CCRS Quality Indicators Risk Adjustment Methodology

Standards and Data Submission

Canadian Institute for Health Information
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Introduction

This document provides a technical description of the risk adjustment methodology for the Continuing Care Reporting System (CCRS) quality indicators (QIs) implemented by the Canadian Institute for Health Information (CIHI) in 2010 to replace the first generation Center for Health Systems Research and Analysis (CHSRA) QIs.

Please note that at this time, CIHI does not expect facility software vendors to include risk adjustment procedures in their software. This document has been generated to provide users with an understanding of the statistical theory and technical details of risk adjustment procedures.

The first section of this document provides some background on the CCRS QIs and explains why they are risk-adjusted. This is followed by a technical description of the multi-step risk adjustment process. The final section provides a worked example of the risk adjustment for one of the CCRS QIs.

The CCRS QIs, their specifications, the risk adjustment methodology and the information set out in this document are based on research carried out by interRAI and on documentation provided by the Institute for Aging Research, Hebrew SeniorLife.

Background

The CCRS QIs are intended to measure the quality of care delivered by continuing care facilities. However, some factors are beyond the facility's control, even though they affect resident outcomes. As a result, some facilities appear to have poorer performance levels than others but only because they have more higher-risk residents. To enable more appropriate and fair comparisons of the actual quality of care, these population differences need to be taken into account through a process of risk adjustment.

For the CCRS QIs, risk adjustment uses statistical techniques to control for population differences at two levels: at the individual resident level, using logistic regression to adjust for multiple individual-level covariates, and at the facility level by stratifying and reweighting data relative to a key adjustment variable (such as an outcome scale or Case Mix Index), using direct standardization. It should be noted that risk adjustment does not control for all factors that affect resident outcomes.

The risk adjustment methodology compares the risk profile of the resident population in an individual facility, organization or jurisdiction with the profile of a *standard reference population* and then modifies the quality indicator results for that facility/organization/jurisdiction so it is relative to the standard reference population.

The standard reference population and the associated statistical parameters that are used for the CCRS QIs risk adjustment are those created by interRAI research, and are based on a cross-national sample of more than 3,000 facilities in six U.S. states and 92 residential care facilities and continuing care hospitals in Ontario and Nova Scotia.

Risk-adjusted QIs are designed to allow comparison of facility results with those of other facilities and to overall populations of interest. They take into account differences in the risk profiles of resident populations within individual facilities. However, the risk-adjusted scores cannot be used to measure the actual frequency of outcomes in a facility.

Unadjusted QI scores (and the numerators and denominators used in their calculation) give accurate information about the frequency of quality of care outcomes and are therefore most useful for quality improvement activities within a facility. Comparing unadjusted QI scores across facilities should be done with caution, as the unadjusted QI scores do not take into account differences in resident populations.

Because risk-adjusted QIs are reported by CIHI on a quarterly basis to provide comparative reporting to facilities, and as the risk adjustment requires sophisticated statistical computations, which usually require specialist software (such as SAS, SPSS, STATA), **at the current time, CIHI does not expect facility software vendors to include risk adjustment procedures in their software**.

Risk Adjustment Process

Risk adjustment is a multi-stage process, which includes the following steps:

- Data preparation;
- Stratification;
- Indirect standardization using logistic regression;
- Direct standardization and creation of a single adjusted QI score; and
- Outlier trimming.

The description below refers to the calculations of facility-level results. The same process is applied to the calculation of indicator results at other levels, such as corporations, regions, provinces and territories. The data for each organizational unit is combined and then the adjustment methodology is applied.

Please note that the number of assessments counted in the denominator determines whether risk-adjusted QI values are calculated. If there are fewer than 10 assessments in the denominator, risk adjustment is not performed; if the total number of assessments is greater than or equal to 20, risk adjustment is performed. However, if the number of assessments in the denominator is greater than or equal to 10 but less than 20, risk adjustment is performed only in specific cases. For more information on the criteria for each case, please contact CCRS by email (ccrs@cihi.ca).

