysis).

RAR = [risk-adjusted ratio × weight] + [reference population ratio × (1 – weight)]

Table 4 shows the average reliability weights for the PDIs based on denominator size. For small providers, the weight is closer to 0. For large providers, the weight is closer to 1. For a given provider, if the denominator is 0, then the weight assigned is 0 (i.e., the reliability-adjusted ratio is the reference population ratio).

Step 4. Select the component weights

The composite measure is the weighted average of the scaled and reliability-adjusted ratios for the component indicators. Table 5 shows examples of alternative weights that might be used. Other weights are also possible.

Single indicator weight. In this case, the composite is simply the reliability-adjusted ratio for a single indicator. The reference population rate is the same among all providers (see Figures 1.1 and 1.2 in Appendix C).

[6] The State data organizations that participated in the 2001-2003 HCUP State Inpatient Databases are: Arizona Department of Health Services; California Office of Statewide Health Planning and Development; Colorado Health and Hospital Association; Connecticut - Chime, Inc.; Florida Agency for Health Care Administration; Georgia - GHA: An Association of Hospitals and Health Systems; Hawaii Health Information Corporation; Illinois Health Care Cost Containment Council; Indiana Hospital & Health Association; Iowa Hospital Association; Kansas Hospital Association; Kentucky Department for Public Health; Maine Health Data Organization; Maryland Health Services Cost Review Commission; Massachusetts Division of Health Care Finance and Policy; Michigan Health & Hospital Association; Minnesota Hospital Association; Missouri Hospital Industry Data Institute; Nebraska Hospital Association; Nevada Department of Human Resources; New Hampshire Department of Health & Human Services; New Jersey Department of Health and Senior Services; New York State Department of Health; North Carolina Department of Health and Human Services; Ohio Hospital Association; Oregon Association of Hospitals and Health Systems; Pennsylvania Health Care Cost Containment Council; Rhode Island Department of Health; South Carolina Budget & Control Board; South Dakota Association of Healthcare Organizations; Tennessee Hospital Association; Texas Health Care Information Council; Utah Department of Health; Vermont Association of Hospitals and Health Systems; Virginia Health Information; Washington State Department of Health; West Virginia Health Care Authority; Wisconsin Department of Health and Family Services.

Equal weight. In this case, each component indicator is assigned an identical weight based on the number of indicators. That is, the weight equals 1 divided by the number of indicators in the composite (e.g., 1/8 = 0.1250).

Numerator weight. A numerator weight is based on the relative frequency of the numerator for each component indicator in the reference population. In general, a numerator weight reflects the amount of harm in the outcome of interest, in this case a potentially preventable adverse event. One might also use weights that reflect the amount of excess mortality or complications associated with the adverse event, or the amount of confidence one has in identifying events (i.e., the positive predictive value).

Denominator weight. A denominator weight is based on the relative frequency of the denominator for each component indicator in the reference population. In general, a denominator weight reflects the amount of risk of experiencing the outcome of interest in a given population. For example, the denominator weight might be based on the demographic composition of a health plan, the employees of a purchaser, a State, an individual hospital, or a single patient.

Factor weight. A factor weight is based on some sort of analysis that assigns each component indicator a weight that reflects the contribution of that indicator to the common variation among the indicators. The component indicator that is most predictive of that common variation is assigned the highest weight. The weights in Table 5 are based on a principal components factor analysis of the reliability-adjusted ratios.

Step 5. Construct the composite measure

The composite measure is the weighted average of the component indicators using the selected weights and the scaled and reliability-adjusted indicators.

> Composite = [indicator1 RAR × weight1] + [indicator2 RAR × weight2] + . . . + [indicatorN RAR ∗ weightN]

The confidence interval of the composite is based on the standard error of the composite, which is the square root of the variance. The variance is computed based on the signal variance-covariance matrix and the reliability weights. Details of the computation are provided in Appendix D.

4.4. Sample Computation of the Composite Measure

This example demonstrates the construction of the composite for a representative provider beginning with the risk-adjusted rate and standard error for each PDI. An important consideration in the development of the composite measure methodology was that the computation of the composite and the weights be transparent and that a provider be able to trace the computation from the component indicators to the composite and back again.

Step 1. Compute the risk-adjusted rate and standard error

PDI	Average Annual Denominator	Observed Rate	Risk-Adjusted Rate	Rate Std. Error
PDI #01 Accidental Puncture or Laceration	7,120	0.796	0.561	0.169
PDI #02 Decubitus Ulcer	1,149	2.611	2.492	0.938
PDI #05 Iatrogenic Pneumothorax	6,491	0.873	0.645	0.089
PDI #08 Postop Hemorrhage or Hematoma	839	1.192	1.195	0.800
PDI #09 Postop Respiratory Failure	682	11.247	15.891	3.010
PDI #10 Postop Sepsis	445	38.981	39.494	3.795
PDI #11 Postop Wound Dehiscence	416	0.801	0.977	0.875
PDI #12 Selected Infections Due to Medical Care	5,270	10.436	6.141	0.306

Note: Observed and risk-adjusted rate are per 1,000.

This is the output a user would obtain from applying the AHRQ QI software (SAS and Windows) to the user's data.

Step 2. Scale the risk-adjusted rate using the reference population

PDI	Reference Population Rate	Risk-Adjusted Ratio	Ratio Std. Error
PDI #01 Accidental Puncture or Laceration	0.884	0.635	0.191
PDI #02 Decubitus Ulcer	3.285	0.759	0.286
PDI #05 Iatrogenic Pneumothorax	0.209	3.088	0.425
PDI #08 Postop Hemorrhage or Hematoma	1.649	0.725	0.485
PDI #09 Postop Respiratory Failure	13.650	1.164	0.221
PDI #10 Postop Sepsis	22.425	1.761	0.169
PDI #11 Postop Wound Dehiscence	0.784	1.247	1.116
PDI #12 Selected Infections Due to Medical Care	2.661	2.307	0.115

Step 3. Compute the reliability-adjusted ratio

Step S3A. Compute the reliability weight

PDI	Ratio Std. Error	Noise Variance	Signal Variance	Reliability Weight
PDI #01 Accidental Puncture or Laceration	0.191	0.0365	0.3088	0.8942
PDI #02 Decubitus Ulcer	0.286	0.0815	0.0181	0.1814
PDI #05 Iatrogenic Pneumothorax	0.425	0.1809	0.2102	0.5376
PDI #08 Postop Hemorrhage or Hematoma	0.485	0.2352	0.1922	0.4497
PDI #09 Postop Respiratory Failure	0.221	0.0486	0.2500	0.8372
PDI #10 Postop Sepsis	0.169	0.0286	0.1070	0.7889
PDI #11 Postop Wound Dehiscence	1.116	1.2454	0.0183	0.0145
PDI #12 Selected Infections Due to Medical Care	0.115	0.0132	0.4718	0.9727

Note: Noise variance is standard error squared (for details on calculating the noise variance, see Appendix D); reliability weight is signal variance/(signal variance + noise variance).

The noise variance is computed from the user's data as the square of the standard error. The signal variance is a reference population parameter that reflects the amount of provider-level variation remaining after the noise variance is removed. Note that the noise variance will vary by provider and by indicator.

Step S3B. Compute the reliability-adjusted ratio

PDI	Reliability Weight	Risk-Adjusted Ratio	Reference Population Ratio	Reliability-Adjusted Ratio
PDI #01 Accidental Puncture or Laceration	0.8942	0.635	1.006	0.674
PDI #02 Decubitus Ulcer	0.1814	0.759	0.891	0.867
PDI #05 Iatrogenic Pneumothorax	0.5376	3.088	0.806	2.033
PDI #08 Postop Hemorrhage or Hematoma	0.4497	0.725	0.985	0.868
PDI #09 Postop Respiratory Failure	0.8372	1.164	0.877	1.117
PDI #10 Postop Sepsis	0.7889	1.761	0.965	1.593
PDI #11 Postop Wound Dehiscence	0.0145	1.247	0.950	0.954
PDI #12 Selected Infections Due to Medical Care	0.9727	2.307	0.707	2.263

Note: Reliability-adjusted ratio is [risk-adjusted ratio × weight] + [reference population ratio × (1 – weight)].

The first "composite" is the weighted average of the provider's risk-adjusted ratio and the reference population ratio, where the weight reflects the reliability of the provider's risk-adjusted ratio. This "composite" is the reliability-adjusted ratio.

