DEVELOPING COST WEIGHTS WITH LIMITED COST DATA - EXPERIENCES USING CANADIAN COST DATA
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ABSTRACT
Until 1998, the calibration of Canadian cost weights (Resource Intensity Weights, also known as RIW) relied on U.S. charge data from the state of Maryland. In 1998, The Canadian Institute for Health Information (CIHI) was able to use a limited amount of Canadian cost data to calibrate RIW. This allowed the concatenation of the Canadian and American databases for the calibration of RIW. The Maryland Health Services Review Commission charge database dominated the calibration since it constituted approximately 85% of the available cost data. In 1999, the size of the Ontario cost database more than doubled allowing it to become the principal calibration database. Health care delivery in the United States is based on a profit-motivated charge system while the Canadian health care system is a non-profit government funded service. Therefore, one would expect differences in the cost profiles of the two systems. Statistical analysis demonstrated that calibrating with U.S. data caused many weights to be ‘compressed’ such that low resource intensity cases (Complexity level 1) were being overvalued while highly resource intensive cases were undervalued (Complexity level 4). This was particularly true for the pregnancy/childbirth and neo-nate cases. In 1999 a more robust methodology was introduced which, for the first time, used the Canadian cost data as the principal calibration database. However, the U.S. charge data was still required for case mix groups where there was an insufficient amount of Canadian cost data. Two separate sets of RIW, one using only the Canadian cost data, the other using only the Maryland charge data were calculated. The Maryland RIW were then adjusted to lessen the effect of compression introduced by the U.S. data. Statistical tests were conducted on the Canadian RIW to determine if there were enough cases to exclusively employ Canadian data. When the minimum volume threshold was not reached a weighted average between the two RIW was utilized. For the purpose of comparison, both 1998 and 1999 cost weights were applied to the 1998/99 activity data from Canada’s Discharge Abstract Database (DAD). Weighted cases were then calculated using both methodologies for all cases and the subset of pregnancy/childbirth/neo-nates. The revised 1999 Methodology changed the weights as expected. Compression was largely alleviated. The RIW for most pregnancy and childbirth case mix groups increased. High intensity cases (level 4) accounted for 9.32% more weighted cases in 1999. Pregnancy, childbirth and neo-nate cases accounted for 9.90% more of the total weighted cases in 1999 than in 1998. Level 1 complexity cases (low resource use) saw a 4.2% decline.

KEYWORDS: Cost weight, Case Mix Group, Plx, RIW, Inpatient group, Case cost, Resource utilization

INTRODUCTION
The Canadian Institute for Health Information (CIHI) plays a critical role in the development of Canada’s health information system. CIHI is a leader in the standardization, collection, analysis and distribution of health information. One of the largest databases maintained by CIHI is the Discharge Abstract Database (DAD). For 19 years, hospitals across Canada have submitted standard abstracts of hospital discharges to the DAD. Currently CIHI receives 3.6 million records annually. Each discharge is grouped using the Case Mix Group methodology (CMG™) and the Complexity methodology (Plx™) which is an overlay to CMG that further refines inpatient groupings based on co-morbid conditions.
One of the principal applications of the CMG/Plx methodology is the development of cost weights or Resource Intensity Weights (RIW). The RIW are calculated annually and used as benchmarks in the planning and management of hospital services. In 1999 a new methodology was developed which for the first time put Canadian cost data at the forefront of the RIW calibration process. Since the Canadian cost database used did not contain a sufficient number of cases to calibrate the 1999 RIW, a number of steps were necessary to blend in outside data where necessary. The purpose of this article is to provide a background of the RIW in Canada, detail how CIHI’s 1999 RIW methodology was able to overcome the problem of a limited amount of domestic cost data, and examine the impact of the changes on the weights.

THE CANADIAN HEALTH CARE SYSTEM
The health needs of all Canadians are cared for by a publicly funded health care system. Although the Federal Government largely supplies the funding for the health care system through Federal – Provincial transfer payments, each of Canada’s ten provinces and three territories has its own ministry of health which individually oversees the distribution of health care resources. Citizens and landed immigrants are issued a provincial health card that guarantees them access to medical treatment. There is portability in the system such that residents of one province are free to seek medical attention in any other province.

BACKGROUND TO CASE MIX GROUPS (CMG)
CMG are designed to group acute care inpatients with similar clinical and resource utilization characteristics into homogeneous groups. Originally introduced in 1983, CMG were adapted from Diagnosis Related Groups (DRG) which were developed in the United States. In 1990, the CMG went through an extensive modification to reflect Canadian clinical practice and length of stay patterns. The method is continually reviewed and updated in order to ensure that the patient case mix system reflects the changing requirements and patterns of practice in Canadian hospitals.