Data Preparation

Various steps are required to prepare the data before the indicators can be calculated and adjusted:

- Identify which assessment records will be used in the calculation of the incidence and prevalence indicators;
- Determine the time period over which the quality indicators will be calculated. CIHI uses a rolling four quarters system (for example, the QIs for Quarter 1, 2010–2011, are based on data from Quarter 2, 2009–2010 to Quarter 1, 2010–2011);
- Calculate the numerator and denominator flags;
- Calculate the stratification variables; and
- Calculate variables for the individual covariates to be used in the logistic regression models.

Stratification

A key feature of the risk adjustment methodology is the stratification of the facility population into three risk groups, or strata: high, medium and low. The strata for each indicator are based on either a RAI-MDS 2.0© outcome scale (such as the Cognitive Performance Scale, Activities of Daily Living Long Form Scale) or the Case Mix Index (CMI). They were derived so that roughly 20% of the standard reference population was in the low-risk group, 60% in the medium-risk group and 20% in the highest-risk group. However, each stratification variable is made up of discrete categories, and the population counts and proportions of the standard reference population in each risk group vary slightly and are calculated for each indicator.

The quality indicator rates in each risk group of the reference population are also calculated, as these are used in the indirect standardization:

Risk Group (Stratum)	Numerator	Denominator	Observed QI	Proportion in Strata (Weight)
Low	tr	tw	tg = (tr/tw × 100)	trp = tw/aw
Medium	er	ew	eg = (er/ew × 100)	erp = ew/aw
High	hr	hw	hg = (hr/hw × 100)	hrp = hw/aw
All	ar	aw	ag = (ar/aw × 100)	1.00 (aw/aw)

Next, the observed (unadjusted) QI score for each risk group in the facility is calculated.

Risk Group (Stratum)	Numerator	Denominator	Observed QI
Low	ts	tn	tm = (ts/tn × 100)
Medium	es	en	em = (es/en × 100)
High	hs	hn	hm= (hs/hn × 100)
All	as	an	am = as/an × 100

Indirect Standardization

Within each risk group, the QI score is indirectly standardized to take into account multiple resident-level risk factors, called covariates.

An expected QI score for each risk group is calculated using a logistic regression model. The parameters for the logistic regression models (one for each risk group) are calculated from the standard reference population and then applied to the data for each risk group from the facility.

The formula for the expected risk group QI score is given as

$$y = \frac{\exp(\beta_0 + \beta_1 m_1 + \beta_2 m_2 + \beta_3 m_3 ... + \beta_k m_k)}{(1 + \exp(\beta_0 + \beta_1 m_1 + \beta_2 m_2 + \beta_3 m_3 ... + \beta_k m_k))}$$

Where β_0 represents the intercept, β_1, β_2, $\beta_3 \ldots \beta_k$ represent the regression coefficients for each of the covariates included in the model, and m_1, m_2, $m_3 \ldots m_k$ represent the mean value of each covariate in the risk group.

Next, a performance ratio for each risk group is calculated by dividing the observed QI score for the strata by the respective expected QI score. The performance ratio has different interpretations depending on whether the QI relates to worsening (negative outcomes) or improving (positive outcomes).

- For QIs measuring negative outcomes: If this performance ratio is less than one (<1), it indicates that the facility has better performance than would be predicted based on the resident characteristics in that risk group. Similarly, if the performance ratio is greater than one (>1), this indicates that the facility had poorer performance than would be expected based on the resident characteristics for that risk group.
- For QIs measuring positive outcomes: If this performance ratio is greater than one (>1), it indicates that the facility has better performance than would be predicted based on the resident characteristics in that risk group. Similarly, if the performance ratio is less than one (<1), this indicates that the facility had poorer performance than would be expected based on the resident characteristics for that risk group.

Finally, the adjusted QI score for each risk group is calculated by multiplying the performance ratio by the QI score from the standard reference population.

