Abstract

Health Canada’s Registered Nurses’ (RNs) demand model for Alberta assigns full-time equivalent registered nurses (FTE RNs) by nursing function (e.g., paediatric, oncology, mental health etc.) to inpatient age-sex groupings in proportion to their expected use of hospital resources (i.e., nursing and other hospital staff time, equipment, supplies, drugs). The RIW -- a relative value assigned to each patient upon discharge – predicts the use of hospital resources on the basis of patient case-mix, severity, age, and procedures performed. This paper validates using the RIWs to assign RNs to inpatient-groupings by using a simple mathematical conceptual model and a simulation. It shows that RIW is a good predictor of nurse-use across nursing function. Differences in health human resource intensity across different nursing functions, and differences in prices of non-human elements, e.g., drugs, also does not affect the proportional relationship between total RIW and FTE of RNs within a nursing function in the absence of technological change. Thus, we find strong association between the RIW and the in-hospital requirement for nurses.

Key Words: Resource Intensity Weight, Nurses, Simulation, Hospital

Introduction

The Microsimulation Modelling and Data Analysis Division of the Applied Research and Analysis Directorate, Health Canada, has built a Health Human Resources (HHR) model to project future requirement for Registered Nurses (RNs) in Alberta [1]. In brief, the model uses the base-year relationship between the demographic/clinical characteristics of active care inpatients (i.e., age, sex, most responsible diagnosis), the relative need for nursing and other resources (case-mix and case-complexity), and the full-time equivalence (FTE) of RNs who provide such nursing care. The base-year relationship is estimated using patient data reported for each discharge and the Canadian Institute for Health Information (CIHI) Registered Nurse Database (RNDB), which is an annual registry of all RNs eligible (i.e., registered) to practice by nursing function and employment status. The sensitivity of projections of future requirements for RNs takes into account scenarios of possible changes in population need for active inpatient care and patterns of RN staffing.

As the RNDB reports head-counts by employment status (part-time, full-time) and inpatient nursing function (i.e., paediatric, medical/surgical, oncology, rehabilitation, psychiatric/mental health, critical care, operating room/recovery room) the following steps are addressed:
- estimate FTE status of RN-staffing by nursing function [2], and
- partition RN-staff among inpatient groupings (age, sex) seen in these units using the CIHI Resource Intensity Weights (RIW) as the basis of allocation.

We assign FTE RNs by patient-groupings in proportion to their actual share of the total RIW’s within each nursing function. This assumes that the RIW is a valid predictor of expected use of nursing care. The RIW is a relative value assigned by CIHI to each patient upon discharge according to the amount of resources they were expected to use. These resources include the component costs of patient care (e.g., nursing services, drugs, etc.) and the RIW is an index that expresses inpatient use of resources relative to the average for certain age and severity of illness. The estimation of the RIW accounts for differences in age (three groupings), case-mix group (909 groups), and case-complexity (four categories). Cost is greater for older
patients (e.g., 70+ versus others), certain case-mix groups (e.g. unstable angina with cardiac catheterization; co-morbid diabetes versus that without specified cardiac conditions and without diabetes), and by degree of complexity [3,4] (e.g., related to potentially life-threatening conditions versus uncomplicated). The validation of this method of assigning FTEs requires two interlinked conditions: First, price must not influence RIW and second, total RIW within a nursing function (paediatric, oncology, mental health, etc.) must be proportional to the RIW attributed to the use of RNs.

The validation of the first requirement is important because it may be argued that a higher or a lower price can over-estimate or under-estimate the total RIW within a nursing function. If so, projecting requirements for RNs based on total RIW within a nursing function may be misleading. For example, the price of chemotherapy and related therapeutics to treat cancer, in general, is higher than that of other drugs used for other diseases. Therefore, it may be asserted that total RIW for oncology will be over-estimated and hence the requirement for RNs based on that RIW would also over-estimate the requirement for RNs in the projection.

In this paper, we show that the price of the non-human factors (e.g., drugs) does not affect the total RIW within a nursing segment. We further show that total RIW attributable to nurses in those functions (e.g. oncology) is proportional to the total RIW in that nursing function, in the absence of technological change. The assumption that RIWs are an indicator (predictor) of RNs services is valid.