Step 4. Select the component weights

The weights are selected depending on the intended use of the composite. In this example, we use the factor weight.

PDI	Factor Weight
PDI #01 Accidental Puncture or Laceration	0.0584
PDI #02 Decubitus Ulcer	0.1428
PDI #05 Iatrogenic Pneumothorax	0.1908
PDI #08 Postop Hemorrhage or Hematoma	0.0607
PDI #09 Postop Respiratory Failure	0.1224
PDI #10 Postop Sepsis	0.1608
PDI #11 Postop Wound Dehiscence	0.0595
PDI #12 Selected Infections Due to Medical Care	0.2046

Step 5. Construct the composite measure

PDI	Factor Weight (A)	Reliability-Adjusted Ratio (B)	(A) × (B)
PDI #01 Accidental Puncture or Laceration	0.0584	0.674	0.039
PDI #02 Decubitus Ulcer	0.1428	0.867	0.124
PDI #05 Iatrogenic Pneumothorax	0.1908	2.033	0.388
PDI #08 Postop Hemorrhage or Hematoma	0.0607	0.868	0.053
PDI #09 Postop Respiratory Failure	0.1224	1.117	0.137
PDI #10 Postop Sepsis	0.1608	1.593	0.256
PDI #11 Postop Wound Dehiscence	0.0595	0.954	0.057
PDI #12 Selected Infections Due to Medical Care	0.2046	2.263	0.463
Pediatric Patient Safety for Selected Indicators			*1.517*
Standard Error			*0.094*
Confidence Interval at p<0.05		*1.332*	*1.701*

Note: For details on calculating the composite variance (standard error), see Appendix D.

The final composite is the weighted average of the component indicators, which is the sum of A × B for each indicator. Note the potential application of the composite construction for use in quality improvement. The final computation shows that selected infections due to medical care is the largest single contributor to the composite both because the indicator was heavily weighted and because the performance of the provider was worse than average. The incentive created in using the composite is to allocate resources to reducing selected infections due to medical care as the best mechanism to lower the composite score.

5. Performance of the AHRQ QI Composite Measures

5.1. Evaluation Criteria

Tables 6-8 in Appendix B and Figures 2.1-2.5 and 3.1-3.5 in Appendix C show the performance of each composite measure. The composite measures are evaluated using three criteria: discrimination, forecasting, and construct validity.

Discrimination is the ability of the composite measure to differentiate performance as measured by statistically significant deviations from the average performance.

Forecasting is the ability of the composite measure to predict performance for each of the component indicators. Ideally, the forecasting performance would reflect the weighting of the components, in the sense that forecasting would maximize the differences for the most highly weighted components.

Construct validity is the degree of association between the composite and other aggregate measures of quality. In this report we look primarily at the consistency in the composites with one another. A broader analysis of construct validity would examine the relationship between the composites and external measures of quality and patient safety or other factors that might influence quality and patient safety.

5.2. Results

Table 6 shows the discrimination performance of the composite measure *Pediatric Patient Safety for Selected Indicators*. The columns show the percentage of providers that are worse than average, average, or better than average based on the confidence interval for the composite measure. The discrimination performance varies depending on the weight used. The single and equal weights have the least ability to discriminate. The single indicator used as an example is "postoperative respiratory failure." The numerator weight tends to have the greatest ability to discriminate, followed by the denominator and factor weight.

In general, the composite identifies a relatively small number of providers with performance that is better or worse than average. Figures 2.1-2.5 show the range of values for each composite for 400 randomly selected hospitals, with the 95 percent confidence interval, which illustrates the precision of the composites.

Table 7 shows the forecasting performance of the composite measure. In this analysis each provider is assigned to a quintile (Q1-Q5) based on the performance on the composite in 2001-2003. The columns show the relative difference in the predicted risk-adjusted ratio in 2004 for the best and worst performing quintile relative to the middle 60 percent.

Forecasting performance varies depending on the weights used to construct the composite. In general, the composite is better at forecasting performance on component indicators that are more heavily weighted. In this sense the weights reflect the goals of the composite; more weight is assigned to component indicators where the goal is to reduce variability in performance.

Table 8 shows the correlation among the composite measures using the alternative weights. For *Pediatric Patient Safety for Selected Indicators*, the correlations range from 0.040 to 0.952. The single indicator weight is the least correlated. For other weights, the performance of individual hospitals on the composite tends to be highly correlated.

6. Concluding Comments

The intent of the AHRQ QI Composite Measure project was to develop a general methodology that could be used primarily to monitor performance in national and regional reporting, but that also could be applied to comparative reporting and quality improvement at the provider level. An important caveat in using the composite measures is that the measures are not intended to reflect any broader construct of quality or patient safety than is reflected in the component indicators themselves. The composites are only as useful and valid as are the component indicators that make up the composite. The AHRQ QIs are currently undergoing review through the National Quality Forum (NQF) consensus development processes, and a number of validation studies of the component indicators are underway. The actual content of the composite (i.e., what component indicators to include) and the potential uses of the composite will depend on the results of that process for the component indicators.

As the AHRQ QIs and the data upon which they are based continue to improve, the composite measures will improve as potentially useful tools for decisionmaking in allocating quality improvement resources. For example, potential extensions of the composite measure method include the incorporation of process measures (from other data sources) and measures of cost (estimated from HCUP). We encourage AHRQ QI users to continue to submit comments and suggestions for improvement on the composite measures and the component indicators to the AHRQ QI support team at support@qualityindicators.ahrq.gov.

Appendix A. AHRQ QI Composite Measure Workgroup

Workgroup Members

- John Birkmeyer, University of Michigan
- Bruce Boissonnault, Niagara Health Quality Coalition
- John Bott, Employer Health Care Alliance Cooperative
- Dale Bratzler, Oklahoma Foundation for Medical Quality
- Sharon Cheng, Medicare Payment Advisory Commission (MedPAC)
- Elizabeth Clough, Wisconsin Collaborative for Healthcare Quality
- Nancy Dunton, University of Kansas Medical Center, School of Nursing
- John Hoerner, Hospital Industry Data Institute
- David Hopkins, Pacific Business Group on Health
- Gregg Meyer, Massachusetts General Physicians Organization
- Elizabeth Mort, Massachusetts General
- Janet Muri, National Perinatal Information Center
- Vi Naylor, Georgia Hospital Association
- Eric Peterson, Duke University Medical Center
- Martha Radford, New York University Hospitals Center
- Gulzar Shah, National Association of Health Data Organizations
- Paul Turner, Vermont Program for Quality in Health Care

Liaison Members

- Justine Carr, National Committee on Vital and Health Statistics
- Robert Hungate, National Committee on Vital and Health Statistics
- Sheila Roman, Centers for Medicare & Medicaid Services
- Amy Rosen, Bedford Veterans Affairs Medical Center
- Stephen Schmaltz, Joint Commission on Accreditation of Healthcare Organizations
- Jane Sisk, National Center for Health Statistics
- Ernie Moy, Agency for Healthcare Research and Quality

Technical Advisors

- John Adams, RAND Corporation
- Bob Houchens, Medstat
- Bill Rogers, Rogers Associates
- Chunliu Zhan, Agency for Healthcare Research and Quality

AHRQ QI Support

- Mamatha Pancholi, AHRQ QI Project Officer
- Marybeth Farquhar, AHRQ NQF Project Officer
- Jeffrey Geppert, Project Director, Battelle Memorial Institute
- Theresa Schaaf, Project Manager, Battelle Memorial Institute
- Douglas O. Staiger, Technical Consultant, Dartmouth College

Appendix B. PDI Composite Tables

Table 1. Reference Population

PDI	Numerator	Denominator	Rate
PDI #01 Accidental Puncture or Laceration	7,237	8,189,085	0.884
PDI #02 Decubitus Ulcer	2,962	901,601	3.285
PDI #05 Iatrogenic Pneumothorax	1,544	7,394,640	0.209
PDI #08 Postop Hemorrhage or Hematoma	550	333,435	1.649
PDI #09 Postop Respiratory Failure	3,918	287,028	13.650
PDI #10 Postop Sepsis	6,091	271,612	22.425
PDI #11 Postop Wound Dehiscence	206	262,862	0.784
PDI #12 Selected Infections Due to Medical Care	16,802	6,313,587	2.661

Source: HCUP State Inpatient Databases, 2001-2003; rate per 1,000.