Risk Group (Stratum)	Observed QI	Expected QI	Performance Ratio	Adjusted QI
Low	tm	tx	tm/tx	(tm/tx) × tg
Medium	em	ex	em/ex	(em/ex) × eg
High	hm	hx	hm/hx	(hm/hx) × hg

Theoretically, the calculations described above could result in an adjusted QI score for a risk group falling outside the range of 0% to 100%. For this reason, these values are transformed using the logit function, the calculations are performed and the result is transformed back to the original scale to provide an adjusted QI score that is between 0% and 100%. The Appendix provides a more detailed explanation of how this transformation is done.

Direct Standardization

As each facility has its own unique distribution of residents across the three risk groups, this stage of adjustment modifies the adjusted QI scores to treat each facility as though it had the same distribution among the three risk groups (and the same as the standard reference population).

The adjusted QI scores for each risk group are combined and weighted to reflect the distribution of the risk groups in the standard reference population:

Adjusted QI = (tqi × trp) + (eqi × erp) + (hqi × hrp)

where tqi, eqi and hqi represent the adjusted QI scores for the low-, medium- and high-risk groups, respectively, and trp, erp and hrp represent the proportions of the low-, medium- and high-risk groups within the standard reference population.

Outlier Trimming

The final stage of the adjustment is to check the distribution of the adjusted QI scores. If the adjusted score for a specific facility is above (or below) the maximum (or minimum) unadjusted QI score across all the facilities that are being risk-adjusted, the facility's adjusted QI is "trimmed" to within 10% of the standard deviation of the unadjusted QI.

Worked Example

The following example shows how the risk adjustment methodology is applied to calculate the worsening bladder continence quality indicator:

Reference	CNT03
Name	Percentage of residents with worsening bladder continence
Type	Incidence
Numerator	Residents whose bladder continence was worse on target assessment compared with prior assessment*
Denominator	Residents with valid assessments, excluding those with maximum bladder incontinence score on previous assessment, comatose and end-of-life residents*
Stratification	ADL Long Form
Individual Covariates	PSI: Subset 1 Diagnoses PSI: Subset 2 Non-Diagnoses CPS RUG Nursing CMI Age Younger Than 65

Note

* For a full description of the numerator and denominator inclusion and exclusion criteria, see the *Continuing Care Reporting System RAI-MDS 2.0 Output Specifications, 2011–2012*.

Risk Adjustment Steps

Stratification

1. Use reference population information for stratification cut-off scores (based on ADL Long Form) and calculate relative weights (N) for each risk group and calculate observed (unadjusted) QI score for each risk group.

Risk Group (Stratum)	Numerator	Denominator	Observed QI	Proportion in Strata (Weight)
Low	5,255	52,607	0.09989	0.42810
Medium	11,855	62,562	0.18949	0.50911
High	1,696	7,717	0.21977	0.06280
All	18,806	122,886	0.15304	1.00000

2. Divide facility population into the three risk groups, based on the same ADL Long Form categories.

3. Count the number of residents in each risk group that meet the numerator and denominator definitions.

4. Calculate the observed (unadjusted) QI score for each risk group.

Risk Group (Stratum)	Numerator	Denominator	Observed QI Score
Low	22	214	0.10280
Medium	36	206	0.17476
High	25	66	0.37879
All	83	486	0.17078

Indirect Standardization

5. Calculate expected scores for each risk group. This is done using logistic regression models (one for each risk group), where the parameters for each model are calculated for the standard reference population and then applied to the data for each risk group from the facility.

