



Quality Indicator Empirical Methods

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Disclaimer

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Overview

This document describes the empirical methods used to calculate the AHRQ Quality Indicators™ (AHRQ QI). The QI measure health care quality and can be used to highlight potential quality concerns, identify areas that need further study and investigation, and track changes over time. The QIs are calculated using software that is freely available at www.qualityindicators.ahrq.gov

The current AHRQ QI modules represent various aspects of quality:

- Prevention Quality Indicators (PQI) identify hospital admissions in geographic areas that evidence suggests might have been avoided through access to high-quality outpatient care. (first released November, 2000, last updated November, 2014)
- Inpatient Quality Indicators (IQI) reflect quality of care inside hospitals, as well as across geographic areas, including inpatient mortality for medical conditions and surgical procedures. (first released May, 2002, last updated November, 2014)
- Patient Safety Indicators (PSI) reflect quality of care inside hospitals, as well as geographic areas, to focus on potentially avoidable complications and iatrogenic events. (first released March 2003, last updated November, 2014)
- Pediatric Quality Indicators (PDI) use indicators from the other three modules with adaptations for use among children and neonates to reflect quality of care inside hospitals, as well as geographic areas, and identify potentially avoidable hospitalizations. (first released April 2006, last updated November, 2014)

The input data for QI calculation consist of discharge-level administrative records from inpatient hospital stays; this document often refers to them as discharge records. Each indicator can be described as giving results at either the provider-level (i.e., Did the patient experience an adverse quality-related event while in the healthcare provider's facility?) or area-level (Was the inpatient admission for a condition that might have been avoided if the patient's area of the country had more or better preventive or outpatient care?). Some indicators report the number of times a hospital performed a medical procedure of interest. These volume indicators do not have denominators. Most of the AHRQ QI are ratios where the numerator is a count of hospitalizations with the condition or outcome of interest and the denominator is an estimate of the population (or hospitalizations) at risk for that outcome. The QI software calculates several rates:

Observed rate – Conceptually, provider-level rates are the number of discharge records where the patient experienced the QI adverse event divided by the number of discharge records at risk for the event; area-level rates are the number of hospitalizations for the condition of interest divided by the number of persons who live in that area who are at risk for the condition.

1. **Expected rate** – A comparative rate that incorporates information about an external **reference population** that is not part of the user's input dataset – what rate would be observed if the expected level of care observed in the reference population and estimated with risk adjustment regression models, were applied to the mix of patients with demographic and comorbidity distributions observed in the user's dataset? The expected

rate is calculated only for risk-adjusted indicators. [Chapter 4](#) describes the QI reference population.

2. **Risk-adjusted rate** – A comparative rate that also incorporates information about a **reference population** that is not part of the input dataset – what rate would be observed if the level of care observed in the user’s dataset were applied to a mix of patients with demographics and comorbidities distributed like the reference population? Appendix A lists which QIs are risk-adjusted.
3. **Smoothed rate** – A weighted average of the risk-adjusted rate from the user’s input dataset and the rate observed in the **reference population**; the smoothed rate is calculated with a shrinkage estimator to result in a rate near that from the user’s dataset if the provider’s (or area’s) rate is estimated in a stable fashion with minimal noise, or to result in a rate near that of the reference population if the rate from the input dataset is unstable and based on noisy data. In practice, the smoothed rate brings rates toward the mean, and does this more so for outliers (such as rural hospitals).

In data collected beginning October 1, 2007¹, each diagnosis code may be accompanied by a data element that indicates whether the diagnosed condition was **Present-on-Admission (POA)**, and is therefore a pre-existing **comorbidity**, or whether the condition developed during the hospitalization of interest and is therefore a **complication**. Some datasets include POA data, while others do not. Some datasets have POA data for many, but not all of the discharge records. POA is handled in different ways in the QI software depending on a) whether POA data are present in the discharge record and b) whether the user specifies that the software should use the POA data elements when calculating QI rates, or ignore the POA data elements. In prior versions of QI software prior to 5.0, a “prediction module” was used to impute missing POA information. Beginning with version 5.0 the QI software no longer uses the “prediction module” and missing POA information is treated as if the condition is not present on admission. This document begins with a brief description of the dataset that a user must assemble to run the QI software and then it describes the methods associated with various types of indicators. Simpler indicators are described first. Volume indicators are the simplest of the QIs. Area-level indicators are described next, along with their several possible denominators, and the method used to risk-adjust them. Building in complexity, the document describes the calculation of provider-level indicators, where the denominator is tailored to the indicator and the QI may be affected by the POA data element, and how the software accounts for missing POA data. Composite indicators are described next and then the document concludes with a description of the methods used to maintain the QI software – specifically the calculations performed to update the reference population and to update denominator data.

Other Helpful Documents

Readers may wish to access additional QI-related documentation. Helpful examples include:

¹ The Centers for Medicaid and Medicare Services required all hospitals participating in the Inpatient Prospective Payment System to submit POA data beginning October 1, 2007. However, these data were not included in some datasets until later years.

QI Empirical Methods

QI Software Instructions

SAS: See <http://www.qualityindicators.ahrq.gov/software/SAS.aspx>
WinQI: See <http://www.qualityindicators.ahrq.gov/Software/WinQI.aspx>

QI Technical Specifications

PQI: See http://www.qualityindicators.ahrq.gov/Modules/PQI_TechSpec.aspx
IQI: See http://www.qualityindicators.ahrq.gov/Modules/IQI_TechSpec.aspx
PSI: See http://www.qualityindicators.ahrq.gov/Modules/PSI_TechSpec.aspx
PDI: See http://www.qualityindicators.ahrq.gov/Modules/PDI_TechSpec.aspx

QI Risk-adjustment Coefficient Tables

PQI: See http://www.qualityindicators.ahrq.gov/modules/pqi_resources.aspx
IQI: See http://www.qualityindicators.ahrq.gov/modules/iqi_resources.aspx
PSI: See http://www.qualityindicators.ahrq.gov/modules/psi_resources.aspx
PDI: See http://www.qualityindicators.ahrq.gov/modules/pdi_resources.aspx

QI Population Documentation File

See <http://www.qualityindicators.ahrq.gov/software/SAS.aspx>

Healthcare Cost and Utilization Project (HCUP) State Inpatient Database (SID) Documentation
(to better understand the source of the reference population)

See <http://www.hcup-us.ahrq.gov/db/state/siddbdocumentation.jsp>

Chapter 1. The User's Dataset

An AHRQ QI software user should prepare the input dataset according to the software instructions.

Table 1.1 Required Data Elements

Data Element	Label	PQI	IQI	PSI	PDI
AGE	Age in years at admission	X	X	X	X
AGEDAY	Age in days (when age < 1 year)				X
ASCHED	Admission scheduled vs. unscheduled			X	X
ASOURCE	Admission source (uniform)	X	X	X	X
ATYPE	Admission type			X	X
DISPUNIFORM	Disposition of patient (uniform)		X	X	X
DQTR	Discharge quarter	X	X	X	X
DRG	DRG in effect on discharge date	X	X	X	X
DRGVER	DRG grouper version used on discharge date	X	X	X	X
DSHOSPID	Data source hospital identifier		X	X	X
DX1-DX30	Diagnosis	X	X	X	X
DXPOA1-DXPOA30	Diagnosis present on admission indicator		X	X	X
E_POA1-E_POA10	E code present on admission indicator		X	X	X
ECODE1-ECODE10	E code		X	X	X
HOSPST	Hospital state postal code		X	X	X
KEY	HCUP record identifier	X	X	X	X
LOS	Length of stay (cleaned)		X	X	X
MDC	MDC in effect on discharge date	X	X	X	X
PAY1	Primary expected payer (uniform)		X	X	X
PAY2	Secondary expected payer (uniform)		X	X	X
POINTOFORIGINUB04	Point of origin for admission or visit, UB-04 standard coding	X	X	X	X
PR1-PR30	Procedure	X	X	X	X
PRDAY1-PRDAY30	Number of days from admission			X	X
PSTCO	Patient state/county FIPS code	X	X	X	X
PSTCO2	Patient state/county FIPS code, possibly derived from ZIP Code	X	X	X	X
RACE	Race (uniform)	X	X	X	X
SEX	Sex	X	X	X	
YEAR	Calendar year	X	X	X	X

Note: The AHRQ QI software deletes discharge records with missing values for SEX.

In preparing a dataset for analysis, data elements and data values shown in the right side of Table 1.2 are constructed from the discharge data elements.

Table 1.2 Data Elements and Data Values to Be Constructed by the User

DISCHARGE DATA (e.g., SID)		AHRQ QI	
Data Element	Data Value	Data Element	Data Value
FEMALE	0 – Male 1 – Female	SEX	1 – Male 2 – Female
ATYPE, ASCHEd and AGEDAY	IF ATYPE = Missing AND ASCHEd = 1 (Scheduled admission) AND AGEDAY ~ = 0	ATYPE	3- Elective
ECODE1-ECODE10	As reported	DX31-DX40	As reported
E_POA1-E_POA10	As reported	DXPOA31-DXPOA40	As reported

Discharge records in the dataset are analyzed as either adult or pediatric data based on age and Major Diagnostic Category (MDC) (Table 1.3). Discharges in MDC 14 (Pregnancy, Childbirth & the Puerperium) are assigned to the adult analysis data regardless of age.

Table 1.3 Analysis Data Inclusion Rule

Analysis data	Inclusion Rule
Adult	AGE greater than or equal to 18 or MDC equal to 14
Pediatric	AGE less than 18 and MDC not equal to 14

Adult analysis data are used to calculate Prevention Quality Indicators (PQI), Inpatient Quality Indicators (IQI), and Patient Safety Indicators (PSI). Pediatric records are used to calculate Pediatric Quality Indicators (PDI), Neonatal Quality Indicators (NQI) and indicators from other modules defined on pediatric discharges (i.e., PQI 09 Low Birth Weight Rate, PSI 17 Birth Trauma Rate – Injury to Neonate).

Chapter 2. Calculating Volume and Count Indicators

Table 2.1 lists the seven **volume indicators** for inpatient procedures for which there is evidence that a higher volume of procedures conducted by a provider is associated with lower mortality. The volume indicators are measured as counts of hospitalizations in which particular procedures were performed.

Table 2.1 AHRQ QI Volume Indicators

Name
IQI 01 – Esophageal Resection Volume*
IQI 02 – Pancreatic Resection Volume*
IQI 04 – Abdominal Aortic Aneurysm (AAA) Repair Volume*
IQI 05 – Coronary Artery Bypass Graft (CABG) Volume
IQI 06 – Percutaneous Coronary Intervention (PCI) Volume
IQI 07 – Carotid Endarterectomy Volume
PDI 07 – RACHS-1 Pediatric Heart Surgery Volume

*IQI 1, IQI 2 and IQI 4 are intended to be reported with IQI 8 IQI 9 and IQI 11, respectively.

Table 2.2 lists the four **count indicators** for serious reportable events.

Table 2.2 AHRQ QI Count Indicators

Name
PSI 15 – Retained Surgical Item or Unretrieved Device Fragment Count
PSI 16 – Transfusion Reaction Count
PDI 03 – Retained Surgical Item or Unretrieved Device Fragment Count
PDI 13 – Transfusion Reaction Count

Discharge Level Indicator Data Element (T)

The phrases **numerator** and **denominator** appear throughout the QI documentation. There are no denominators for volume or count indicators. The quantity of interest at the provider level is the magnitude of the number of times the procedure or the event occurs, and that number is not normalized by or divided by any denominator. The technical specifications do, however, use the phrase “numerator” to define the procedure of interest. Discharge records are flagged for inclusion or exclusion from the numerator of each volume QI based on the data elements, data values, and logic described in the technical specifications for each indicator.