Table 2. Provider-Level Rates

		Risk Adjusted		Reliability Adjusted	
PDI	**Hospitals**	**Rate**	**Std. Dev.**	**Rate**	**Std. Dev.**
PDI #01 Accidental Puncture or Laceration	3,602	1.129	4.305	0.897	0.231
PDI #02 Decubitus Ulcer	3,284	2.017	11.422	2.933	0.078
PDI #05 Iatrogenic Pneumothorax	3,602	0.095	0.480	0.170	0.028
PDI #08 Postop Hemorrhage or Hematoma	2,537	1.183	10.718	1.625	0.123
PDI #09 Postop Respiratory Failure	2,530	5.507	30.720	11.897	2.344
PDI #10 Postop Sepsis	2,388	14.686	61.925	21.681	2.379
PDI #11 Postop Wound Dehiscence	3,274	0.646	6.750	0.744	0.004
PDI #12 Selected Infections Due to Medical Care	3,593	0.857	2.707	1.749	0.731

Source: HCUP State Inpatient Databases, 2001-2003; rate per 1,000.

Table 3. Provider-Level Correlation

PDI	PDI #01	PDI #02	PDI #05	PDI #08	PDI #09	PDI #10	PDI #11	PDI #12
PDI #01 Accidental Puncture or Laceration	1.000	0.015	0.071	0.006	-0.021	-0.023	-0.006	-0.006
PDI #02 Decubitus Ulcer		1.000	0.073	-0.007	0.020	0.029	-0.002	0.075
PDI #05 Iatrogenic Pneumothorax			1.000	0.003	0.108	0.073	0.017	0.231
PDI #08 Postop Hemorrhage or Hematoma				1.000	0.000	0.006	-0.004	0.009
PDI #09 Postop Respiratory Failure					1.000	0.071	0.026	0.132
PDI #10 Postop Sepsis						1.000	0.025	0.106
PDI #11 Postop Wound Dehiscence							1.000	0.012
PDI #12 Selected Infections Due to Medical Care								1.000

Source: HCUP State Inpatient Databases, 2001-2003.

Table 4. Reliability Weight by Average Annual Denominator

Average Annual Denominator Size (by quartile)					
PDI	**Hospitals**	**Q1**	**Q2**	**Q3**	**Q4**
PDI #01 Accidental Puncture or Laceration	3,602	109	522	1,509	6,950
PDI #02 Decubitus Ulcer	3,284	7	23	79	990
PDI #05 Iatrogenic Pneumothorax	3,602	105	488	1,383	6,233
PDI #08 Postop Hemorrhage or Hematoma	2,537	5	13	31	477
PDI #09 Postop Respiratory Failure	2,530	5	13	30	406
PDI #10 Postop Sepsis	2,388	4	8	21	422
PDI #11 Postop Wound Dehiscence	3,274	6	14	35	266
PDI #12 Selected Infections Due to Medical Care	3,593	67	364	1,130	5,463
Average Reliability Weight					
PDI	**Q1**	**Q2**	**Q3**	**Q4**	**Weighted Average**
PDI #01 Accidental Puncture or Laceration	0.0197	0.0609	0.1495	0.4669	0.5183
PDI #02 Decubitus Ulcer	0.0004	0.0012	0.0043	0.0491	0.1351
PDI #05 Iatrogenic Pneumothorax	0.0042	0.0142	0.0376	0.1780	0.2475
PDI #08 Postop Hemorrhage or Hematoma	0.0013	0.0034	0.0082	0.0960	0.3173
PDI #09 Postop Respiratory Failure	0.0062	0.0162	0.0414	0.3300	0.6454
PDI #10 Postop Sepsis	0.0049	0.0104	0.0294	0.3112	0.6322
PDI #11 Postop Wound Dehiscence	0.0001	0.0001	0.0003	0.0041	0.0108
PDI #12 Selected Infections Due to Medical Care	0.0347	0.1262	0.3213	0.7028	0.7012

Source: HCUP State Inpatient Databases, 2001-2003.

Table 5. Alternative Composite Weights

PDI	Single Indicator Weight	Equal Weight	Numerator Weight	Denominator Weight	Factor Weight
PDI #01 Accidental Puncture or Laceration	0.0000	0.1250	0.1841	**0.3419**	0.0584
PDI #02 Decubitus Ulcer	0.0000	0.1250	0.0753	0.0376	0.1428
PDI #05 Iatrogenic Pneumothorax	0.0000	0.1250	0.0393	0.3087	0.1908
PDI #08 Postop Hemorrhage or Hematoma	0.0000	0.1250	0.0140	0.0139	0.0607
PDI #09 Postop Respiratory Failure	**1.0000**	0.1250	0.0997	0.0120	0.1224
PDI #10 Postop Sepsis	0.0000	0.1250	0.1549	0.0113	0.1608
PDI #11 Postop Wound Dehiscence	0.0000	0.1250	0.0052	0.0110	0.0595
PDI #12 Selected Infections Due to Medical Care	0.0000	0.1250	**0.4274**	0.2636	**0.2046**

Source: HCUP State Inpatient Databases, 2001-2003. For each indicator, the most highly weighted component is in **bold**.

Table 6. Discrimination Performance of Alternative Composites

Composite	Providers	Better Than Average	Average	Worse Than Average
Pediatric Patient Safety for Selected Indicators				
Single Indicator Weight	2,530	0.63%	97.94%	1.42%
Equal Weight	3,586	0.08%	98.88%	1.03%
Numerator Weight	3,593	0.47%	96.63%	2.89%
Denominator Weight	3,595	0.25%	97.86%	1.89%
Factor Weight	3,585	0.06%	98.30%	1.65%

Source: HCUP State Inpatient Databases, 2001-2003.

Table 7. Forecasting Performance of Alternative Composites

PDI	PDI #01	PDI #02	PDI #05	PDI #08	PDI #09	PDI #10	PDI #11	PDI #12
Pediatric Patient Safety for Selected Indicators								
Single Indicator Weight								
Best 20%	0.148*	0.025*	0.142*	-0.043*	**-0.329***	-0.123*	0.005*	-0.018
Worst 20%	-0.100*	-0.003	-0.116*	0.025*	**0.685***	0.016	-0.005*	0.055*
Equal Weight								
Best 20%	-0.251*	-0.013*	-0.097*	-0.024*	-0.078*	-0.045*	-0.002*	-0.291*
Worst 20%	0.235*	0.022*	0.356*	0.065*	0.200*	0.175*	0.001	0.701*
Numerator Weight								
Best 20%	-0.206*	-0.012*	-0.079*	-0.017*	-0.054*	-0.032*	-0.003*	**-0.357***
Worst 20%	0.155*	0.026*	0.294*	0.014*	0.154*	0.163*	-0.004*	**0.820***
Denominator Weight								
Best 20%	**-0.287***	-0.012*	-0.107*	-0.027*	-0.017	-0.002	0.000	-0.272*
Worst 20%	**0.366***	0.020*	0.368*	0.039*	0.043*	0.087*	0.004*	0.652*
Factor Weight								
Best 20%	-0.145*	-0.012*	-0.100*	-0.008	-0.052*	-0.046*	-0.002*	**-0.368***
Worst 20%	0.093*	0.024*	0.387*	0.059*	0.177*	0.176*	-0.001	**0.760***

Source: HCUP State Inpatient Databases, 2001-2003;
*Significant at p<.05. The forecast predicts performance in 2004 based on performance in 2001-2003 (by quintile) using five alternative measure composite weights. For each indicator, the most highly weighted component is in **bold**.