   The table below shows the logistic regression parameters for the CNT03 indicator:

Logistic Regression Parameter		Risk Group (Stratum)		
		Low	Medium	High
Intercept	b_0	-3.13538	-1.83147	-1.64911
PSI: Subset 1 Diagnoses	b_1	0.03901	-0.06807	0.18776
PSI: Subset 2 Non-Diagnoses	b_2	0.11296	0.07532	-0.00778
CPS	b_3	0.20813	0.09379	0.06105
RUG Nursing CMI	b_4	0.85531	0.16075	-0.06845
Age Younger Than 65	b_5	-0.9695	-0.3769	-0.38272

Regression formula (expected QI for each strata/risk group):

$$y = \frac{\exp(b_0 + b_1 \times m_1 + b_2 \times m_2 + b_3 \times m_3)}{(1 + \exp(b_0 + b_1 \times m_1 + b_2 \times m_2 + b_3 \times m_3))}$$

6. Calculate performance ratio and adjusted scores.

Risk Group (Stratum)	Observed QI	Expected QI (From Logistic Regression Model)	Performance Ratio (Observed QI/ Expected QI)	QI for Reference Population	Adjusted QI (Performance Ratio × QI for Reference Population)
Low	0.10280	0.10004	1.02763	0.09989	0.10265
Medium	0.17476	0.27101	0.64484	0.18949	0.12219
High	0.37879	0.20116	1.88302	0.21977	0.41383

Note: The description above describes the essence of the process of how the risk-adjusted indicators are calculated. Unfortunately, the actual process is not quite as direct as that because extreme values of the performance ratios, when multiplied by the reference population rates, may result in adjusted indicator values greater than 1 (or greater than 100%, if expressed as a percentage). For this reason, the calculations described above are done on a transformed scale that will not permit values of the risk-adjusted indicator score to exceed 1 (or 100%). This transformation is described in the Appendix.

Direct Standardization

7. Multiply adjusted scores by weight of each risk group from the reference population.

8. Sum the three weighted adjusted scores to get overall adjusted QI for the facility.

Risk Group (Stratum)	Risk Group Adjusted QI	Weight From Reference Population	Weighted Score
Low	0.10265	0.42810	0.04394
Medium	0.12220	0.50911	0.06221
High	0.41383	0.06280	0.02599
Overall			0.13215

As the adjusted QI score falls within the minimum and maximum values for the distribution of the unadjusted QI scores, no outlier trimming is performed.

The adjusted QI score for this facility is 13.2%.

Appendix: Transformation of Scores

In general, indirect standardization is obtained by dividing the observed rate by the expected rate and multiplying that by the standard rate (here, called the reference rate).

The observed rate divided by the expected rate is also called the performance ratio.

So, practically, the indirectly standardized (or adjusted) QI for each risk group can be computed (done at step 6 above) as follows:

For low-risk group: $= \left(\frac{tm}{tx} \right) \times tg$

For medium-risk group: $= \left(\frac{em}{ex} \right) \times eg$

For high-risk group: $= \left(\frac{hm}{hx} \right) \times hg$

Within each risk group, m represents the observed QI, x represents the expected QI score and g represents the reference rate.

However, mathematically, each of these estimates can be more than 1 (or 100% when expressed as a percentage). For this reason, these values are transformed using the logit function, the calculations are then performed and the result is transformed back to the original scale to provide the final adjusted QI score that is between 0 and 1 (or 0% and 100% in percentage terms).

The transformations are defined below as F(p) and $F^{-1}(z)$:

$$F(p) = \ln\left(\frac{p}{1-p} \right)$$

$$F^{-1}(z) = \left(\frac{\exp(z)}{1+\exp(z)} \right)$$

The transformation for the low-risk group would be

$F^{-1}[F(tg) + F(tm) - F(tx)]$

$F(tg) + F(tm) - F(tx)$ will be $\ln\left(\frac{tg}{1-tg}\right) + \ln\left(\frac{tm}{1-tm}\right) - \ln\left(\frac{tx}{1-tx}\right)$

Which in turn will be

$$\ln\left(\frac{\frac{tm}{1-tm}}{\frac{tx}{1-tx}} \times \frac{tg}{1-tg}\right)$$

This is the observed QI divided by the expected QI, multiplied by the reference QI on the natural log scale, except that the QIs have been transformed.

The result is then back-transformed using F^{-1} to obtain an adjusted QI value for the low-risk group.

Values for the other risk groups are transformed in a similar way.

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