For each discharge record, a binary flag variable is calculated by the software for each volume or count QI. In this document, we denote the discharge level indicator data element with the letter T. Each discharge record has a T variable for each QI, so in the software the data elements have longer names to clarify which QI they describe. (e.g., the variable for IQI 01 is called TPIQ01.)

Numerator

Discharges are flagged for inclusion in the numerator of each volume QI according to the specification for the **procedure of interest** (for volume indicators) or **outcome of interest** (for count indicators). Discharges flagged for inclusion in the numerator are assigned a value of “1” for T.

Exclusions

The specifications often stipulate that records should be excluded from calculation of a volume indicator if the record is missing an important data element. Discharges are also excluded from the numerator of a volume QI if the procedure of interest has more than one component, and the discharge is not in the population at risk for one component but remains in the population at risk for another component. These discharges are assigned a value of “0” for T.

The Observed Value

The observed provider-level value of a volume or count indicator is simply the sum of T over all records for that provider in the dataset.

Chapter 3. Calculating Area-Level Indicators – Observed Rates

Area-level indicators identify hospital admissions that evidence suggests might have been avoided through access to high-quality outpatient or preventive care. The numerator is a count of admissions for the condition of interest. The denominator is an estimate of the number of persons at risk for such a hospitalization. The denominator is usually a population estimate from a U.S. Census Bureau dataset.

Table 3.1 lists the area level indicators.

Table 3.1 AHRQ QI Area-Level Indicators

Name
IQI 26 – Coronary Artery Bypass Graft (CABG) Rate
IQI 27 – Percutaneous Coronary Intervention (PCI) Rate
IQI 28 – Hysterectomy Rate
IQI 29 – Laminectomy or Spinal Fusion Rate
PDI 14 – Asthma Admission Rate
PDI 15 – Diabetes Short-Term Complications Admission Rate
PDI 16 – Gastroenteritis Admission Rate
PDI 17 – Perforated Appendix Admission Rate
PDI 18 – Urinary Tract Infection Admission Rate
PQI 01 – Diabetes Short-Term Complications Admission Rate
PQI 02 – Perforated Appendix Admission Rate
PQI 03 – Diabetes Long-Term Complications Admission Rate
PQI 05 – Chronic Obstructive Pulmonary Disease (COPD) or
PQI 07 – Hypertension Admission Rate
PQI 08 – Heart Failure Admission Rate
PQI 09 – Low Birth Weight Rate
PQI 10 – Dehydration Admission Rate
PQI 11 – Bacterial Pneumonia Admission Rate
PQI 12 – Urinary Tract Infection Admission Rate
PQI 13 – Angina Without Procedure Admission Rate
PQI 14 – Uncontrolled Diabetes Admission Rate
PQI 15 – Asthma in Younger Adults Admission Rate
PQI 16 – Lower-Extremity Amputation Among Patients With Diabetes Rate

The software provides the user with the option of producing output by metropolitan area or by county. The term **metropolitan area (MA)** was adopted by the U.S. Census in 1990 and referred collectively to metropolitan statistical areas (MSAs), consolidated metropolitan statistical areas (CMSAs), and primary metropolitan statistical areas (PMSAs). In addition, “area” could refer to either 1) FIPS county, 2) modified FIPS county, 3) 1999 OMB Metropolitan Statistical Area, or 4) 2003 OMB Metropolitan Statistical Area. As an aside, Micropolitan Statistical Areas are not used in the QI software.

For information about how the denominators are calculated from Census data, see the QI Population Documentation File at <http://www.qualityindicators.ahrq.gov/software/SAS.aspx>.

For diabetes-related area measures, the QI software user has an option of calculating rates where the denominator is an estimate of the number of persons living in the state who have diabetes. For information on how those **condition-specific denominators** are estimated, see [Chapter 3](#). The diabetes indicators are PQI 01 Diabetes Short-Term Complications Admission Rate, PQI 03 Diabetes Long-Term Complications Admission Rate, PQI 14 Uncontrolled Diabetes Admission Rate, and PQI 16 Lower-Extremity Amputation among Patients with Diabetes Rate. [Chapter 12](#) describes how the diabetes denominators are estimated.

Future versions of the QI software may include other condition-specific denominator options.

Discharge Level Indicator Data Element (T)

Numerator

Discharges are flagged for inclusion in the numerator of each area-level QI according to the specification for the condition of interest. Discharges flagged for inclusion in the numerator are assigned a value of “1” for T.

Exclusions

Generally, discharges may be flagged for exclusion from the numerator of an area-level AHRQ QI for one (or more) of several reasons.

1. The outcome of interest is very difficult to prevent, and therefore not an indication of substandard care.
2. The patient was transferred from another health care facility.
3. Some exclusion criteria are included for the purpose of enhancing face validity with clinicians.
4. Some exclusion criteria are an inherent part of the QI definition.

Discharge records that meet one or more of the exclusion criteria in the QI technical specification are assigned a value of “missing (.)” for T.

The Observed Rate

The observed rate of an area-level indicator is simply the sum of T over all records for that area of the country divided by the Census population estimate for the area (adult population for adult measures and child population for pediatric measures). For condition-specific indicators, if the

user requests it, the denominator is the estimated count of persons living in that area of the country who are living with the condition of interest.

Area Rates Stratified by Quarter of the Year

The WinQI software has an option to stratify area-level rates by quarter of the year in which they occurred. When the user selects that option, the rate reported for each quarter is the number of admissions for the condition of interest that occurred during that quarter, divided by the Census population for the area divided by four. The four quarterly rates sum to the annual rate.

Chapter 4. Risk Adjustment for Area-Level Indicators

In order to make meaningful comparisons of the area-level rate for one area with that of another area, it is helpful to account statistically for differences in demographics between areas. To do so for most QIs, the software calculates a risk-adjusted rate which answers the question: What QI rate would we expect to observe in a particular area of the country if the persons living there shared the same demographic profile of a reference population? In statistical language, the risk-adjustment controls for demographic differences via logistic regression.

For area rates, the risk-adjustment models adjust for age-group proportions by gender, and optionally for poverty. That is to say that the models include age (in 5 year groups), gender, and if it is statistically significant, the model includes the interaction between age and gender.

When comparing outcomes from different areas, there may be several reasons for differences in risk-adjusted rates. Some of the most important reasons may be related to the availability of quality preventive and outpatient care, and other reasons may contribute as well, but after risk-adjustment, the differences should not be attributable to differences in the age and gender profiles in the areas.

The AHRQ QI Reference Population

To accomplish risk adjustment, in annual updates of the QI software a **reference population** is analyzed that consists of all HCUP SID data that are available for the year most recently released by AHRQ at the time the QI software is updated. For example when version 5.0 of the QI software was updated in January of 2013 for the May 2013 software release, SID data were available from 2010 from 44 states, so those records serve as the reference population for AHRQ QI software version 5.0.

For area-level indicators, the reference population plays two important roles:

1. The **reference population rate** for each QI is calculated and included in the software to serve as a comparative standard for areas of the country. One can analyze data to determine which areas have higher or lower rates than the overall reference population. The reference population rates are published on the AHRQ QI website in documents named Benchmark Tables (formerly known as Comparative Data Tables). See the [links](#) in the Overview chapter of this document.
2. The **risk adjustment models** are re-estimated on the new reference population dataset in an annual process that is described in [Chapter 11](#) of this document. The models are distributed within the QI software, and they facilitate the calculation of risk-adjusted rates. The risk adjustment model covariates and regression coefficients are published on the AHRQ website. See the [links](#) in the Overview chapter of this document.

Chapter 5. Calculating Area-Level Indicators – Expected, Risk-Adjusted, & Smoothed Rates

In addition to observed rates, three other sets of QI rates are calculated for risk-adjusted area-level indicators.

The Expected Rate

The **expected rate** for an area-level QI is the rate that would be observed if the amount and quality of outpatient and preventive care available across the reference population were available to persons living in this specific area. It is predicted for each area using risk-adjustment model coefficients and covariates that summarize the age and gender distribution of the area's population.

The Risk-Adjusted Rate

The AHRQ QI use indirect standardization to calculate the risk-adjusted rate. The risk-adjusted rate equals the reference population rate multiplied by the ratio of observed rate divided by expected rate.

$$\text{Risk Adjusted Rate} = \text{Reference Population Rate} \times (\text{Observed Rate} / \text{Expected Rate})$$

Note that for the reference population, the observed rate equals the expected rate equals the reference population rate equals the risk-adjusted rate.

The software estimates the standard error of the risk adjusted rate for each area using a method recommended by Iezzoni and described by Hosmer and Lemeshow (1995) that represents the amount of within provider or area variance due to sampling (i.e. as the number of patients per provider or persons per area increases this variance tends to zero). This standard error is used to calculate lower and upper bound 95% confidence intervals around the risk adjusted rate as [risk adjusted rate +/- 1.96 * risk adjusted rate SE] (stored in a data element with a “L” and “U” prefix). (See [Chapter 9](#) section entitled: Computing the Risk-Adjusted Rate Variance. See also http://qualityindicators.ahrq.gov/Downloads/Resources/Publications/2011/Calculating_Confidence_Intervals_for_the_AHRQ_QI.pdf).

The Smoothed Rate

Each area's **smoothed rate** is a weighted average of the risk-adjusted rate and the reference population rate; the smoothed rate is calculated with an empirical Bayes shrinkage estimator to result in a rate near that from the input dataset if the area's rate is estimated in a stable fashion with minimal noise, or to result in a rate near that of the reference population if the rate from the area is unstable and based on noisy data. Thus, the smoothed rate for a hospital with stable estimates will be similar to the hospital's risk adjusted rate, while the smoothed rate for a hospital with unstable estimates will be more similar to the reference population rate.

The formula for the smoothed rate is:

$$\text{Smoothed Rate} = (\text{Risk adjusted Rate} \times \text{Shrinkage Weight}) + \text{Reference Population Rate} * (1 - \text{Shrinkage Weight})$$

where

$$\text{Shrinkage Weight} = \frac{\text{Signal Variance}}{\text{Signal Variance} + \text{Noise Variance}}$$

The noise variance is an estimate of variability in the QI outcome within the area of interest (county), and the signal variance is an estimate of variability across all areas.

$$\begin{aligned} \text{Noise Variance } \hat{\sigma}_a^2 &= \left(\frac{\bar{Y}}{n_a E_a} \right)^2 \sum_{i \in A_a} \hat{Y}_i (1 - \hat{Y}_i) \\ \text{Signal Variance } \tau^2 &= \frac{\sum_{a=1}^A \frac{1}{(\tau^2 + \sigma_a^2)^2} \{ (RAR_a - \bar{RAR})^2 - \hat{\sigma}_a^2 \}}{\sum_{a=1}^A \frac{1}{(\tau^2 + \sigma_a^2)^2}} \end{aligned}$$

where A is the number of areas with persons at risk for the measure, \bar{Y} is the observed rate for the reference population; \hat{Y}_i is the person-level predicted probability for area i ; and for area a , A_a is the collection of persons in the population at risk, n_a is the number of persons, E_a is the expected rate, and RAR_a is the risk-adjusted rate. Note that $\hat{\tau}^2$ appears on both sides of the signal variance equation; it is estimated in an iterative fashion (Morris, 1983).