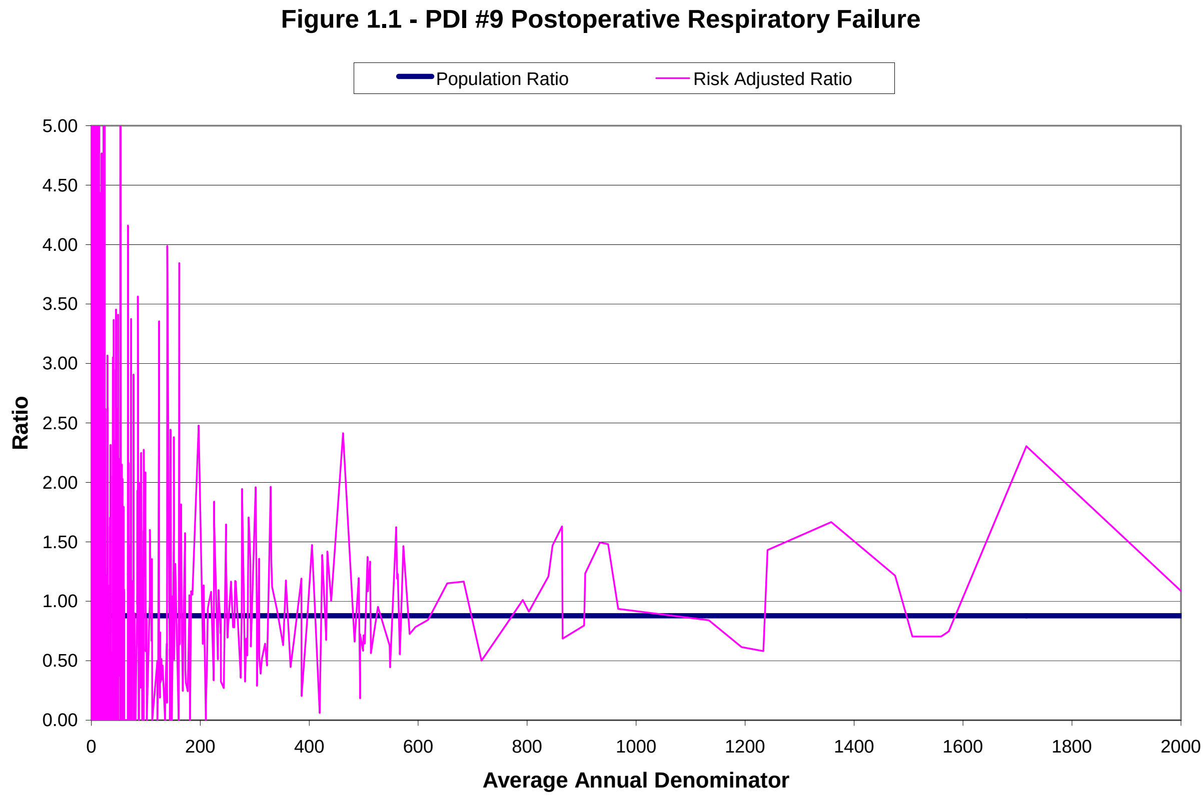
Table 8. Correlation of Alternative Composites

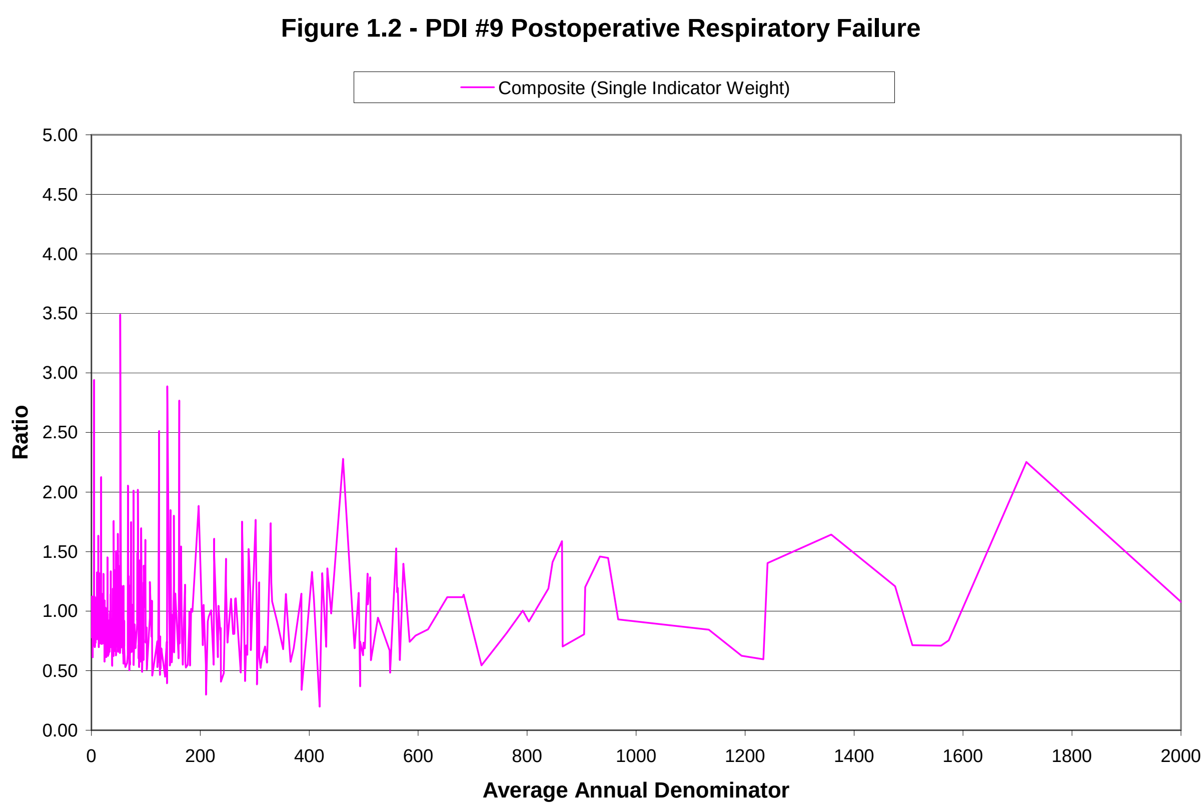
Composite	Single Indicator Weight	Equal Weight	Numerator Weight	Denominator Weight	Factor Weight
Pediatric Patient Safety for Selected Indicators					
Single Indicator Weight	1.000	0.401	0.221	0.040	0.338
Equal Weight		1.000	0.889	0.897	0.952
Numerator Weight			1.000	0.857	0.935
Denominator Weight				1.000	0.854
Factor Weight					1.000

Source: HCUP State Inpatient Databases, 2001-2003.

Appendix C. Composite Figures

1. Single Indicator Composites





2. Precision of Alternative Composites

Figure 2.1 - Pediatric Patient Safety for Selected Indicators, Single Indicator Weight