A CMG is a subgroup of one of 25 Major Clinical Categories (MCC). Each MCC identifies either a body system, such as the Respiratory System, or other specific types of clinical problems, such as HIV, Neonates, and Burns. Diagnosis codes from the International Classification of Diseases, Ninth Revision (ICD-9) are used to broadly categorize patients into each MCC. Since many hospitals in Canada are now coding with ICD-9-Clinical Modification (ICD-9-CM), CIHI has developed a conversion methodology that allows data submitted in both classifications to be grouped into a CMG.

In order to group a patient into a MCC, the Most Responsible Diagnosis (MRDx) is identified upon discharge. The MRDx is defined as the diagnosis that is responsible for the greatest portion of the patient’s length of stay (LOS). Each MCC is divided into medical and surgical partitions. In general, those cases which have a surgical procedure are assigned to the surgical branch, while those without a procedure are assigned to the medical partition. When a case is assigned to the medical partition, a list of diagnosis codes grouped according to similarities in LOS is used to assign the patient to a CMG. When a case is assigned to the surgical partition, a hierarchical list of procedure codes is used to assign the patient to a CMG. Finally, where age is found to be predictive of LOS the patient’s age group will be used to further refine the CMG split. In such CMG, cases are categorized into one of three age groups (0-17, 18-69, and 70+).

BACKGROUND TO COMPLEXITY (PLX™)
The complexity overlay (Plx) further refines the CMG to reflect a patient’s total medical condition. Plx takes into account the effects of co-morbid conditions either present at the time of admission or occurring during the hospital stay. Each diagnosis coded in Canada is assigned a ‘diagnosis type’ which identifies it as either the MRDx, a pre-admission comorbidity, a post-admission comorbidity or a service transfer diagnosis. Cases are assigned first to a CMG and then to one of following four Plx levels:
Level 1 – no co-morbid conditions;
Level 2 – complexity related to chronic conditions;
Level 3 – complexity related to serious / important conditions;
Level 4 – complexity related to potentially life threatening conditions.

Therefore, a patient within any one given CMG may be grouped into 12 possible Age-Complexity (APlx) cells depending into which of the four Plx levels and three age categories they fall. Complexity is not applied to a CMG where it does not demonstrate improved homogeneity in LOS.

The data elements used to establish an individual patient’s Plx level are collected as part of the discharge abstract submitted to CIHI’s DAD. The Plx methodology identifies both chronic disease conditions that are outside of the primary focus of the acute care episode, as well as cases with multi-system failure and cases with iatrogenic or other complications. The number and seriousness of complicating diagnoses are combined according to statistically and clinically validated rules to determine the Plx level of a case.

Four MCC for which a complexity level is not assigned to a CMG are the exception to the above. These complexity ‘exclusions’ include Pregnancies and Childbirth (MCC 14), Newborn and Neonates (MCC 15), Mental Disease and Disorders (MCC 19) and HIV Infections (MCC 24). For the purposes of statistical analysis and reporting, CMG cases where complexity is not applied are referred to as having a Plx level of 9.

**CMG MODEL TYPES**

Every year, before RIW values are calculated, each CMG is statistically assessed to determine whether or not age and complexity are predictive of the LOS of its patients. The following five different statistical models are considered:

1. CMG model which is applied to CMG where neither age nor complexity is a significant predictor of LOS;
2. Plx model which is applied to CMG where the Plx level of a patient significantly affects their LOS;
3. Age model which is applied where the categorical age of the patient has a statistically significant impact on the LOS;
4. Additive model which is applied to CMG where both the categorical age and Plx level are significant predictors of LOS;
5. Interaction model which is applied to CMG where categorical age, Plx level and an interaction between Plx level and age are predictive of LOS.

Table 1 outlines the variables and specifications of the five models.