For purposes of confidence interval estimation, the *smoothed rate* is assumed to follow a Gamma distribution $G(shape, scale)$ where

$$shape = \frac{(\text{Smoothed Rate})^2}{\text{Posterior Variance}}$$

$$scale = \frac{\text{Posterior Variance}}{\text{Smoothed Rate}}$$

$$\text{Posterior Variance} = \text{Signal Variance} - (\text{Shrinkage Weight} * \text{Signal Variance})$$

When there is a fixed comparative rate of interest, it is possible to parameterize the smoothed rate posterior probability based on the Gamma distribution and calculate the probability that the smoothed area rate falls below or above the comparative rate that is of interest.

Chapter 6. Overview of Provider-Level QI & Present-on-Admission (POA)

Provider-level indicators address questions like: Did the patient experience an adverse quality-related event while in the care of a specific healthcare provider? Or did the patient have an inpatient procedure for which there are questions of overuse, underuse, or misuse?

Adverse-event indicators are for medical conditions and procedures that have been shown to have complication/adverse event rates that vary substantially across institutions and for which evidence suggests that high rates may be associated with deficiencies in the quality of care. They usually include only those cases where a secondary diagnosis code flags a potentially preventable complication. A few indicators are based on procedure codes that imply a potential preventable adverse event.

Mortality indicators are for medical conditions and surgical procedures that have been shown to have mortality rates that vary substantially across institutions and for which evidence suggests that high mortality may be associated with deficiencies in the quality of care.

Utilization indicators track procedures where there are questions of overuse, underuse, or misuse. The usage of the procedures being examined varies significantly across hospitals and areas, and high or low rates by themselves do not represent poor quality of care; rather the information is intended to inform consumers about local practice patterns.

Provider-level indicators are measured as rates—number of hospitalizations with the outcome (or procedure) of interest divided by the population at risk for the outcome (or procedure). Recall that area-level indicators each use the same denominator for each area – the Census-derived estimate of the count of persons who live in the area. Provider-level indicators are more complicated because they have **indicator-specific denominators**, to identify only the hospitalizations that were at risk for the outcome of interest.

Recall that area-level indicators all use similar risk-adjustment coefficients: age-groups by gender. But the risk-adjustment models for provider-level measures are more complicated. Each risk-adjusted provider-level indicator uses a customized list of regression covariates that are selected when the QI software is updated annually using methods described in [Chapter 11](#).

Present-on-Admission (POA) status is a third factor that makes provider-level indicators more complex than volume or area-level indicators. Current AHRQ QIs that use POA are listed in [Appendix A](#). Some of the indicators look for adverse conditions that develop as **medical complications** during the hospitalization of interest. Evidence suggests that high rates may be associated with lower quality of care. Think, for instance, of pressure ulcers, which are measured with PSI 03. However, some of these complications may have been present on admission, which would not be related to the quality of inpatient care. The AHRQ QI software uses three methods to distinguish between **complications**, which develop during the hospitalization and should be counted in the QI numerator, and **comorbidities**, which are present on admission and should exclude the discharge record from the QI calculation, because the patient is not at risk for the event. Table 6.1 summarizes those methods, and they are described in more detail in the following

chapters.

Table 6.1 Methods Used by QI Software to Distinguish Complications from Comorbidities

Method	Description	Can the QI User Turn This Off?
1. The POA-Related Exclusion Method (See Chapter 7.)	Some QIs use data elements other than DX_POA to infer that the condition is more likely than not to be POA. Those records are excluded from the population at risk.	No. The WinQI software does not allow modifications to the exclusion criteria. However, the SAS software can be altered by the User, noting that the User should document any modifications to the program.
2. DX_POA Data Element (See Chapter 8.)	If the diagnosis is flagged as POA using the DX_POA data element, then the record is excluded from the population of interest.	Yes. The user can specify %LET USEPOA = 0; in the CONTROL.SAS program or un-check the WinQI box entitled “Use POA in rate calculation”, either of which will cause the software to ignore DX_POA data that are present in the dataset. Every potential complication will be flagged as an adverse event, and if it does not meet any of the exclusion criteria, it will contribute to the QI numerator. For the purposes of risk-adjustment, a set of coefficients will be employed that were estimated ignoring POA; all complications will be treated as comorbidities.

POA Data Element - Background Information

Present-on -Admission was added as a data element to the uniform bill form (UB-04) effective October 1, 2007, and hospitals incurred a payment penalty for not including POA on Medicare records beginning October 1, 2008. Each of the several diagnoses in a discharge record can be flagged as “present at the time the order for inpatient admission occurs”² or not. This is accomplished with data element DX_POAi which uses a one-character text code to characterize the POA status of the diagnosis in DXi. Conditions that develop during an outpatient encounter, including treatment in an emergency department, are considered as present on admission. Most states have adopted POA in the discharge data submitted by hospitals to either the state department of health or the state hospital association.

² <http://www.cdc.gov/nchs/data/icd9/icdguide10.pdf>.

Table 6.2 lists the possible character values of the POA data elements (Y,N,U,W,E, or missing) along with corresponding numeric values (0 or 1) used in the AHRQ QI software. Additional information about the coding guidelines for POA can be found at: www.cdc.gov/nchs/data/icd/icd9cm_guidelines_2011.pdf. Again, current AHRQ QI that use POA are listed in [Appendix A](#).

Table 6.2 Values for the Present-on-Admission Data Element

ICD-9-CM Guidelines	Description	AHRQ QI POA Data Element	Description
Y - Yes	Diagnosis is present at the time of inpatient admission	1	Diagnosis present at admission
N – No	Diagnosis is not present at the time of inpatient admission	0	Diagnosis not present at admission
U - Unknown	Documentation is insufficient to determine if condition is present on admission	0	Diagnosis not present at admission
W – Clinically undetermined	Provider is unable to clinically determine whether condition was present on admission or not	1	Diagnosis present at admission
E - Unreported/Not used; Also includes UB-04 values previously coded as "1"	Reported as exempt from reporting on a non-exempt diagnosis.	0	Diagnosis not present at admission

Source: http://www.cms.hhs.gov/HospitalAcqCond/05_Coding.asp#TopOfPage; http://www.hcup-us.ahrq.gov/db/vars/siddistnote.jsp?var=e_poan.

An individual discharge record might include 20 or more diagnoses. For purposes of the AHRQ QI, the principal diagnosis is always assumed to be present on admission by definition, regardless of the coding of the POA data element in the principal field. Secondary diagnosis codes are first checked to see if the diagnosis is exempt from reporting POA or not. If the secondary diagnosis is exempt, it is considered present on admission. If the secondary diagnosis is not exempt, then it is considered present on admission if the POA data element is coded with a Y or W. Secondary diagnosis codes are considered not present on admission if the POA data element is coded with a N, U, Blank, E, 1, or X. The AHRQ QI software assumes that POA information is present and accurately coded.

Chapter 7. Calculating Provider-Level Observed Rates – Ignoring POA

Provider-level QI calculations are simplest when POA is ignored altogether, so those calculations are described first. Later chapters describe what happens when POA data are present and accounted for, and how the calculations are performed when POA data are missing but modeled. The AHRQ QI software user may ignore the influence of DX_POA data, either present or missing, by specifying “%LET USEPOA = 0;” in the CONTROL.SAS file or by un-checking the WinQI box entitled “Use POA in rate calculation”.

When ignoring POA, the main difference between area-level indicators and provider-level indicators is the way the denominator is calculated.

Discharge Level Indicator Data Element (T)

Each provider-level observed QI rate consists of a conceptually simple fraction where the denominator is the count of discharge records at risk and the numerator is the count of the records with the outcome of interest. This fraction is calculated using a single discharge level indicator data element, T, described in earlier chapters for volume and area-level indicators. In those earlier chapters, the T variable took on the value “1” if the discharge record met the definition for the numerator that is spelled out in the technical specifications. For volume and area-level indicators it does not matter whether the T variable takes the value “0” or “missing (.)” for other records, because the numerator is simply the count of records where T=1.

Provider-Level Denominator

Discharges are flagged for inclusion in the denominator of each AHRQ QI according to the specification for the population at risk. Discharges flagged for inclusion in the denominator are assigned a value of “0” for T unless the discharge also experienced the outcome of interest in which case the value of “1” is assigned. Discharges that experienced the outcome of interest are in the population at risk by definition.

Denominator Exclusions

Generally, discharges may be flagged for exclusion from the denominator of an AHRQ QI for one (or more) of several reasons.

1. The outcome of interest is more likely than not to be present on admission and conditions that are POA should not “count” as an adverse event.
2. The outcome of interest is very difficult to prevent, and therefore not an indication of substandard care.
3. The exclusion identifies populations who are at very low risk for the adverse event and who are excluded to keep from diluting the QI denominator.

4. Some exclusion criteria are included for the purpose of enhancing face validity with clinicians (e.g., exclude patients from being at risk of a pressure ulcer (PSI 03) if they have not been hospitalized for at least 5 days).
5. Some exclusion criteria are an inherent part of the QI definition (e.g., exclude persons from being at risk for a post-operative hip fracture if the hip repair is the only surgical procedure during the hospitalization).

Discharge records that meet one or more of the denominator exclusion criteria in the QI technical specification are assigned a value of “missing (.)” for T.

Three Values of T

To summarize:

- A “1” in the T variable means that the record was in the population at risk, experienced the outcome of interest, and was not excluded for any reason.
- A “0” in the T variable means the record was in the population at risk, did not experience the outcome of interest, and was not excluded for any reason.
- A “missing (.)” value for the T variable means that the record was not in the population of interest, either because it did not meet the denominator definition, or because it met one or more of the exclusion criteria.

The Observed Rate

For provider-level indicators, the observed rate is simply the arithmetic mean of the T variable over all of the provider’s discharge records.

Consequence of Ignoring POA Data

When POA data are ignored, the observed rate calculation will include records where the outcome of interest was indeed present on admission, and so will inflate the numerator, the denominator, and the observed rate, compared with an **unknown but true underlying rate** that excludes records from population at interest when the outcome was truly POA.

Chapter 8. Calculating Provider-Level Observed Rates – With POA Data

Consideration of POA should improve the accuracy of QI rate calculation because pre-existing comorbidities can be distinguished from complications that develop during the hospital stay of interest. Records with outcomes that were POA will no longer appear erroneously in the numerator, denominator, or observed rate, and the risk adjustment models will no longer erroneously treat complications as comorbidities, thus yielding improvement in the comparative expected, risk-adjusted, and smoothed rates above and beyond that in the numerator, denominator, and observed rates.

The degree of improvement attained when accounting for POA will vary depending on the number of records where the outcomes were POA, and with the accuracy of POA coding. This document does not address the topic of POA accuracy. The QI software treats eligible values in the DX_POA data elements as if they were completely accurate. Values that are ineligible or missing are treated as if they were coded as “not present on admission”. In other words missing or ineligible values lead to a condition being treated as a complication.

Discharge Level POA Exclusion Data Element (Q)

When accounting for POA, the QI software codes the discharge level indicator data element, T, in the same manner described in [Chapter 7](#), using technical specifications to define which records are included in the denominator, numerator, and which should be excluded for one or more reasons. The meaning and possible values of T are described in [Chapter 7](#).