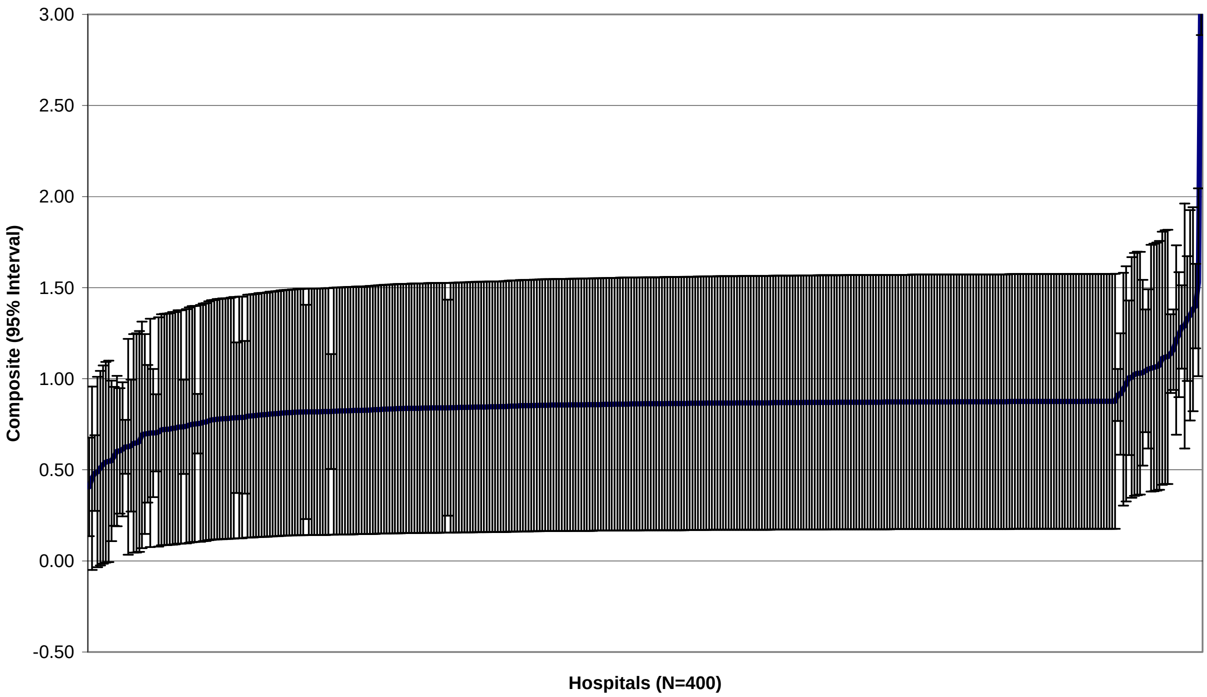


Figure 2.2 - Pediatric Patient Safety for Selected Indicators, Equal Weight

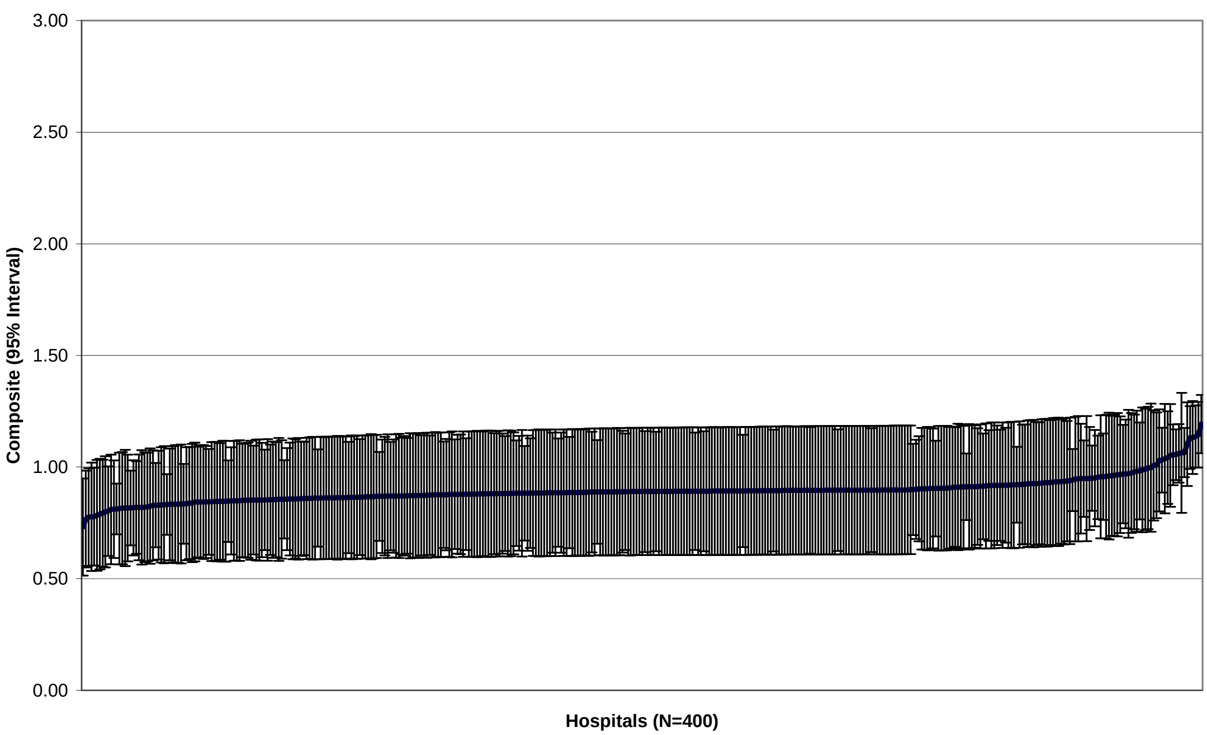


Figure 2.3 - Pediatric Patient Safety for Selected Indicators, Numerator Weight

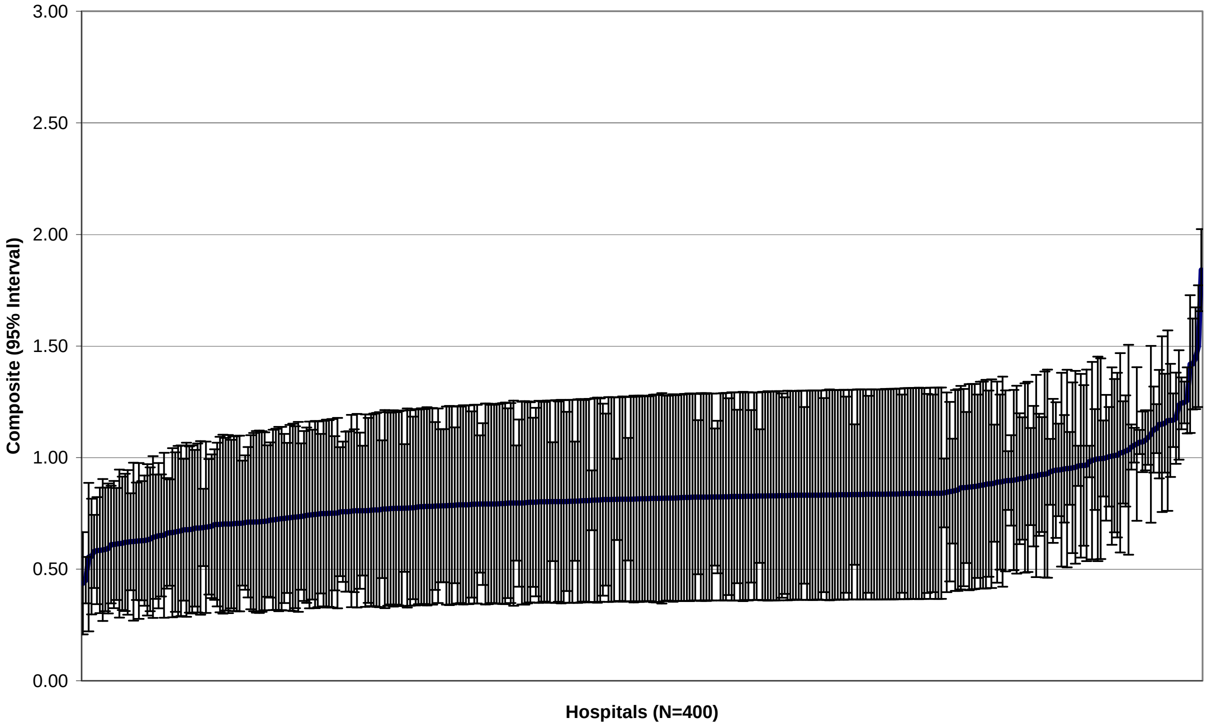


Figure 2.4 - Pediatric Patient Safety for Selected Indicators, Denominator Weight