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Predicting Variables</th>
<th>Model Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMG</td>
<td>None</td>
<td>ELOS = CMG</td>
</tr>
<tr>
<td>Plx</td>
<td>Plx</td>
<td>ELOS = CMG + Plx</td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
<td>ELOS = CMG + Age</td>
</tr>
<tr>
<td>Additive</td>
<td>Age, Plx</td>
<td>ELOS = CMG + Age + Plx</td>
</tr>
<tr>
<td>Interaction</td>
<td>Age, Plx, Age*Plx</td>
<td>ELOS = CMG + Age + Plx + Age*Plx</td>
</tr>
</tbody>
</table>

There are volume constraints associated with some of the model types including a minimum of 200 cases within a CMG to adopt either the Age or the Additive model and 200 cases in each APlx cell of a CMG to adopt the interaction model. Based on the statistical test repeated every year, each CMG is assigned the most appropriate model. CMG where Plx is not applied (Plx level 9) can only be assigned to the CMG model or the Age model.
RESOURCE INTENSITY WEIGHTS (RIW™)
RIW have been available in Canada since 1989. Currently, most provinces are using CIHI’s RIW as part of their hospital funding formulas. Until recently, no satisfactory inpatient Canadian cost data existed and, therefore, the calibration of the RIW has relied exclusively on data from the Maryland Health Services Review Commission Charge Database. One of the main issues surrounding this database is that the dollar values it represents are those of charges and not costs. In 1994, the Ontario Provincial Ministry of Health (in conjunction with the Ontario Hospital Association) established the Ontario Case Cost Project (OCCP) to collect patient specific cost data for resource utilization purposes. This database began collecting cost data on inpatient cases in 1994 and is now also collecting cost data related to outpatient day procedures.

The advent of the OCCP data allowed CIHI to incorporate Canadian cost data into the annual calibration of the RIW beginning in 1998. This move was well received by the stakeholders and clients of CIHI who rely on the RIW for their funding and resource allocation planning. There are inherent differences between healthcare delivery in the United States and Canada. American residents are served by a profit motivated payer system whereas the Canadian health care system is publicly funded.

Although the population demographics in Maryland are thought to closely match those in Canada, differences in practice patterns are known to exist. Statistical analysis demonstrated that calibrating with U.S. data caused many weights to be ‘compressed’ (see figure 1) such that low resource intensity cases (Complexity level 1) were being overvalued while highly resource intensive cases were undervalued (Complexity level 4). This was particularly true for the pregnancy/childbirth and neo-nate cases. Therefore, CIHI’s objective was to utilize as much Canadian cost data in the calibration of the RIW as possible while minimizing the influence of the Maryland charge data.

Despite these efforts, the OCCP database is not large enough to adequately calculate stable estimates of RIW. Therefore in 1998, the first year OCCP data was used, American and Canadian cost data were combined into one large data set before being run through the RIW calibration process. Although this was a promising first step, it was not ideal because the OCCP data only constituted 15% of the total number of cases in the combined Canada – U.S. cost database. In 1999, an expanded OCCP database allowed for a more robust RIW methodology that, for the first time, used the Canadian cost data as the principal calibration database. However, the U.S. charge data was still required for case mix groups where there was an insufficient amount of Canadian cost data.

**Figure 1. Graphical Representation of RIW Compression**
METHODS
When changes and enhancements are made to the RIW methodology, CIHI consults with its RIW National Technical Working Group (RIW TWG). This committee is comprised of a number of health care experts from across the country that represents a broad spectrum of expertise from many facets of the health care system. The members include physicians, epidemiologists, hospital administrators, statisticians and provincial ministry of health representatives. All members of the RIW TWG have extensive experience dealing with the resource allocation of health care budgets. All changes to the 1999 RIW methodology were debated and subsequently approved by the RIW TWG.

Because there was enough Canadian cost data to populate most of the cells, two separate sets of RIW were calculated, one using only Canadian cost data, the other using only Maryland charge data. This resulted in the first ever set of Canadian only RIW. Both sets were calibrated according to the Hospital Specific Relative Value (HSRV) method originally proposed by Vertrees and Pettengill and described in Lave et al (1981).

The APlx Group
A new conceptual grouping of APlx cells was needed for the calculation of the 1999 RIW. Typically, APlx cells have been grouped based on age (3 APlx cells), Plx level (4 APlx cells), or CMG (12 APlx cells). When calculating this year’s values, aggregate data of a different nature were employed. The model type of a CMG dictated how the APlx cells were grouped to form APlx Groups. Figure 2 graphically illustrates the relationship between APlx cells, groups, and CMG. Each oval represents an APlx Group, each small rectangle an APlx cell and each large rectangle a CMG.