Conceptual Framework

A RIW is assigned to each inpatient upon discharge from the hospital, according to the amount of resources they used. We can observe the total RIW of each nursing functions. However, the RIW of the nursing segments, which are the components of the total RIW within a particular nursing function are not observable. This paper simulates the non-observable RIW of different nursing segments and then finds the relationship between the total RIW within a nursing function and nursing segment that is attributable to the service of the nurses. Figure 1 shows the different non-observable components attributed to the total RIW.

Does price matter?

The chart shows that a nursing function involves several segments such as the direct services of the nurses, administration of drugs, services of different technicians etc. For the sake of simplicity, for the time being, we assume that a nursing function is limited to one segment, which is dispensing therapeutic drugs to patients.

Let $p_j$ represent the price of drug $j$ and $q_{jk}$ the quantity of drug $j$ consumed by patient $k$ in the given
year. \( Y_i \) is the dollar value of one \( RIW \) corresponding to the group \( i \) of patients. These groups are based on patient age and severity of illness. The number of groups of patients based on age and severity of illness, the number of different drugs, and number of patients are represented by \( l, m, \) and \( n \) respectively. Then \( RIW \) for all drugs is simply:

\[
RIW_{\text{Drugs}} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} p_j q_{jk}}{Y_i}.
\]  

(1)

Let us suppose that for all drugs the price is equal to \( \bar{P} \), the weighted average of prices.

Then, \( \bar{P} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m} \sum_{k=1}^{n} q_{jk}} \).

Now, let \( RIW'_{\text{Drugs}} \) be the total \( RIW \) if the price for all the drugs are equal to \( \bar{P} \). Then

\[
RIW'_{\text{Drugs}} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} p_j q_{jk}}{Y_i} = \sum_{j=1}^{m} \sum_{k=1}^{n} \frac{p_j q_{jk}}{Y_i} \cdot \sum_{j=1}^{m} \sum_{k=1}^{n} q_{jk}.
\]

(2)

Clearly, \( RIW'_{\text{Drugs}} \) in (2) is equal to \( RIW_{\text{Drugs}} \) which is derived from \( m \) different prices and \( l \) different values of \( RIW \) in (1). This means that if the drug price is lower than the weighted average, \( RIW \) is underestimated, and if the price is above the weighted average, \( RIW \) is overestimated. However, overestimation and underestimation cancel out each other within a group and as such total \( RIW \) for all the patients within the hospital segment remains unaffected. Note that two patients with same price and quantity of drugs will have different \( RIW_{\text{Drugs}} \) if \( Y \) is different. This is semi-parametric and does not require any assumption about the distribution.

**Does the use of nursing services and \( RIW \) show a linear trend in the future?**

The average weighted quantity of drugs for each patient is:

\[
\bar{Q} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} q_{jk}}{n} \quad \text{and the average weighted price is still:} \quad \bar{P} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m} \sum_{k=1}^{n} q_{jk}}
\]

The total drug cost can be expressed as:
\[
\overline{PQ} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{n} p_{j,k} \sum_{j=1}^{m} \sum_{k=1}^{n} q_{j,k}}{\sum_{j=1}^{m} \sum_{k=1}^{n} q_{j,k}} \cdot n
\]

Let \( K = \overline{P} \), then the total drug cost can be expressed as \( K \overline{Q} \). The \( RIW \) associated with drug cost, \( RIW_{DC} \) can be expressed as:

\[
RIW_{DC} = \sum_{i=1}^{l} \frac{K \overline{Q}}{Y_i} = K \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i}
\]

Now, suppose that the cost of delivering each patient the average quantity of drugs is \( K' \). The cost for the personnel delivering these drugs is then \( K' \overline{Q} \). We now we have:

\[
RIW_{HHR} = \sum_{i=1}^{l} \frac{K' \overline{Q}}{Y_i} = K' \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i}
\]