A second, POA-related binary flag is calculated, also. The **discharge level POA exclusion data element** is abbreviated with the letter Q.³ Put simply, Q records whether the outcome of interest was present on admission or not. The outcome of interest is considered present on admission (Q is assigned “1”) if any of the diagnosis codes that define the outcome of interest are coded as present on admission. Otherwise a value of “0” is assigned to Q. For every record that includes POA data in the SID DX_POA data elements, Q will have a value of “0” or “1” and will not be “missing (.)”.

The Observed Rate

Before calculating the observed rate, Q is used to correct the value of T if the condition of interest was POA. If the value of Q is “1” (outcome was POA) then the record is removed from the population at risk by setting T to “missing (.)”. The observed rate is simply the arithmetic mean of the T variable after this correction. Note that if POA had been ignored, as in [Chapter 7](#), every

³ The letter P was not available, having been used already for the notion of population at risk. In this document the variables are denoted simply as T and Q, but each discharge record has a binary T variable and a binary Q variable for each QI, so the variables have longer names to clarify which QI they describe. (e.g., The variables for PSI 08 are called TPPS08 and QPPS08.)

record removed from the population at risk by the Q variable would have appeared as a “1” in both the numerator and the denominator. So accounting for POA data yields lower observed rates than when the POA data are ignored. The magnitude of the difference between the rate estimated when POA are ignored and when POA are incorporated will depend on the proportion of records that are flagged as POA that do not meet any of the other indicator exclusion criterion. The accuracy of the difference between the rate estimated when POA are ignored and the rate estimated when POA are incorporated (via the Q flag) depends both on the magnitude of the difference, and the accuracy of the POA coding.

Chapter 9. Risk Adjustment for Provider-Level Indicators

This chapter describes risk-adjustment for provider-level QIs. Provider-level indicators are risk-adjusted in a manner similar to that described in Chapters [4](#) and [5](#) for area-level indicators. One important difference is that the list of covariates for provider-level indicators differs from indicator to indicator more than those for the area-level indicators. The next section describes the types of data elements that are considered as potential risk-adjusters.

Where possible, the logistic regression models use a generalized estimating equations (GEE) approach to account for correlation at the provider level. When GEE models do not converge during the annual AHRQ QI software update, then multivariable logistic regression models are employed that do not account for that correlation. See [Chapter 11](#) for more details.

Risk-adjustment Covariates

Each risk-adjusted QI (listed in [Appendix A](#)) has a set of covariates that have been identified as useful covariates in a logistic regression risk-adjustment model. [Chapter 11](#) describes the variable selection process.

For the PSIs, covariates indicate whether the discharge record meets the technical specification for gender, age, modified Diagnosis-Related Group (MDRG) and at least one of twenty-five (25) co-morbidities that are used as covariates in the risk-adjustment model.

For the IQIs, covariates indicate whether the discharge record meets the technical specification for gender, age, All Patient Refined Diagnosis Related Groups (APR-DRG) and risk-of-mortality subclass (minor, moderate, major, extreme) that are used as covariates in the risk-adjustment model.

For the PDIs, covariates indicate whether the discharge record meets the technical specification for birth weight, age in days, age in years, modified Diagnosis-Related Group (MDRG), at least one of forty-six (46) clinical classification software (CCS) co-morbidities and some indicator-specific risk categories that are used as covariates in the risk-adjustment model.

Risk Adjustment Parameters CSV File

Each risk-adjusted provider-level indicator has its risk adjustment parameter estimates stored in a comma separated values (.csv) file that accompanies the QI software.

The Expected Rate

Using the risk adjustment parameters, each eligible discharge (i.e. one that is included in the denominator of the indicator) is scored for its expected (or predicted) rate using PROC SCORE.

This output score is simply the sum across all covariates in the risk adjustment model of the scalar multiplication of the presence or absence of a covariate (one or zero) times the value of the coefficient from the risk adjustment model for that covariate. This score is the logit of the predicted value (denoted MHAT in the software). The predicted probability for the discharge is computed as:

$$\text{EHAT} = \exp(\text{MHAT}) / (1 + \exp(\text{MHAT}))$$

The discharge-level predicted probabilities are used to compute an expected rate for the indicator by:

$$\text{Expected Rate} = \frac{\text{Sum of the predicted rates for each discharge}}{\text{Count of discharges in the population at risk}}$$

The Risk-Adjusted Rate

The AHRQ QI use indirect standardization to calculate the risk-adjusted rate.

$$\text{Risk adjusted Rate} = \text{Reference Population} \times (\text{Observed Rate} / \text{Expected Rate})$$

Note that for the reference population, the observed rate, the expected rate, the reference population rate, and the risk-adjusted rate are equivalent.

The software estimates the standard error of the risk adjusted rate for each provider or area using a method recommended by Iezzoni and described by Hosmer and Lemeshow that represents the amount of within provider or area variance due to sampling (i.e. as the number of patients per provider or persons per area increases this variance tends to zero). This standard error is used to calculate lower and upper bound 95% confidence intervals around the risk adjusted rate as [risk adjusted rate +/- 1.96 * risk adjusted rate SE] (stored in a data element with a “L” and “U” prefix). (See the note below entitled: Computing the Risk-Adjusted Rate Variance. See also http://qualityindicators.ahrq.gov/Downloads/Resources/Publications/2011/Calculating_Confidence_Intervals_for_the_AHRQ_QI.pdf).

The Smoothed Rate

The formula for the smoothed rate is:

$$\begin{aligned} \text{Smoothed Rate} = & (\text{Risk Adjusted Rate} \times \text{Shrinkage Weight}) \\ & + \text{Reference Population Rate} \times (1 - \text{Shrinkage Weight}) \end{aligned}$$

where

$$\text{Shrinkage Weight} = \frac{\text{Signal Variance}}{\text{Signal Variance} + \text{Noise Variance}}$$

The noise variance is calculated for each hospital based on the user’s data. The signal variance is a

parameter calculated from the reference population. Beginning in Version 4.3, there are two signal variance estimates: one using POA and one ignoring POA data.

$$\begin{aligned} \text{Noise Variance } \hat{\sigma}_h^2 &= \left(\frac{\bar{Y}}{n_h E_h} \right)^2 \sum_{i \in A_h} \hat{Y}_i (1 - \hat{Y}_i) \\ \text{Signal Variance } \hat{\tau}^2 &= \frac{\sum_{h=1}^H \frac{1}{(\hat{\tau}^2 + \sigma_h^2)^2} \{ (RAR_h - \overline{RAR})^2 - \hat{\sigma}_h^2 \}}{\sum_{h=1}^H \frac{1}{(\hat{\tau}^2 + \sigma_h^2)^2}} \end{aligned}$$

where H is the number of hospitals with patients at risk for the QI, \bar{Y} is the observed rate for all discharges in the reference population; \hat{Y}_i is the patient-level predicted probability; and for hospital h , A_h is the collection of patients, n_h is the number of patients, E_h is the expected rate, and RAR_h is the risk-adjusted rate. Note that $\hat{\tau}^2$ appears on both sides of the signal variance equation; it is estimated in an iterative fashion (Morris, 1983).

For purposes of confidence interval estimation, the smoothed rate is assumed to follow a Gamma distribution $G(shape, scale)$ where

$$\begin{aligned} shape &= \frac{(\text{Smoothed Rate})^2}{\text{Posterior Variance}} \\ scale &= \frac{\text{Posterior Variance}}{\text{Smoothed Rate}} \end{aligned}$$

$$\text{Posterior Variance} = \text{Signal Variance} - (\text{Shrinkage Weight} * \text{Signal Variance})$$

When there is a fixed comparative rate of interest, it is possible to parameterize the smoothed rate posterior probability based on the Gamma distribution and calculate the probability that the smoothed area rate falls below or above the comparative rate that is of interest.

Computing the Risk-Adjusted Rate Variance

Let

- Y_i be the observed (0, 1) outcome for patient i
- E_i be the expected (predicted) rate;
- n_h be the number of discharges at hospital h ; and
- α be the reference population rate (average outcome in the entire sample).

We define the observed rate at hospital h as

$$O_h = \frac{1}{n_h} \sum_{i=1}^{n_h} Y_i$$

the expected rate at hospital h as

$$E_h = \frac{1}{n_h} \sum_{i=1}^{n_h} E_i$$

and the Risk Adjusted Rate

$$RAR_h = \alpha \times \frac{O_h}{E_h}$$

Using a Taylor expansion for the formula for the variance of the ratio of two stochastic variables R, S (delta method)

$$Var\left(\frac{R}{S}\right) \cong \frac{E[R]^2}{E[S]^2} \left(\frac{Var(R)}{E[R]^2} - 2 \frac{Cov(R, S)}{E[R]E[S]} + \frac{Var(S)}{E[S]^2} \right)$$

We compute the variance on the risk-adjusted rate

$$Var(RAR_h) \cong \alpha^2 \frac{E[O_h]^2}{E_h^2} \left(\frac{Var(O_h)}{E[O_h]^2} - 2 \frac{Cov(O_h, E_h)}{E[O_h]E_h} + \frac{Var(E_h)}{E_h^2} \right)$$

It is common practice in these calculations to neglect the variance of the predictor E_h (Hosmer & Lemeshow, 1995) and to consider a normal distribution for the Risk Adjusted Rate (only true in the limit $n_h \rightarrow \infty$). In this case the above formula simplifies to

$$Var(RAR_h) \cong \alpha^2 \frac{Var(O_h)}{E_h^2}$$

and the 95% confidence intervals are calculated assuming normality. However, arguments to support using non-approximate equations (see Luft & Brown, 1993 for an example) for the RAR confidence intervals (in particular when n_h is small) may be considered in future releases of the AHRQ QI software.

Computing the Smoothed Rate Variance

The detailed formula for calculating the probability interval around the smoothed rate is described in [Chapter 10](#) on composite measures. Calculation of the smoothed rate is a step in the process of computing the composite measures. However, the basic formula is:

$$\text{Smoothed Rate} = (\text{Risk Adjusted Rate} \times \text{Shrinkage Weight})$$

$$+ \text{Reference Population Rate} \times (1 - \text{Shrinkage Weight})$$

$$\text{Shrinkage Weight} = \frac{\text{Signal Variance}}{\text{Signal Variance} + \text{Noise Variance}}$$

$$\text{Posterior Variance} = \text{Signal Variance} - (\text{Shrinkage Weight} \times \text{Signal Variance})$$

The *smoothed rate* follows a Gamma distribution $G(shape, scale)$ where

$$shape = \frac{(Smoothed\ Rate)^2}{Posterior\ Variance}$$

$$scale = \frac{Posterior\ Variance}{Smoothed\ Rate}$$

When there is a fixed comparative rate of interest, it is possible to parameterize the posterior probability based on the Gamma distribution and calculate the probability that the smoothed area rate falls below or above the comparative rate that is of interest.

Chapter 10. Estimating Composite Measures

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 as described below. 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 non-empirical considerations.

Composite Value

The basic steps for computing the composite are as follows:

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

The AHRQ QI risk-adjusted rate and confidence interval are computed as described above.