Figure 2. Graphical Representation of APlx Groups

Legend:
Oval = APlx Group
Small rectangle = APlx cell
Large Rectangle = CMG
In the case of a CMG model (figure 2A), all 12 APlx cells are lumped together to form a single APlx Group. For an Age model (figure 2B), three APlx groups result, one for each age category. Similarly, for Plx model (figure 2C), four APlx groups are created, one for each Plx level by collapsing the age categories. For the Additive and Interaction models (figure 2D), no aggregations are made and therefore each APlx cell forms its own APlx Group.

Calculation of the Canadian RIW
The Canadian based RIW were calibrated using data from the OCCP that contained 272,401 cases from fiscal year 1994/95 and 1995/96. Thirteen hospitals in 1994/95 and 7 in 1995/96 contributed data to the calibration process. The OCCP’s sites include a variety of facilities including both urban and rural hospitals as well as large teaching facilities and smaller community hospitals.

Once the Canadian RIW were generated APlx groups were statistically tested to determine whether or not there were a sufficient number of cases to generate a stable estimate of the RIW. The number of cells pooled together in an APlx group in order to make the calculation depended on the model type of the CMG. Therefore, for an Additive or Interaction model CMG, each individual Age/Plx cell was tested. In the case of a Plx model CMG, the cases from all three age groups within a Plx level were added together then tested. For Age model CMG, the cases were collapsed across Plx levels and each age group was individually tested.

The statistical threshold depended not only on the volume in a given APlx group but on the dispersion of the data as well. The standard deviation of the difference between patient LOS and the calculated expected length of stay (ELOS) was used to determine the amount of variance in each APlx group. The following formula was used to decide whether or not there was sufficient data in the Canadian database:

$$\text{SD APlx Group}_{(\text{LOS} - \text{ELOS})} = \left(\frac{(\text{LOS} - \text{ELOS})^2}{n-1}\right)^{1/2}$$

where:

- LOS-ELOS = Length of Stay – Expected Length of Stay
- SD APlx Group_{(LOS-ELOS)} = Standard deviation of LOS – ELOS within an APlx Group
- n = Volume in tested APlx group

The volume in a given OCCP APlx group was considered appropriate if it was greater than the value of N when calculated using the following solved equation where the 0.10 represents a 10% difference between the ELOS value and the SD of LOS-ELOS.

$$N_{\text{APlx group}} \geq \left[\frac{\text{SD}_{(\text{LOS}-\text{ELOS})}}{(\text{ELOS} \times 0.10)}\right]^2$$

If the equation above was satisfied then only RIW using Canadian data was utilised.

An additional criterion was inserted into the process to ensure that the data was not meeting the criteria by chance. Specifically, a minimum of six cases was needed regardless of whether or not the group passed the statistical test. If there was not a volume of at least six cases a weighted average of the Maryland calibrated RIW and the Canadian calibrated RIW was automatically employed.

Calculation of the Maryland RIW
Maryland RIW were calculated using data from the Maryland Health Services Review Commission Charge Database. This charge database contained 1,105,957 inpatient cases from 1996 and 1997. In order to deal with the compression problem, a scaling methodology was used to adjust the Maryland RIW so that they better reflected the distribution of cases by Plx level in Canada. First, the RIW values
from Maryland and the OCCP were merged onto the Canadian activity data extracted from CIHI’s Discharge Abstract Database (DAD). Each case in the database then had both of its corresponding Canadian and Maryland RIW values attached. In addition, all CMG were classified as either medical or surgical and fit into one of the 25 Major Clinical Categories (MCC). Then the mean RIW were calculated for each MCC-Medical and MCC-Surgical cluster. The mean OCCP RIW was then divided by the mean Maryland RIW for each cluster to arrive at the Calibration Database Adjustment (CDA), again for each MCC-Medical and MCC-Surgical cluster. The original Maryland RIW were then multiplied by the CDA to arrive at the Maryland adjusted RIW values. It was these new adjusted RIW values that were used in the next step of the calibration process.

**Blending of OCCP and Maryland RIW**

When the minimum volume threshold was not reached a weighted average between the adjusted Maryland RIW and the OCCP RIW was utilized.

\[
\text{Blended RIW} = \frac{N_{\text{OCCP}} \times \text{OCCP RIW} + N_{\text{Maryland}} \times \text{Maryland Adjusted RIW}}{N_{\text{Maryland}} + N_{\text{OCCP}}}
\]

In order to quantify the differences between the 1998 and 1999 RIW, both values were merged onto the 1998 activity data. This allowed unbiased comparisons to be made while controlling for case mix.

**RESULTS**

The CIHI inpatient case mix system includes 477 Case Mix Groups. Table 2 indicates the number of APIx groups for which the statistical volume test was carried out.