There is no restriction on \( K' \); it can take any positive value depending on the intensity of the use of health human resources within a nursing function. However, \( K' \) is assumed to be constant within a nursing segment, though it can vary across nursing segment. Now, we have the total \( RIW \):

\[
RIW_{TOT} = RIW_{DC} + RIW_{HHR} = \left( K \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i} \right) + \left( K' \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i} \right) = (K + K') \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i}
\]

We can rearrange (3) as

\[
RIW_{TOT} = \left( K + K' \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i} \right) \frac{K'}{K'} = \left( K + K' \sum_{i=1}^{l} \frac{\overline{Q}}{Y_i} \right) \frac{K'}{K'} = \left( K + K' \right) \frac{K}{K} RIW_{HHR}
\]

That implies that \( RIW_{HHR} \) is proportional to \( RIW_{TOT} \). For a particular segment within a nursing function in the absence of technological changes, the proportion of different categories of health human resources is fixed. So it is reasonable to believe that \( RIW_{Nurses} \) is proportional to \( RIW_{HHR} \) and hence to \( RIW_{TOT} \) when there is no technological change.

**Extending the concept to all segments within a nursing function**

A nursing function involves several segments. We assume that each nursing function has \( r \) segments. Suppose the subtotal of \( RIW \) for each of these segments within a nursing function is denoted by \( RIW_r \). We then have

\[
RIW_r = K_r RIW_{TOT}
\]

\[
RIW_{Nurses} = \overline{K}_r RIW_r
\]

Now,

\[
RIW_{Nurses} = \sum_r RIW_{Nurses} = \sum_r K_r RIW_r.
\]

Substituting the value of \( RIW_{r} \) in (6) we get

\[
RIW_{Nurses} = \left( \sum_r K_r \right) RIW_{TOT}.
\]

This implies that \( RIW_{Nurses} \) is proportional to \( RIW_{TOT} \).

**Simulating the total RIW and RNs requirement**

In this section we illustrate some simulation of \( RIW_{total} \) and \( RIW_{nurses} \) in a nursing function based on our conceptual model. Table 1 shows a perfect correlation between total \( RIW \) and the total \( RIW \) attributable to
the services of the nurses. This is true despite different prices and health human resource intensities across nursing segments. However, as we demonstrated, that it is the utilization of human resources and not the price of the non-human factors that are reflected in $RIW$.

### Table 1: Relationship between Total $RIW$ and Total $RIW$ attributable to Nurses

<table>
<thead>
<tr>
<th>Year</th>
<th>Total RIW</th>
<th>RIW Nurses</th>
<th>RIW Nurses / Total RIW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,437,825</td>
<td>1,073,630</td>
<td>74.6%</td>
</tr>
<tr>
<td>2002</td>
<td>1,848,991</td>
<td>1,381,459</td>
<td>74.7%</td>
</tr>
<tr>
<td>2003</td>
<td>2,439,771</td>
<td>1,823,337</td>
<td>74.7%</td>
</tr>
<tr>
<td>2004</td>
<td>2,757,772</td>
<td>2,063,128</td>
<td>74.8%</td>
</tr>
<tr>
<td>2005</td>
<td>2,455,367</td>
<td>1,834,977</td>
<td>74.7%</td>
</tr>
</tbody>
</table>

Note: Correlation Coefficient between Total $RIW$ and $RIW$ Nurses is 1.00.

### Conclusion
The sum of $RIW$s across individual patients by nursing functions turns out to be a good proxy for the requirement of nursing services in the absence of a technological change. Variation in the proportion of nurses across different nursing segments does not distort the relationship between total $RIW$ and total $RIW$ related to nurses, which we have shown is proportional. This also holds for differing values of $RIW$ by age groups and risk groups. Differences in health human resource intensity across different nursing functions and differences in prices of non-human elements also do not affect the proportional relationship. There is a strong association among the requirement of nurses, total health human resources and total $RIW$ within a nursing function. And, there is a significant association between the requirement for nurses within a nursing function and the total $RIW$ in that nursing function. Thus, the $RIW$ is a good predictor of full-time equivalent nurse requirements by nursing function.

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### References