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

The levels of the rates vary from indicator to indicator. To combine the component indicators using a common scale, each indicator’s risk-adjusted rate is first 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 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).

$$\begin{aligned} & \text{Reliability Adjusted Ratio (risk – adjusted ratio} \times \text{weight)} \\ & + \text{reference population ratio} \times (1 - \text{weight}) \end{aligned}$$

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. The AHRQ QI software user has the ability to modify these weights in the software, either in the SAS code, or in the WinQI user interface. Options for weights include:

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.

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., $1/11 = 0.0909$).

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 degree 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 an 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 for each composite are based on a principal components factor analysis of the reliability-adjusted ratios.

Note: The IQI composites (IQI 90 and 91) use denominator weights and the PSI and PDI composites (PSI 90 and PDI 19) use numerator weights.

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.

$$\begin{aligned} \text{Composite} = & (\text{indicator}_1 \text{RAR} \times \text{weight}_1) \\ & + (\text{indicator}_2 \text{RAR} \times \text{weight}_2) + \cdots + (\text{indicator}_N \text{RAR} \times \text{weight}_N) \end{aligned}$$

Composite Variance

The probability interval of the composite measure is based on its standard error, which is the square root of the variance. The variance is computed based on the signal variance-covariance matrix and the reliability weights.

Let M be a $1 \times K$ vector of observed quality measures (for a given hospital, suppress hospital subscript for convenience), noisy measures of the true underlying $1 \times K$ quality vector μ , such that:

$$M = \mu + \epsilon \quad (11.1)$$

where ϵ is a $1 \times K$ noise vector with zero mean and $K \times K$ variance-covariance matrix $\text{Var}(\epsilon) =$

Ω_ϵ . Let the $K \times K$ signal variance-covariance be $\text{Var}(\mu) = \Omega_\mu$.

Let $\hat{\mu}$ a $1 \times K$ vector indicating the posterior (filtered) estimate of μ , such that:

$$\hat{\mu} = \mu + v \quad (11.2)$$

where v is a $1 \times K$ vector with zero mean and $K \times K$ variance-covariance matrix $\text{Var}(v)$ representing the prediction error of the posterior estimates.

The goal is to estimate the variance for any weighted average of the posterior estimates. For a given $1 \times K$ weighting vector w , this is given by:

$$\text{Var}(vw) = w' \text{Var}(v) w$$

where w' indicates the transpose of w .

Thus, we need an estimate of $\text{Var}(v)$. We simplify the calculation by assuming that the 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).

Forming each measure in isolation, using superscripts $k = 1, \dots, K$ to indicate the measure, we have:

$$\begin{aligned} \hat{u}^k &= M^k \hat{\beta}^k = M^k (\Omega_\mu^{kk} + \Omega_\epsilon^{kk})^{-1} \Omega_\mu^{kk} \\ \text{Var}(v^k) &= \Omega_\mu^{kk} (1 - \hat{\beta}^k) = \Omega_\mu^{kk} - \Omega_\mu^{kk} (\Omega_\mu^{kk} + \Omega_\epsilon^{kk})^{-1} \Omega_\mu^{kk} \end{aligned}$$

where

$$\hat{\beta}^k = (\Omega_\mu^{kk} + \Omega_\epsilon^{kk})^{-1} \Omega_\mu^{kk}$$

is the signal ratio of measure k , the reliability of the measure, and is the r-squared which measures how much of the variation in the true measure can be explained with the filtered measure. Note that in this simplified case the filtered estimate is a univariate shrinkage estimator. For the non-diagonal elements of the covariance matrix (for $j \neq k$):

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

assuming independent estimation error in the two measures, one gets the following simplified expression (see supplemental notes below for the derivation):

$$\text{Cov}(v^j, v^k) = \Omega_\mu^{jk} [(1 - \hat{\beta}^j)(1 - \hat{\beta}^k)]$$

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.

The standard error on the composite is the square root of the variance, which is then used to compute the 95% probability interval.

The composite value to follows a Gamma distribution $G(\text{shape}, \text{scale})$ where

$$\text{shape} = \frac{(\text{Composite Value})^2}{\text{Posterior Variance}}$$
$$\text{scale} = \frac{\text{Posterior Variance}}{\text{Composite Value}}$$

A 95% probability interval can be calculated using the inverse CDF of the gamma distribution as

$$\text{lowerbound} = \text{inv_cdf_gamma}(0.025, \text{shape}, \text{scale})$$

$$\text{lowerbound} = \text{inv_cdf_gamma}(0.975, \text{shape}, \text{scale})$$

Supplemental Notes:

To derive formula (11.6), we substitute

$$\hat{\mu} = M\hat{\beta} = (\mu + \epsilon)\hat{\beta}$$

into (11.5) and obtain (for $j \neq k$)

$$\begin{aligned} Cov(v^j, v^k) &= E[(\mu^j - (\mu^j + \epsilon^j)\hat{\beta}^j)(\mu^k - (\mu^k + \epsilon^k)\hat{\beta}^k)] = \\ &= E[(\mu^j(1 - \hat{\beta}^j) - \epsilon^j\hat{\beta}^j)(\mu^k(1 - \hat{\beta}^k) - \epsilon^k\hat{\beta}^k)] = \\ &= E[\mu^j\mu^k(1 - \hat{\beta}^j)(1 - \hat{\beta}^k) + \mu^k\epsilon^j(1 - \hat{\beta}^k)\hat{\beta}^j + \mu^j\epsilon^k(1 - \hat{\beta}^j)\hat{\beta}^k + \epsilon^j\epsilon^k\hat{\beta}^j\hat{\beta}^k] = \\ &= E[\mu^j\mu^k](1 - \hat{\beta}^j)(1 - \hat{\beta}^k) + E[\mu^k\epsilon^j](1 - \hat{\beta}^k)\hat{\beta}^j + E[\mu^j\epsilon^k](1 - \hat{\beta}^j)\hat{\beta}^k + E[\epsilon^j\epsilon^k]\hat{\beta}^j\hat{\beta}^k \end{aligned}$$

Assuming $E[\mu^j\mu^k] = E[\epsilon^j\mu^k] = E[\epsilon^j\epsilon^k] = 0$ and $E[\mu] = 0$, we have

$$\begin{aligned} Cov(v^j, v^k) &= E[\mu^j\mu^k](1 - \hat{\beta}^j)(1 - \hat{\beta}^k) = \\ &= Cov(\mu^j, \mu^k)(1 - \hat{\beta}^j)(1 - \hat{\beta}^k) - E[\mu^j]E[\mu^k](1 - \hat{\beta}^j)(1 - \hat{\beta}^k) = \\ &= Cov(\mu^j, \mu^k)(1 - \hat{\beta}^j)(1 - \hat{\beta}^k). \end{aligned}$$

QED.

Chapter 11. Software Maintenance – Updating the Reference Population

In order to maintain the scientific acceptability of the AHRQ QI, the indicators are updated annually to reflect the Uniform Bill (UB-04) coding updates effective each year on July 1st, and the International Classification of Diseases- Ninth Revision- Clinical Modification (ICD-9-CM) and Medicare Severity Diagnosis-related Group (MS-DRG) coding updates effective each fiscal year on October 1st of the prior year. In addition, the annual updates include new Census data on the population of counties and new Healthcare Cost and Utilization Project (HCUP) data for the reference population and risk-adjustment covariate coefficients. This chapter describes the methods employed to update the QI reference population and the associated risk-adjustment covariate coefficients.

For the version 5.0 release (May, 2015), the AHRQ QI program used the Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases (SID) for 2012 to compute reference population data. HCUP is a family of health care databases and related software tools and products developed through a Federal-State-Industry partnership and sponsored by the Agency for Healthcare Research and Quality (AHRQ). HCUP databases bring together the data collection efforts of State data organizations, hospital associations, private data organizations, and the Federal government to create a national information resource of encounter-level health care data. HCUP includes the largest collection of longitudinal hospital care data in the United States, with all-payer, encounter-level information beginning in 1988. These databases enable research on a broad range of health policy issues, including cost and quality of health services, medical practice patterns, access to health care programs, and outcomes of treatments at the national, State, and local market levels. The HCUP SID encompass about 97 percent of all annual inpatient discharges in the United States.

The reference population file was limited to community hospitals, excluding rehabilitation and long-term acute care hospitals. Information on the type of hospital was obtained by the American Hospital Association (AHA) Annual Survey of Hospitals. AHA defines community hospitals as "all non-Federal, short-term, general, and other specialty hospitals, excluding hospital units of institutions." Included among community hospitals are specialty hospitals such as obstetrics-gynecology, ear-nose-throat, orthopedic, and pediatric institutions. Also included are public hospitals and academic medical centers.

The 2012 HCUP State Inpatient Databases (SID) includes information on all inpatient discharges from hospitals in 45 participating States (excluding Mississippi and New Hampshire). In 2012, 36 of the SID include indicators of the diagnoses being present on admission (POA) and included the PRDAY data element. Edit checks on POA were developed during a HCUP task that examined POA coding in the 2011 SID at hospitals that were required to report POA to CMS. The edits identify general patterns of suspect reporting of POA. The edits do not evaluate whether a valid POA value (e.g., Y or N) is appropriate for the specific diagnosis. There are three hospital-level edit checks:

1. Indication that a hospital has POA reported as Y on all diagnoses on all discharges
2. Indication that a hospital has POA reported as missing on all non-Medicare discharges

3. Indication that a hospital reported POA as missing on all nonexempt diagnoses for 15 percent or more of discharges. The cut-point of 15 percent was determined by 2 times the standard deviation plus the mean of the percentage for hospitals required to report POA to CMS.

There are several important steps in the annual update process upstream from risk-adjustment and rate estimation. Changes may be made to QI technical specifications for one reason or another. Those must be implemented in the software. ICD-9 (and soon ICD-10) code sets may be modified. Those need to be updated in the software as well. The software is designed to be backward compatible, applying the appropriate sets of codes to older datasets. This work is accomplished before risk-adjustment models are calculated. Those steps are described briefly in [Appendix C](#).

Estimating risk-adjustment models and calculating QI rates in the reference population involves running the QI software on the reference population dataset.

Assemble the Reference Population Dataset

The user should prepare the input dataset according to the software instructions.

- SID data from all available states are appended together and processed in the manner described in [Chapter 1](#).
- The APR-DRG grouper is run on the adult dataset for the purpose of calculating IQIs. The grouper is run once considering all secondary diagnoses to be POA, and run a second time with POA diagnoses removed. This difference captures the fact that when POA is ignored, complications are treated like comorbidities for risk adjustment, and the risk of mortality is probably overstated compared to the risk if the patient were classified using only the conditions that were truly present on admission.
- Beginning with version 5.0, sex not assumed to be male if the value is missing. In versions of the QI software before 5.0, missing values of SEX are set to “0” (Male) so they will not be dropped by the QI software.
- Beginning in Version 4.3, discharges from non-community hospitals are deleted from the adult and pediatric analysis data. Community hospitals, as defined by American Hospital Association (AHA), include "all nonfederal, short-term, general and other specialty hospitals, excluding hospital units of institutions." Included among community hospitals are academic medical centers and specialty hospitals such as obstetrics, gynecology, ear nose throat, short-term rehabilitation, orthopedic, and pediatric hospitals. Non- community hospitals include federal hospitals (Veterans Administration, Department of Defense, and Indian Health Service hospitals), long-term hospitals, psychiatric hospitals, alcohol/chemical dependency treatment facilities and hospitals units within institutions such as prisons. (See http://hcup-us.ahrq.gov/db/state/siddist/siddist_hospital.jsp#2008).
- No other edits are applied to the State Inpatient Databases (SID).