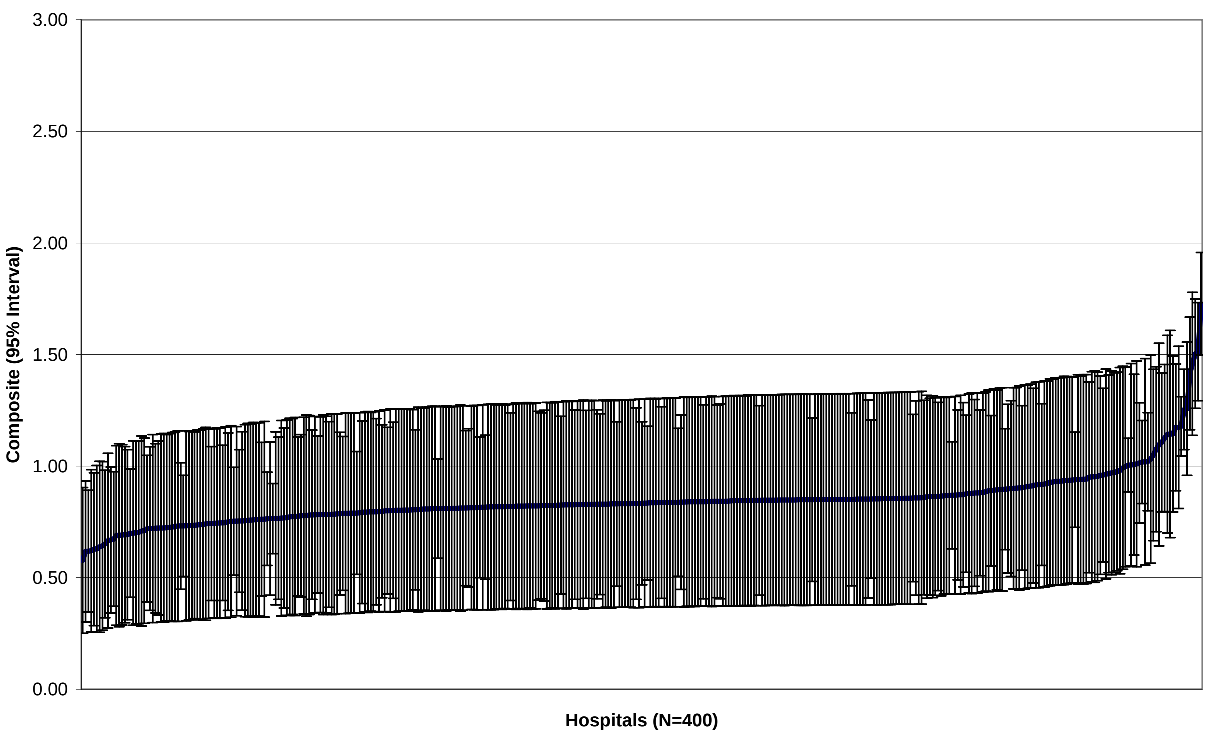
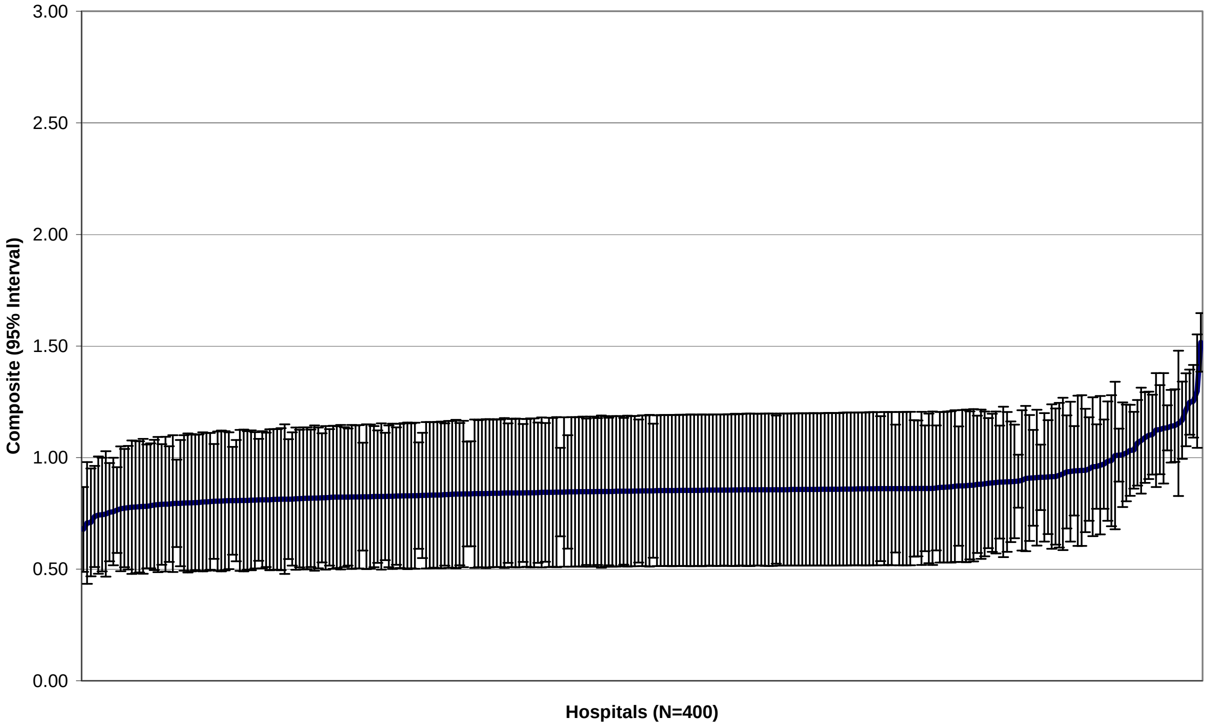


Figure 2.5 - Pediatric Patient Safety for Selected Indicators, Factor Weight



3. Distribution of Alternative Composites

Figure 3.1 - Pediatric Patient Safety for Selected Indicators, Single Indicator Weight