<table>
<thead>
<tr>
<th>Model Type</th>
<th># of CMG</th>
<th>APIx Groups Calculated per CMG</th>
<th>Total Number of APIx Groups calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction</td>
<td>25</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>Additive</td>
<td>202</td>
<td>12</td>
<td>2424</td>
</tr>
<tr>
<td>Age</td>
<td>23</td>
<td>3</td>
<td>69</td>
</tr>
<tr>
<td>PIx</td>
<td>131</td>
<td>4</td>
<td>524</td>
</tr>
<tr>
<td>CMG</td>
<td>96</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>477</strong></td>
<td></td>
<td><strong>3413</strong></td>
</tr>
</tbody>
</table>

Of the 3,413 APIx groups that were calculated, nearly one third (32.0%) were ‘Canadian only’, the remainder were either blended or used Maryland values (Table III). ‘Maryland only’ values occurred when there were no cases at all in either the Canadian Length of Stay or OCCP database.

<table>
<thead>
<tr>
<th>1999 RIW used</th>
<th>Number of APIx Groups</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blended</td>
<td>1421</td>
<td>41.6%</td>
</tr>
<tr>
<td>Canadian</td>
<td>1091</td>
<td>32.0%</td>
</tr>
<tr>
<td>Maryland</td>
<td>901</td>
<td>26.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3413</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
An analysis of the weighted cases indicated that the proportion of Plx level 4 and Plx level 9 cases increased while the proportion of Plx level 1 cases declined slightly (see figure 3). Plx level 9 CMG cases are dominated by the newborns and neonates that typically have high a RIW.

**Figure 3. Frequency Distribution of Weighted Cases by Plx Level Controlling for Activity Data**

Note: Plx level 9 indicates complexity was not applied.

**DISCUSSION**

The first objective of the 1999 RIW methodology was to increase the influence of Canadian cost data in the calibration of the RIW process. For the first time ever, a portion of the RIW were calibrated using only Canadian cost data. In CMG where a blended Maryland-OCCP value was calculated, the Canadian cost data exerted a greater influence than in the previous year. Both the increased volume of the OCCP in 1999 along with the scaling adjustment carried out on Maryland RIW before the blending, contributed to the increased Canadian cost influence.

Nearly one third of the APlx cells were represented by a purely Canadian RIW in 1999 (32.1% - Table III). In terms of overall impact, APlx cells that were calibrated with ‘Maryland only’ data are low volume cells that represent proportionately fewer cases in Canada. Since only APlx cells with either no national volume or no OCCP volume employed the adjusted Maryland RIW, then it follows that their overall impact in terms of hospital funding is slight.

Of the remaining 42 percent of cells, a weighted average between the OCCP and the Adjusted Maryland RIW was employed. Even in these cells, progress was made towards ‘Canadianizing’ the weights because the Maryland data was first subjected to a Canadian cost based scaling algorithm.
In order to be conservative, a 10% threshold was set for the relative difference between the ELOS value of a group and its corresponding standard deviation. As more Canadian cost data is included in the calibration, the 10% value will be re-examined.

The second major objective of the 1999 RIW methodology was to alleviate the compression problem associated with the weights. Previous statistical analysis had indicated that Plx level 4 cases were being slightly undervalued while Plx level 1 cases were slightly overvalued when purely Maryland charge data was used to calibrate the RIW. When the same activity data was used RIW 1999 values attributed more weighted cases to Plx level 4 cases (+.5%) while Plx level 1 cases decreased (-2.1%). Plx level 9 weighted cases also increased by 2.8% in the 1999 version. These cases are dominated by the pregnancy/childbirth and in particular the neonate CMG (MCC 14, MCC15). Most of these CMG have a high RIW, reflecting a significant amount of resources and entail a complex course of treatment.

Since the release of the 1999 RIW values, there has been a considerable amount of positive feedback from the field. A number of health facilities have indicated that the new RIW, especially where they relate to newborns and neonates, are a much more accurate representation of their costs.

NEXT STEPS
The Canadian Institute for Health information hopes to build on this research and has launched the “Development of Canadian Weights” project whose aims are to:
1. identify and evaluate Canadian cost data in inpatient acute care and ambulatory care service settings;
2. identify methodologies to increase and/or exclusively employ Canadian cost data in the existing weighting methodologies; and
3. develop weights in service settings, such as ambulatory care, where Canadian based weights have not yet been developed.

BIBLIOGRAPHY