Calculate Discharge Level Flags

The discharge level T and Q flags are calculated as described in Chapters 3-8.

Estimate Risk-adjustment Models

There are several steps involved in estimating the QI risk-adjustment models.

1. Construct candidate covariates
2. Select model covariates
3. Estimate the models
4. Evaluate the models

Construct Candidate Covariates for Risk-adjustment

Models for version 5.0 of the software were unchanged from version 4.5(a).

For the PSIs, potential risk-adjustment covariates indicate whether the discharge record meets the technical specification for gender, age, modified Diagnosis-Related Group (MDRG) and at least one of twenty-five (25) co-morbidities that are used as covariates in the risk-adjustment model.

For the IQIs, potential risk-adjustment covariates indicate whether the discharge record meets the technical specification for gender, age, All Patient Refined Diagnosis Related Groups (APR- DRG) and risk-of-mortality subclass (minor, moderate, major, extreme) that are used as covariates in the risk-adjustment model.

For the PDIs, potential risk-adjustment covariates indicate whether the discharge record meets the technical specification for birth weight, age in days, age in years, modified Diagnosis-Related Group (MDRG), at least one of forty-six (46) clinical classification software (CCS) co- morbidities and some indicator-specific risk categories that are used as covariates in the risk- adjustment model.

For the PQIs, potential risk-adjustment indicate whether the discharge record meets the technical specification for gender, age in 5-year groups and poverty category that are used as covariates in the risk-adjustment model.

Covariates are coded for each discharge record based on the data elements, data values, and logic described in the technical specifications and the appendices of the risk-adjustment coefficient tables. For a given covariate, if the discharge meets the technical specification for that covariate a value of “1” is assigned to the discharge level covariate data element. Otherwise a value of “0” is assigned to the discharge level covariate data element. For discharge records with POA data, the software creates a second set of data elements (i.e., the **Z** data elements used in the modeling described in [Appendix C](#)) that do not consider secondary diagnosis codes that are not present on admission when assigning comorbidity or risk-of-mortality flags.

Select Model Covariates

For the provider level indicators, each module has a standard set of covariates grouped into four categories: demographics, severity of illness, comorbidities and other (see [Appendix B](#)). The standard set is tailored to each indicator to create a parsimonious set of covariates for each indicator. Based on cross tabulations between each covariate and the outcome of interest, only those covariates with at least 30 cases with the outcome of interest are retained. For categories that

are mutually exclusive, covariates with fewer than 30 cases are pooled into the next covariate along the risk gradient. For example, age 70 to 74 is combined with age 65 to 69, or risk of mortality subclass 3 is combined with subclass 2. For categories with no risk gradient, covariates are pooled into broader covariates. For example, MS-DRGs are pooled into MDCs.

The omitted covariate within mutually exclusive categories is the reference group for those categories. Reference categories are usually 1) the most common and/or 2) the least risk. The choice of omitted reference category does affect how one might use the model coefficients or odds ratios in an English language sentence, but it does not affect predicted probabilities or model performance.

Once the preliminary multivariable model is specified, it is estimated on the adult or pediatric analytic data, as appropriate. Only those covariates that are statistically significant ($p < .05$) are retained. For covariates that are not statistically significant in categories that are mutually exclusive, the pooling process described above is repeated until a complete, parsimonious model is specified.

For the area level indicators, the models use the complete set of covariates for gender, age in 5-year age groups, an interaction with gender * age. There is also an optional set of covariates for poverty category based on the county of patient residence.

The final multivariable model parameters are published on the AHRQ website in Risk Adjustment Coefficient Tables. (See [links](#) in the Overview chapter.)

Estimate the Models

When possible, provider-level models are estimated using generalized estimating equations (GEE) to account for within-hospital correlation. These models are run with PROC GENMOC and use a logit link with an exchangeable covariance matrix. If the GEE model does not converge then a more logistic regression model is fit (i.e. PROC LOGISTIC) that ignores that extra correlation. Whether the model is a GEE or not may be inferred by the final column in the .CSV file for the QI. Area-level indicators use logistic models. Each provider-level module includes a sas program named like *QI50_MakeVars_PSI.sas* (e.g. for the PSI module in version 5.0) that contains a set of macros to construct the covariate set for the risk adjustment model. These covariates are passed as list of variables with the names XCV1 – XCV n , with the set of variables changing from indicator to indicator.

Calculate Rates

After the new risk-adjustment models are fit, PROC SCORE is run on the data to calculate expected values so that observed rates may be calculated for the reference population. Reference population rates and signal variances are calculated both ignoring POA altogether and with POA as recorded. These rates are stored in .TXT files that are part of the SAS AHRQ QI software package. The rates and variances are entered directly into WinQI program code, and do not appear as separate files in the WinQI package. Updating the risk-adjustment .CSV files and the population rate and signal variance .TXT files are a substantial milestone in the annual update process.

Update Software

In addition to the aforementioned .CSV and .TXT files, the AHRQ QI software must be updated to generate and combine the correct set of covariate variables for each risk adjusted QI. These covariates are generated in the so-called ~SAS3.SAS programs, and whenever the list of covariates in a risk-adjustment model changes, that code must be changed accordingly. Note that it is possible to fit new risk-adjustment model coefficients without updating the list of covariates. In that case, the ~SAS3.SAS program may need very little revision, if any.

Evaluate Models

Two desirable qualities of risk-adjustment models are that they discriminate well between discharge records that experience the outcome of interest and those that do not, and that they be well calibrated, predicting that the outcome will occur in approximately the right proportions, over a wide range of predicted probability.

Discrimination

One common scalar measure of logistic regression discrimination is the c-statistic. This may be calculated by computing the area under the Receiver Operating Characteristic (ROC) curve. Alternatively, it may be calculated by forming every possible pair in a dataset where one member of the pair is a discharge with the outcome of interest and the other member is a discharge without the outcome of interest. The c-statistic is the proportion of such pairs where the predicted probability for the member with the outcome of interest is higher than the predicted probability for the other record. Pairs with tied probabilities each contribute one-half to the numerator and denominator of the proportion. A c-statistic of 0.5 is the same discrimination performance as flipping a coin. A c-statistic of 1.0 indicates perfect discrimination. Hosmer and Lemeshow (2000, p.162) have coined three widely adopted labels for discrimination performance based on the c-statistic:

- $0.70 \leq \text{c-statistic} < 0.80$ indicates **acceptable discrimination**
- $0.80 \leq \text{c-statistic} < 0.90$ indicates **excellent discrimination**
- $0.90 \leq \text{c-statistic}$ indicates **outstanding discrimination**

The c-statistics for the AHRQ QI risk-adjustment models are published in on the AHRQ QI website in the Risk Adjustment Coefficient Tables. (See [links](#) in the Overview chapter.)

Calibration

Calibration is often described by sorting the dataset based on predicted probability and dividing it into deciles of risk. It is meaningful to compare the proportion of records in each decile that were observed to have the outcome of interest with the proportion of records that are expected to have that outcome. Hosmer and Lemeshow's logistic regression goodness-of-fit statistic (1980) is based on a chi-square test statistic calculated using the observed and expected counts across the ten deciles. Unfortunately that statistic always rejects the null hypothesis good calibration when the number of observations is large, as is the case with the AHRQ QI reference population. Although the test statistic and its p-value are not informative for these models, the models are sometimes characterized by publishing or plotting the observed and expected counts in the ten deciles of risk.

Chapter 12. Software Maintenance – Other Updates

The AHRQ QI software uses several other files or datasets that are updated periodically. This chapter lists those, and either describes the methods used to generate them, or references other stand-alone documents that do so.

Population Reference File

The file that contains stratified population counts by county and metropolitan statistical area is crucial for calculating the denominators of the area-level measures. That file and the method to construct it are described in a file entitled *AHRQ QI Population File Documentation* on the AHRQ website: (<http://www.qualityindicators.ahrq.gov/software/SAS.aspx>)

Condition-Specific Population File

The AHRQ QI program includes ongoing research into options for estimating condition-specific denominators. At this time, the only condition-specific denominators are related to diabetes. There is a file name QICTYC14.TXT that is included with the v5.0 AHRQ PQI module. That file was calculated using the following steps:

1. Use the census population denominator reference file to estimate 2014 population for each combination of state and age category. In the QI software, age categories are coded as:

VALUE AGECCAT

0 = '00 to 17'

1 = '18 to 44'

2 = '45 to 64'

3 = '65 to 74'

4 = '75+'

2. Obtain the latest diabetes prevalence figures broken out by state and age category from the Centers for Disease Control at <http://gis.cdc.gov/grasp/diabetes/DiabetesAtlas.html>
3. Apply the diabetes proportions to the populations, to estimate the number of adults in each state in each of the four age categories who would have diabetes in 2014. (Population data from 2014 and proportion data from 2012.)

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Appendix A. Table of AHRQ QI Risk-adjustment / POA

Appendix Table A.1 denotes which AHRQ QI are risk-adjusted and which use POA data and for what purpose (i.e., for technical specifications or risk-adjustment).

An entry of ‘X’ in the column entitled ‘Calculate Risk Adjusted Rate’ means that the indicator is risk adjusted using PROC SCORE in SAS with coefficients from the risk-adjustment models estimated using GEE or LOGISTIC models.

An X in the column marked ‘Technical Specifications’ means that the indicator has an exclusion that explicitly references the POA data element. A QI software user may tell the software to ignore the DX_POA data element for purposes of risk-adjustment, but the software will never ignore DX_POA if it is referenced in the technical specifications for the purpose of defining exclusions, and if the data element is present in the discharge record. When a discharge record is missing the DX_POA data element, the Q flag will be set to “missing (.)” and the software will ignore it

An X in the column marked ‘Risk Adjustment’ means that the risk adjustment logistic regression model includes covariates for conditions that are comorbidities if they are POA and are complications if they are not POA. When the discharge record is missing the DX_POA data element, the risk adjustment model will treat the condition as if it was a complication that was not POA.

See [Chapter 9](#) for additional details on risk adjustment.