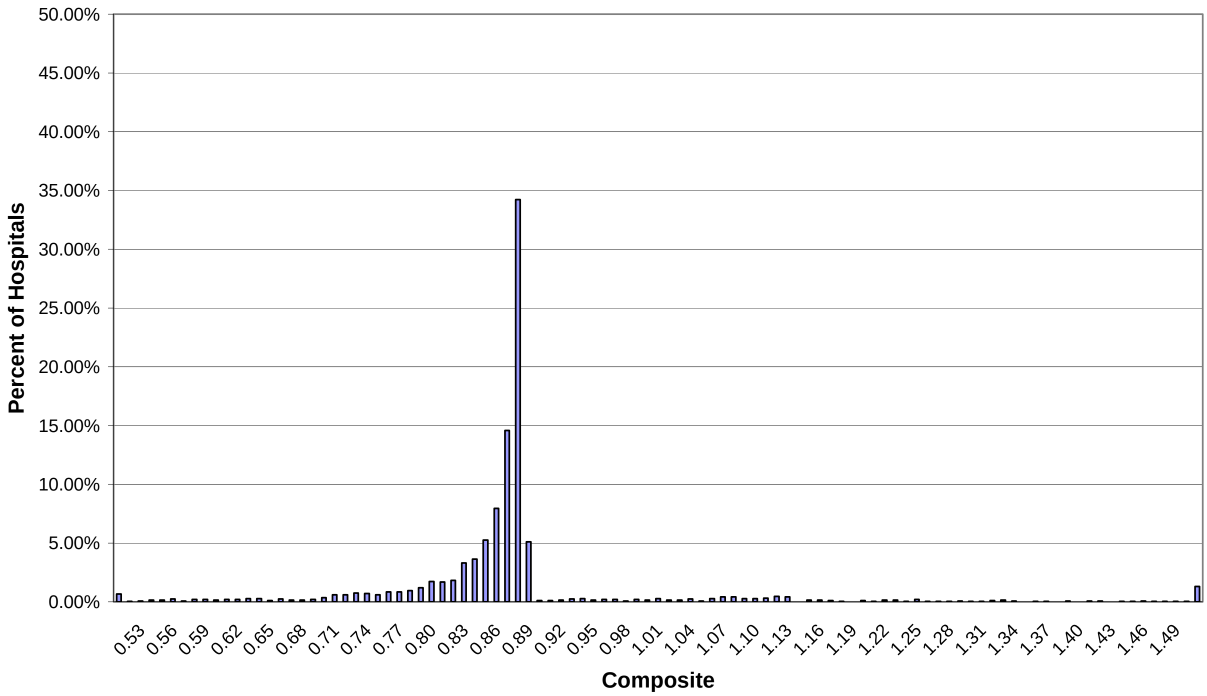


Figure 3.2 - Pediatric Patient Safety for Selected Indicators, Equal Weight

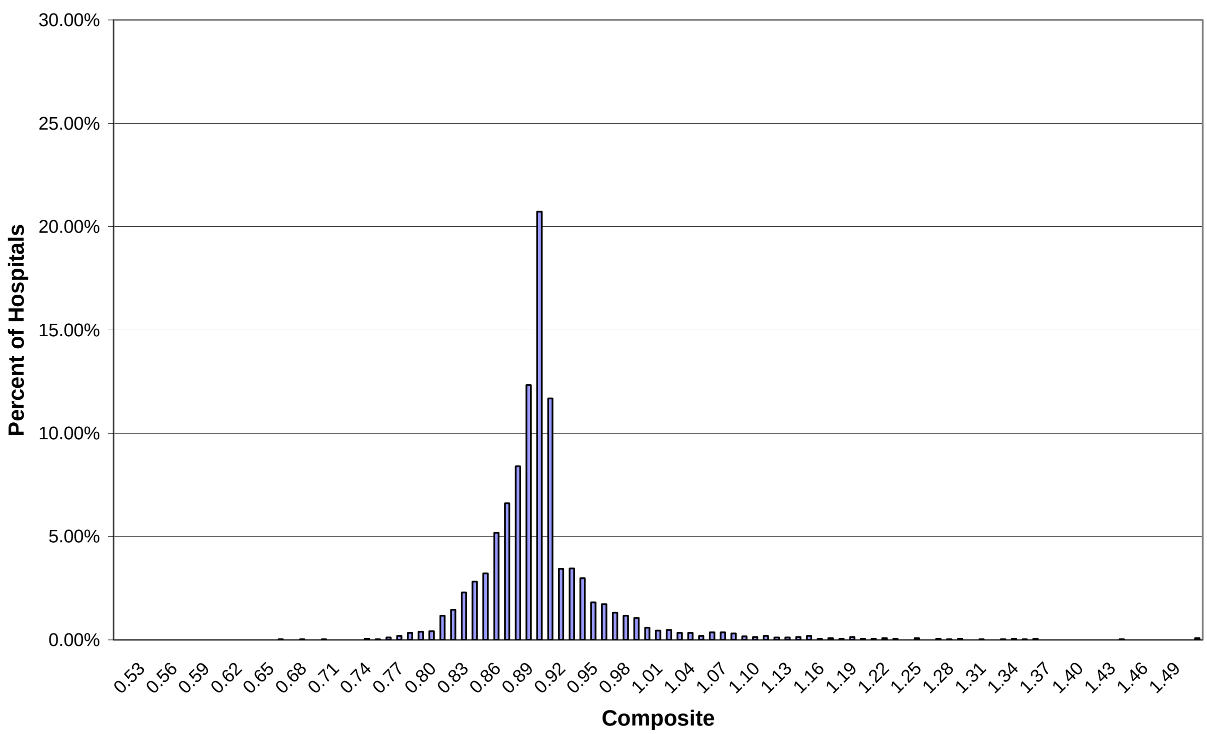


Figure 3.3 - Pediatric Patient Safety for Selected Indicators, Numerator Weight

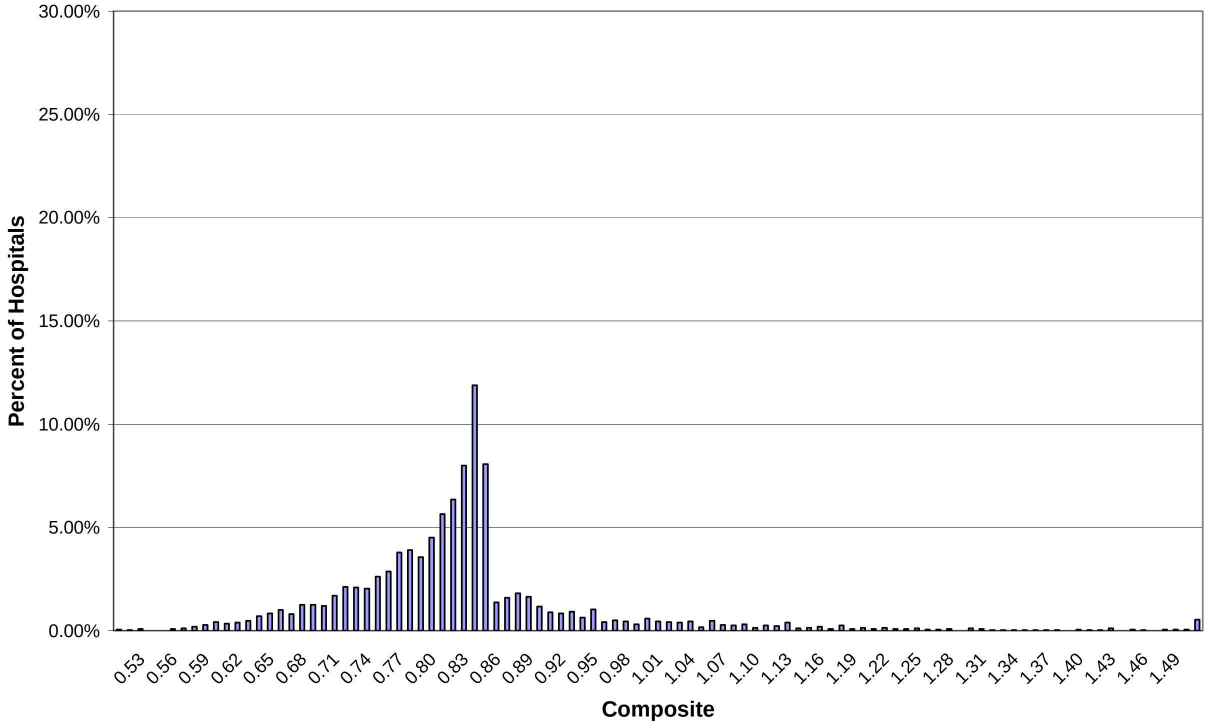


Figure 3.4 - Pediatric Patient Safety for Selected Indicators, Denominator Weight

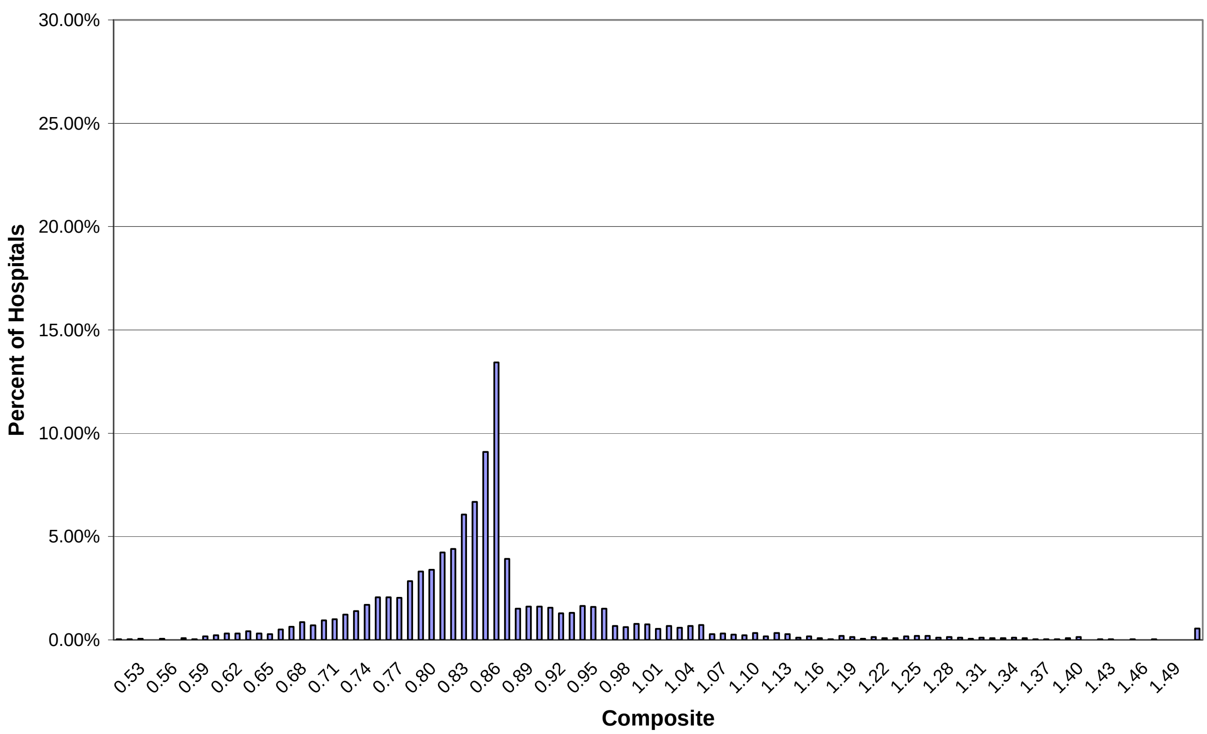
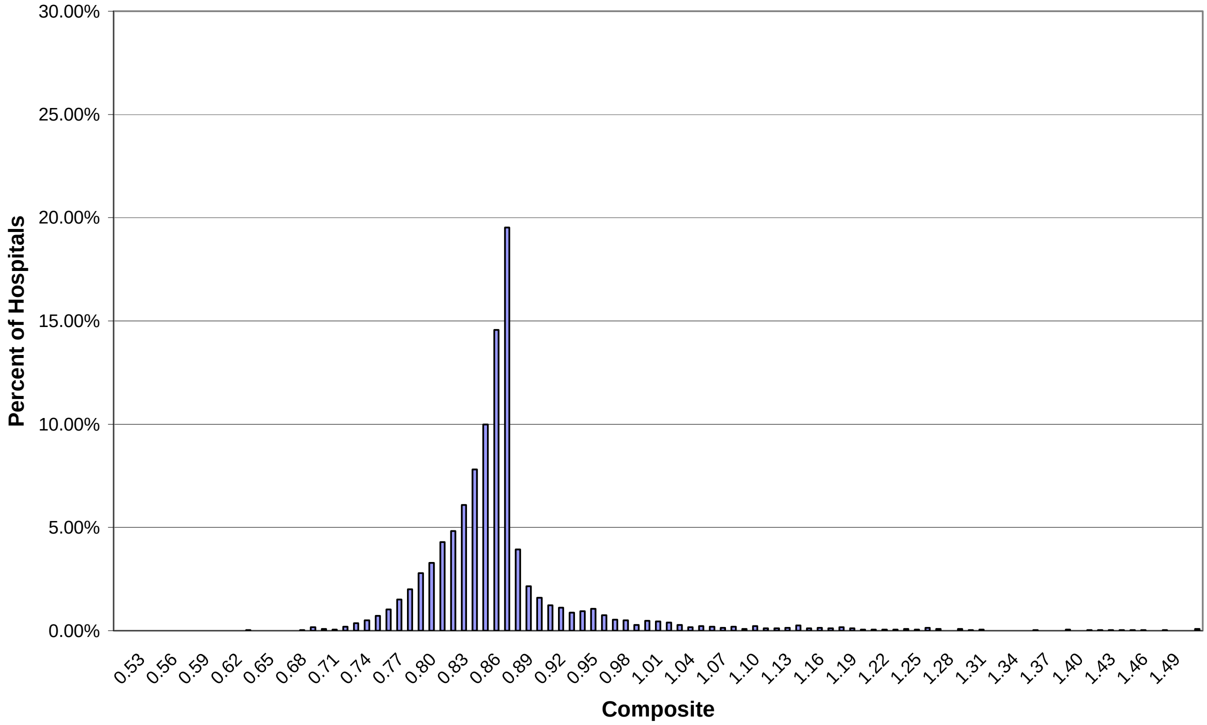