Appendix Table A.1. AHRQ QI Risk-adjustment and Uses of POA

Inpatient Quality Indicators (IQIs)	Calculate Risk-adjusted Rate	Use POA?	
		Technical Specifications	Risk-adjustment
IQI 01 - Esophageal Resection Volume			
IQI 02 - Pancreatic Resection Volume			
IQI 04 - Abdominal Aortic Aneurysm (AAA) Repair Volume			
IQI 05 - Coronary Artery Bypass Graft (CABG) Volume			
IQI 06 - Percutaneous Coronary Intervention (PCI) Volume			
IQI 07 - Carotid Endarterectomy Volume			
IQI 08 - Esophageal Resection Mortality Rate			X
IQI 09 - Pancreatic Resection Mortality Rate	X		X
IQI 11 - AAA Repair Mortality Rate	X		X
IQI 12 - CABG Mortality Rate	X		X
IQI 13 - Craniotomy Mortality Rate	X		X

IQI 14 - Hip Replacement Mortality Rate	X		X
IQI 15 - Acute Myocardial Infarction (AMI) Mortality Rate	X		X
IQI 16 - Heart Failure Mortality Rate	X		X
IQI 17 - Acute Stroke Mortality Rate	X		X
IQI 18 - Gastrointestinal Hemorrhage Mortality Rate	X		X
IQI 19 - Hip Fracture Mortality Rate	X		X
IQI 20 - Pneumonia Mortality Rate	X		X
IQI 21 - Cesarean Delivery Rate, Uncomplicated			
IQI 22 - Vaginal Birth After Cesarean (VBAC) Delivery Rate, Uncomplicated			
IQI 23 - Laparoscopic Cholecystectomy Rate			
IQI 24 - Incidental Appendectomy in the Elderly Rate			
IQI 25 - Bi-lateral Cardiac Catheterization Rate			
IQI 26 - Coronary Artery Bypass Graft (CABG) Rate	X		
IQI 27 - Percutaneous Coronary Intervention (PCI) Rate	X		
IQI 28 - Hysterectomy Rate	X		
IQI 29 - Laminectomy or Spinal Fusion Rate	X		
IQI 30 - Percutaneous Coronary Intervention (PCI) Mortality Rate	X		X
IQI 31 - Carotid Endarterectomy Mortality Rate	X		X
IQI 32 - Acute Myocardial Infarction (AMI) Mortality Rate, Without Transfer Cases	X		X
IQI 33 - Primary Cesarean Delivery Rate, Uncomplicated			
Patient Safety Indicators (PSIs)	Calculate Risk-adjusted Rate	Use POA?	
		Technical Specifications	Risk-adjustment
PSI 02 - Death Rate in Low-Mortality Diagnosis Related Groups (DRGs)	X		X
PSI 03 - Pressure Ulcer Rate	X	X	X
PSI 04 - Death Rate among Surgical Inpatients with Serious Treatable Complications	X		X
PSI 05 - Retained Surgical Item or Unretrieved Device Fragment Count		X	
PSI 06 - Iatrogenic Pneumothorax Rate	X	X	X
PSI 07 - Central Venous Catheter-Related Blood Stream Infection Rate	X	X	X
PSI 08 - Postoperative Hip Fracture Rate	X	X	X
PSI 09 - Perioperative Hemorrhage or Hematoma Rate	X	X	X
PSI 10 - Postoperative Physiologic and Metabolic Derangement Rate	X	X	X
PSI 11 - Postoperative Respiratory Failure Rate	X	X	X

PSI 12 - Perioperative Pulmonary Embolism or Deep Vein Thrombosis Rate	X	X	X
PSI 13 - Postoperative Sepsis Rate	X	X	X
PSI 14 - Postoperative Wound Dehiscence Rate	X		X
PSI 15 - Accidental Puncture or Laceration Rate	X	X	X
PSI 16 - Transfusion Reaction Count		X	
PSI 17 - Birth Trauma Rate – Injury to Neonate			
PSI 18 - Obstetric Trauma Rate – Vaginal Delivery With Instrument			
PSI 19 - Obstetric Trauma Rate – Vaginal Delivery Without Instrument			
Pediatric Quality Indicators (PDIs)	Calculate Risk-adjusted Rate	Use POA?	
		Technical Specifications	Risk-adjustment
PDI 01 - Accidental Puncture or Laceration Rate	X	X	X
PDI 02 - Pressure Ulcer Rate	X	X	X
PDI 03 - Retained Surgical Item or Unretrieved Device Fragment Count		X	
PDI 05 - Iatrogenic Pneumothorax Rate	X	X	X
PDI 06 - RACHS-1 Pediatric Heart Surgery Mortality Rate	X		X
PDI 07 - RACHS-1 Pediatric Heart Surgery Volume			
PDI 08 - Perioperative Hemorrhage or Hematoma Rate	X	X	X
PDI 09 - Postoperative Respiratory Failure Rate	X	X	X
PDI 10 - Postoperative Sepsis Rate	X	X	X
PDI 11 - Postoperative Wound Dehiscence Rate			X
PDI 12 - Central Venous Catheter-Related Blood Stream Infection Rate	X	X	X
PDI 13 - Transfusion Reaction Count		X	
PDI 14 – Asthma Admission Rate	X		
PDI 15 – Diabetes Short-Term Complications Admission Rate	X		
PDI 16 – Gastroenteritis Admission Rate	X		
PDI 17 – Perforated Appendix Admission Rate	X		
PDI 18 – Urinary Tract Infection Admission Rate	X		
NQI 01 - Neonatal Iatrogenic Pneumothorax Rate		X	X
NQI 02 - Neonatal Mortality Rate	X		X
NQI 03 - Neonatal Blood Stream Infection Rate	X	X	X
Prevention Quality Indicators (PDIs)	Calculate Risk-adjusted Rate	Use POA?	
		Technical Specifications	Risk-adjustment

QI Empirical Methods

PQI 01 - Diabetes Short-Term Complications Admission Rate	X		
PQI 02 - Perforated Appendix Admission Rate	X		
PQI 03 - Diabetes Long-Term Complications Admission Rate	X		
PQI 05 - Chronic Obstructive Pulmonary Disease (COPD) or Asthma in Older Adults Admission Rate	X		
PQI 07 - Hypertension Admission Rate	X		
PQI 08 - Heart Failure Admission Rate	X		
PQI 09 - Low Birth Weight Rate	X		
PQI 10 - Dehydration Admission Rate	X		
PQI 11 - Bacterial Pneumonia Admission Rate	X		
PQI 12 - Urinary Tract Infection Admission Rate	X		
PQI 13 - Angina Without Procedure Admission Rate	X		
PQI 14 - Uncontrolled Diabetes Admission Rate	X		
PQI 15 - Asthma in Younger Adults Admission Rate	X		
PQI 16 - Lower-Extremity Amputation Among Patients With Diabetes Rate	X		

Appendix B. Table of AHRQ QI Provider-Level Risk-adjustment Covariates

The categories highlighted in blue are mutually exclusive and exhaustive, meaning that every discharge is assigned a value of “1” for one and only one covariate and there must be an omitted covariate (usually the most common or the least risk). If covariates within a highlighted category are excluded because $N < 30$ or $p < 0.05$ then the covariate is combined with another along the risk gradient. For example, combine birth weight 500-999g with 1000-1499g, age 18-24 with age 25-29 or combine ROM subclass “4” with ROM subclass “3”.

Appendix Table B.1 Table of AHRQ QI Risk-adjustment Covariates for Provider Level Indicators

Category	MutuallyExclusive	IQI	PSI	PDI	NQI
Demographics		Sex	Sex	Sex	Sex
		Age (5-year age groups)	Age (5-year age groups)	Birth weight (500g groups)	Birth weight (500g groups)
				Age in days (90 days to 1 year)	
				Age in years (1 year and above)	
Severity of Illness	DRGs pool into MDCs	APR-DRG	Modified MS-DRG*	Modified MS-DRG*	Modified MS-DRG*
		Major Diagnosis Categories (MDC)	Major Diagnosis Categories (MDC)	Major Diagnosis Categories (MDC)	Major Diagnosis Categories (MDC)
Comorbidities		APR-DRG	AHRQ Comorbidities	AHRQ Clinical Classification Software	Congenital anomalies
		Risk of mortality subclass			
		(1 – minor; 2 - moderate; 3 – major; 4 – extreme)			

QI Empirical Methods

Category	MutuallyExclusive	IQI	PSI	PDI	NQI
Other		Transfer-in status	Transfer-in status	Transfer-in status	Transfer-in status
		Point of Origin status	Point of Origin status	Point of Origin status	Point of Origin status
			Days to Procedure status	Days to Procedure status	Days to Procedure status
				Indicator-specific risk stratifiers	

* Prior to October 1, 2007 use CMS-DRGs; highlighted cateories are mutually exclusive with an omitted covariate.

Appendix C. Helpful Background Information

This appendix includes some helpful information on both annual coding updates and software that is related to, or used by the AHRQ QI software. This information is not specifically statistical in nature, but does inform and affect the methods described in the main body of the document.

A. Fiscal year coding updates

Each fiscal year there are new ICD-9-CM and MS-DRG codes and revisions to existing codes. These changes are effective on October 1st. For example, Version 32 (fiscal year 2014) codes were effective October 1, 2011 and were incorporated in the version 5.0 release of the QI software. Diagnosis and procedure codes are used in the numerator and denominator specifications for the Patient Safety Indicators (PSIs), Prevention Quality Indicators (PQIs), Pediatric Quality Indicators (PDIs), and Inpatient Quality Indicators (IQIs). ICD-9-CM procedure codes affect the Centers for Medicare and Medicaid Services (CMS) classification of “major operating room procedure” for postoperative PSIs and PDIs. Another use of ICD-9-CM is in risk stratification used in the AHRQ Comorbidity Software, AHRQ’s Clinical Classification System, and 3M’s All Patient Refined Diagnosis Related Groups (APR-DRGs). Diagnosis codes are maintained by the Centers for Disease Control and Prevention’s (CDC) National Center for Health Statistics (NCHS). Procedure and MS-DRG codes are maintained by the CMS. The activities of both agencies are conducted jointly through the ICD-9-CM Coordination and Maintenance Committee (the Committee). The Committee meets in September and March to consider proposals for new codes and revisions to existing codes.

The Committee has implemented a partial freeze of the ICD-9-CM and ICD-10-CM/PCS codes in preparation for the implementation of ICD-10 codes on October 1, 2013. As a result, the last regular, annual updates to both ICD-9-CM and ICD-10-CM/PCS codes were made on October 1, 2011 (fiscal year 2012). Following October 1, 2012 only limited coding updates were made to both the ICD-9-CM and ICD-10-CM/PCS codes to capture new technologies and diseases. The Committee meeting agendas and ICD-9-CM timeline is located at the [CMS site](#).

Information on ICD-10-CM coding updates is located on both the NCHS (<http://www.cdc.gov/nchs/icd/icd10cm.htm>) and CMS (http://www.cms.gov/ICD10/11b14_2012_ICD10CM_and_GEMs.asp and http://www.cms.gov/ICD10/11b15_2012_ICD10PCS.asp#TopOfPage) web sites.

APR-DRG codes are maintained by 3M.

A.1 ICD-9-CM coding updates and coding guidelines

Information on ICD-9-CM coding updates is located on both the NCHS and CMS web sites:

(<http://www.cdc.gov/nchs/icd/icd9cm.htm>)
(www.cdc.gov/nchs/data/icd/icd9cm_guidelines_2011.pdf)
(http://www.cms.gov/ICD9ProviderDiagnosticCodes/01_overview.asp)

The anticipated coding updates for the subsequent version of the AHRQ QIs will consist of:

- New codes, if released.
- Limited ICD-9-CM coding revisions or deletions.
- NQF related updates, which may affect one or more indicators (This activity is performed in collaboration with task C.08. A set of NQF requested refinements have been submitted by AHRQ).

Activities during the base year will focus on these coding updates for the subsequent version of the AHRQ QIs. In general, updates to diagnosis and procedure codes are available on the NCHS or CMS web site. Preliminary updates are posted in March and final updates are posted in July. Diagnosis code updates are reported in Volume 1 (a tabular listing containing a numerical list of the disease code numbers) and Volume 2 (an alphabetical index to the disease entries).

Procedure code updates are reported in Volume 3 (an alphabetic index and tabular list for surgical, diagnostic, and therapeutic procedures in hospitals and inpatient settings).