Figure 3.5 - Pediatric Patient Safety for Selected Indicators, Factor Weight



Appendix D. Empirical Methods

Introduction

The AHRQ Quality Indicator risk-adjustment modules begin with estimating a simple logistic model of a 0/1 outcome variable and a set of patient-level covariates as dependent variables, and using the results to form the predicted outcome for each patient (e.g., P=pr(outcome=1)).

Notation

Y_{ij} = 0 or 1, outcome for patient j in hospital i
X_{ij} = covariates (e.g., gender, age, DRG, comorbidity)
P_{ij} = predicted probability from logit of Y on X
= $\exp(X_{ij}\beta)/[1+ \exp(X_{ij}\beta)]$
where β is estimated from logit on entire sample
e_{ij} = $Y_{ij} - P_{ij}$ = logit residual (difference between actual and expected)
N = number of patients in sample at hospital i
α = average outcome in the entire sample* (e.g., Y-bar)

* For the AHRQ QI, the sample is the entire reference population consisting of the discharges in the State Inpatient Databases for the participating States pooled over 3 years (2001-2003). Therefore, the "average outcome for the entire sample" is the population rate.

Computing the Noise Variance

Estimate the risk-adjusted ratio (RAR) and noise variance using the Ratio Method (risk-adjusted rate = (observed rate/expected rate) × population rate) of Indirect Standardization for each hospital:

Estimating RAR

Let $O_i = (1/n_i)\sum(Y_{ij})$ be the observed rate at hospital i
Let $E_i = (1/n_i)\sum(P_{ij})$ be the expected rate at hospital i

RAR_i
= $\alpha(O_i/E_i) = \alpha\ [(1/n_i)\sum(Y_{ij})]/[(1/n_i)\sum(P_{ij})]$ (where sum is for j = 1 to j = n_i)
= population rate × observed/expected at hospital i.

Estimating Variance of RAR (standard error is the square root of the variance)

$Var(RAR_i)$
= $Var[\alpha(O_i/E_i)]$
= $(\alpha/E_i)^2 Var[O_i]$ (since $var(aX) = a^2 var(X)$ for any constant a)
= $(\alpha/E_i)^2 Var[(1/n_i)\sum(Y_{ij})]$ (by the definition of O_i)
= $(\alpha/E_i)^2 (1/n_i)^2 Var[\sum(Y_{ij})]$ (since $var(aX) = a^2 var(X)$ for any constant a)
= $(\alpha/E_i)^2 (1/n_i)^2 [\sum Var(Y_{ij})]$ (since $var(\sum X_i)=\sum var(X_i)$ if X_i is independent)
= $(\alpha/E_i)^2 (1/n_i)^2 \sum [P_{ij}(1-P_{ij})]$ (since Y is 0/1, var(Y) = P(1-P))

Computing the Composite Variance

Setup*

1. Let M be a 1xK vector of observed quality measures (for a given hospital, suppress hospital subscript for convenience), noisy measures of the true underlying 1xK quality vector μ, so that:
   - $M = \mu + \varepsilon$
   - Let the KxK signal variance-covariance be $Var(\mu) = \Omega_{\mu}$
   - Let the KxK noise variance-covariance be $Var(\varepsilon) = \Omega_{\varepsilon}$
2. Let $\hat{\mu}$ (1xK) be the posterior (filtered) estimate of μ, so that:
   - $\mu = \hat{\mu} + \nu$, where the 1xK vector ν represents the prediction error of the posterior estimates, and Var(ν) is the KxK variance-covariance matrix for these posterior estimates.
3. The goal is to estimate the variance for any weighted average of the posterior estimates. For a given (Kx1) weighting vector (w), this is given by:
   - $Var(\nu w) = w' Var(\nu) w$

     Thus, we simply need an estimate of Var(ν).

* For more information on the empirical Bayes estimator method, see the technical appendix in Dimick JB, Staiger DO, Birkmeyer JD. Are mortality rates for different operations related?: Implications for measuring the quality of noncardiac surgery. Med Care 2006 Aug;44(8):774-8; and McClellan MB and Staiger DO. The quality of healthcare providers. Cambridge, MA: National Bureau of Economic Research, 1999. NBER Working Paper #7327. Available at: http://www.nber.org/papers/w7327.

Special Case

Filtered estimates are formed in isolation for each measure (univariate) and the estimation error is assumed not correlated across measures (e.g., each measure is based on a different sample of patients or independent patient outcomes).

1. Forming each measure in isolation, using superscripts to indicate the measure (k=1,…,K) as above, so:

$$\hat{\mu}^k = M^k \hat{\beta}^k = M^k \left[\Omega_{\mu}^{kk} + \Omega_{\varepsilon}^{kk}\right]^{-1} \Omega_{\mu}^{kk}$$

$$Var(\nu^k) = \Omega_{\mu}^{kk} - \Omega_{\mu}^{kk}\left(\Omega_{\mu}^{kk} + \Omega_{\varepsilon}^{kk}\right)^{-1}\Omega_{\mu}^{kk} = \Omega_{\mu}^{kk}\left(1 - \hat{\beta}^k\right)$$

   - Note that in this simple case the filtered estimate is a simple shrinkage estimator and:
     - $\hat{\beta}^k$ is the signal ratio of measure k, is the reliability of the measure, and is the r-squared measuring how much of the variation in the true measure can be explained with the filtered measure.
     - The variance of the filtered estimate is simply the signal variance times 1 minus the signal ratio. Thus, if the signal ratio is 0 (no information in the measure), the error in the estimate is equal to the signal variance. But as the signal ratio grows, the error in the estimate shrinks (to 0 if there is a signal ratio of 1 – no noise).

2. The formula for $Var(\nu^k)$ above provides the diagonal elements of $Var(\nu)$ (the full KxK variance-covariance matrix of the filtered estimates). So, one gets the covariance elements, which are (for j≠k):

$$Cov(\nu^j, \nu^k) = E[(\mu^j - \hat{\mu}^j)(\mu^k - \hat{\mu}^k)]$$

- After some algebra (assuming independent estimation error in the two measures), one gets the following simple expression:

$$Cov(\nu^j, \nu^k) = \Omega_\mu^{jk}(1-\hat{\beta}^j)(1-\hat{\beta}^k)$$

- Note that this is just the signal covariance times 1 minus the signal ratio for each of the measures. Thus, if the signal ratio is 0 for each measure, the covariance in the estimates is simply the signal covariance. As either measure gets a stronger signal ratio (becomes more precise), the covariance in the estimates shrinks to 0.
- Also note that if one measure is missing, then the signal ratio is simply set to 0. The filtered estimate is shrunk all the way back to the (conditional) mean, and the variance and covariance are as defined above.