The meeting calendar of the Committee will be monitored on an ongoing basis for meeting status and updates to the meeting minutes, and the published coding changes (Volumes 1 and 2 for the diagnosis codes and Volume 3 for the procedure codes) and errata, both preliminary and final, will be reviewed.

The processes for evaluating the updates are described within each subsection below.

Diagnosis Codes

An update consists of three documents.

- ICD-9-CM Index to Diseases Addenda – lists changes to the indexing of codes to diseases.
- ICD-9-CM Diagnosis Tabular Addenda – lists changes to the codes and code categories (defined as the first three digits).
- Conversion Table of New ICD-9-CM Codes – maps current codes to previous codes.

The update process consists of reviewing these documents to identify any coding changes that impact the numerator, denominator or exclusion logic of the AHRQ QI. There are two types of changes:

- A current code is split into two or more sub-codes and the current code is retired. Cases previously assigned to the current code are now assigned to the sub-codes.
- A new code or code category is created. Some cases previously assigned to a current code are now assigned to the new code.

Each change is evaluated to determine whether cases assigned to the codes belong in the numerator, denominator or exclusion logic of one or more AHRQ QI.

Procedure Codes

An update consists of two documents.

- ICD-9-CM Procedure Tabular Addenda – lists changes to the codes and code categories

- Conversion Table of New ICD-9-CM Codes – maps current codes to previous codes.

The update process consists of reviewing these documents to identify any coding changes that impact the numerator, denominator or exclusion logic of the AHRQ QI. There are two types of changes.

- A current code is split into two or more sub-codes and the current code is retired. Cases previously assigned to the current code are now assigned to the sub-codes.
- A new code or code category is created. Some cases previously assigned to a current code are now assigned to the new code.

Each change is evaluated to determine whether cases assigned to the codes belong in the numerator, denominator or exclusion logic of one or more AHRQ QI.

A.2 DRG coding updates

There are two editions of the DRGs. The first edition uses CMS-DRGs and the second edition uses MS-DRGs. The first edition is Version 24 and earlier; the second edition is Version 25 and later.

Updates to CMS-DRG are no longer supported by CMS.

Updates to MS-DRG codes are available on the CMS web site and in the Federal Register. Preliminary updates are posted in May and final updates or corrections are posted by August. (See <http://www.cms.gov/AcuteInpatientPPS>).

The update process consists of reviewing Table 5, which is a list of MS-DRGs, Relative Weighting Factors and Geometric and Arithmetic Mean Length of Stay and is one of the data tables from the fiscal year Inpatient Prospective Payment System from CMS. Ambiguity around the content of any update may usually be resolved through a review of the Federal Register notice. Prior to the implementation of the MS-DRGs, CMS would add and revise many DRGs annually. However, with the implementation of the MS-DRGs, changes are less frequent.

Activities during the base year will focus on reviewing the MS-DRG updates and determining what measure(s) are impacted with regards to the AHRQ QIs.

3M APR-DRG coding updates

There is no public posting of updates to the APR-DRG. The commercial product is released in October with an update in April. A research license for the commercial product is available from AHRQ. The limited license grouper used in the AHRQ QI software is available on an ad hoc basis under a voluntary arrangement with 3M. Contact information for the APR-DRG is as follows:

Anne M. Boucher Implementation Manager
Clinical and Economic Research
3M Health Information Systems
100 Barnes Road

Wallingford, CT 06492
Telephone: (203) 949 6497
Email: amboucher@mmm.com

Along with the limited license grouper, 3M provides documentation on changes to the APR-DRG logic. APR-DRG uses the same version numbering system used by NCHS and CMS. Prior to Version 23 (fiscal year 2006), 3M released a new version of the APR-DRG only once every five fiscal years with an ICD-9-CM mapping to maintain compatibility. Currently 3M releases a new version each fiscal year.

Updating the APR-DRG consists of the following steps:

1. Running the commercial product on the most recent year of Healthcare Cost and Utilization Project (HCUP) data available.
2. AHRQ has “pre-grouped” the HCUP data for selected states and made APR-DRG and risk-of-mortality subclass data elements available on the HCUP intramural databases. Step number 1 does not need to be done for these states.
3. Tabulating the frequency of APR-DRGs in the denominator of each IQI that uses the APR-DRG for risk-adjustment.
4. Retaining those APR-DRGs with at least 30 cases in the numerator.
5. Ensuring that those retained APR-DRGs are included in the covariate tables.

B. Related software maintained by HCUP at AHRQ

The AHRQ QI software uses other AHRQ software as components of the indicator specifications or risk-adjustment covariate specifications. These software components are also updated annually to reflect coding changes. The AHRQ QI support team does not independently review these changes; rather the coding changes are implemented without further review.

B.1 Comorbidity software

There are two editions of the comorbidity software. The first edition uses CMS-DRGs and the second edition uses MS-DRGs. The comorbidity software has its own version numbering system. The first edition is version 3.4 and earlier; the second edition is version 3.5 and later. (See <http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp>).

The comorbidity software consists of two SAS programs. The first program, Creation of Format Library for Comorbidity Groups (Comformat.txt), creates a SAS format library that maps diagnosis codes into comorbidity indicators. Additional formats are also created to exclude conditions that may be complications or that may be related to the principal diagnosis. The second SAS program, Creation of Comorbidity Variables (Comoanaly.txt), applies the formats created above to a data set containing administrative data and then creates the comorbidity variables used to define the risk-adjustment covariates.

Updating the comorbidity software as used in the AHRQ QI software consists of the following steps:

- Comparing the current format program with the previous format program to identify any

- changes.
- Comparing the current analysis program with the analysis format program to identify any changes.
- Determine whether any of the changes present a problem for backwards compatibility and, if there is such a problem, design a solution.
- Implement any changes and solutions in the AHRQ QI software.

B.2 Clinical Classification Software (CCS)

The CCS for ICD-9-CM is a diagnosis and procedure categorization scheme that collapses individual codes into a smaller number of clinically meaningful categories. The AHRQ QI uses the single-level edition of the CCS for diagnoses and procedures. The software consists of a SAS formats program.

(See <http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp>).

Updating the clinical classification software as used in the AHRQ QI software consists of the following steps:

- Comparing the current format program with the previous format program to identify any changes.
- Determine whether any of the changes present a problem for backwards compatibility and, if there is such a problem, design a solution.
- Implement any changes and solutions in the AHRQ QI software.

B.3 Procedure classes

The procedure classes assign ICD-9-CM procedure codes to one of four categories:

- Minor Diagnostic - Non-operating room procedures that are diagnostic.
- Minor Therapeutic - Non-operating room procedures that are therapeutic.
- Major Diagnostic - All procedures considered valid operating room procedures by the DRG grouper and that are performed for diagnostic reasons.
- Major Therapeutic - All procedures considered valid operating room procedures by the DRG grouper and that are performed for therapeutic reasons.

(See <http://www.hcup-us.ahrq.gov/toolssoftware/procedure/procedure.jsp>).

There is one file per fiscal year (PC.csv) that includes three elements: ICD-9-CM procedure codes, ICD-9-CM code labels, and procedure class assignments. In general, most of the changes relate to new procedure codes. However, sometimes the procedure class changes for an existing code. In these circumstances, the most recent assignment is used.

Updating the procedure classes as used in the AHRQ QI software consists of the following steps:

- Comparing the current procedure class assignments with the previous procedure class assignments to identify any changes.

- Special attention is given to operating room procedures in classes 3 and 4 (used to identify surgical discharges).
- Implement any changes in the AHRQ QI software.

C. Related classifications maintained by the AHRQ QI support team

The AHRQ QI software also uses other classifications as a component of the indicator specification or risk-adjustment covariate specification. These classification components are updated annually to reflect coding changes. The classifications include the Modified DRGs (MDRGs), birth weight (BWHTCAT), Congenital Anomalies (CONGCAT), and indicator-specification stratifications for the PDIs (HPPD01, GPPD02, GPPD10, HPPD10 and GPPD12).

C.1 Modified DRGs (MDRGs)

The purpose of the MDRG is to maintain a consistent mapping between CMS DRGs and MS-DRGs, and to pool MS-DRGs with and without CCs and MCCs. A new MS-DRG code either divides an existing MS-DRG into sub-MS-DRGs or re-assigns cases from multiple existing MS-DRGs. The MDRG is a four digit code. The first two digits are the Major Diagnosis Category (MDC), and the second two digits are a sequence number (e.g., 01-04) within the MDC.

Updating the modified DRGs consists of the following steps:

- Identify the relevant AHRQ QIs for which the fiscal year MS-DRG changes apply. The MS-DRG changes are identified in the CMS Table 5 (a list of MS-DRGs, Relative Weighting Factors and Geometric and Arithmetic Mean Length of Stay) from the fiscal year Inpatient Prospective Payment System.
- Use the CMS crosswalk to pool CMS-DRGs and MS-DRGs into a single MDRG and compare with the MDRG categories table in the relevant risk adjustment tables document.
- Implement any changes in the AHRQ QI software.

C.2 Birth weight (BWHTCAT)

BWHTCAT in 250g increments are defined by ICD-9-CM codes. Occasionally new codes are derived from existing codes.

Updating the birth weight categories consists of the following steps:

- Identify the relevant ICD-9-CM coding updates that pertain to the definition of the birth weight categories.
- Update the specifications, appendix and change log for the PDIs.
- Implement any changes in the AHRQ QI software.

C.3 Congenital anomalies (CONGCAT)

CONGCAT for gastrointestinal, genitourinary, central nervous system, pulmonary, cardiovascular, skeletal, chromosomal syndromes and selected other congenital anomalies are defined by ICD-9-CM codes (Original source Phibbs, et. al.⁴). Occasionally new codes are derived from existing codes.

Updating the CONGCATs consists of the following steps:

Identify the relevant ICD-9-CM coding updates that pertain to the definition of the congenital anomalies.

- Update the specifications and change log for the relevant AHRQ QIs.
- Implement any changes in the AHRQ QI software.

C.4 Indicator-specific

Some PDIs have classifications used in stratification and as covariates in risk-adjustment. These classifications are procedure type risk category (HPPD01), pressure ulcer risk category (GPPD02), wound class procedure type (GPPD10), immune-compromised risk category (HPPD10) and bloodstream infection risk category (GPPD12). Occasionally new codes are derived from existing codes.

Updating the indicator-specific classifications consists of the following steps:

- Identify the relevant ICD-9-CM coding updates that pertain to the definition of the classifications.
- Update the specifications, appendix and change log for the relevant AHRQ QIs.
- Implement any changes in the AHRQ QI software.

D. Risk-adjustment for Congenital Heart Surgery (RACHS-1) software

RACHS-1 is a type of specification (the numerator and denominator inclusion and exclusion rules). The Pediatric Heart Surgery Mortality (PDI 06) measure uses the RACHS-1 software to assign pediatric heart surgery cases to risk strata depending on the type of surgery (HPPD06). The stratification occurs upon running the RACHS-1 syntax which is embedded in the software. The RACHS-1 software is maintained on an ad hoc basis by Children's Hospital in Boston. (See <http://www.ncbi.nlm.nih.gov/pubmed/15283367>).

⁴ Phibbs CS, Baker LC, Caughey AB, Danielsen B, Schmitt SK, Phibbs RH. Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants. New England Journal of Medicine. 2007;356(21):2165-2175 & Supplement.

Updating the RACHS-1 software consists of confirming the coding updates that apply to RACHS-1 from the Children's Hospital in Boston.