Simulating the Components of Resource Intensity Weight: A Good Proxy for Allocating Health Human Resources Across Inpatients?

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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 catherization; 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.

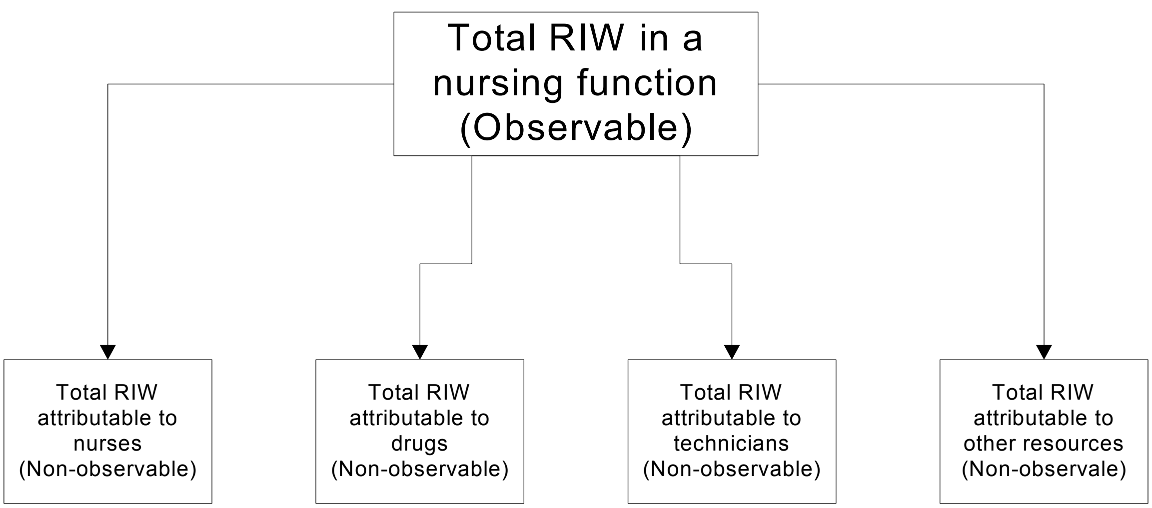
The validation of the first requirement is important because it may be argued that a higher or a lower price can over-estimate or under-estimate the total *RIW* within a nursing function. If so, projecting requirements for RNs based on total *RIW* within a nursing function may be misleading. For example, 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 *RIW*s 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* .

Figure 1: Conceptual Model



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:

$$RIW_{Drugs} = \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}\frac{p_j q_{jk}}{Y_i}. \qquad (1)$$

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

Then, $\overline{P} = \dfrac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}$.

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

$$RIW'_{Drugs} = \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}\frac{\left(\dfrac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}\right) q_{jk}}{Y_i} = \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}\frac{q_{jk}}{Y_i}\cdot\frac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}$$

$$= \sum_{i=1}^{l}\frac{1}{Y_i}\left[\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}\left(\frac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}\right)\right] = \sum_{i=1}^{l}\frac{1}{Y_i}\left(\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}\right)$$

$$= \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}\frac{p_j q_{jk}}{Y_i} = RIW_{Drugs} \qquad (2)$$

Clearly, RIW'_{Drugs} in (2) is equal to RIW_{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_{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:

$\overline{Q} = \dfrac{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}{n}$ and the average weighted price is still: $\overline{P} = \dfrac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}$

The total drug cost can be expressed as:

$$\overline{P}\overline{Q} = \frac{\sum_{j=1}^{m}\sum_{k=1}^{n} p_j q_{jk}}{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}} \cdot \frac{\sum_{j=1}^{m}\sum_{k=1}^{n} q_{jk}}{n}$$

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:

$$RIW_{TOT} = RIW_{DC} + RIW_{HHR} = \left(K\sum_{i=1}^{l} \frac{\overline{Q}}{Y_i}\right) + \left(K'\sum_{i=1}^{l} \frac{\overline{Q}}{Y_i}\right) = (K + K')\sum_{i=1}^{l} \frac{\overline{Q}}{Y_i} \tag{3}$$

We can rearrange (3) as

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

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

$$RIW_r = K_r RIW_{TOT} \tag{4}$$

$$RIW_{Nursei} = \overline{K}_r RIW_r \tag{5}$$

Now,

$$RIW_{Nurses} = \sum_r RIW_{Nursei} = \sum_r \overline{K}_r RIW_r. \tag{6}$$

Substituting the value of RIW_r in (6) we get

$$RIW_{Nurses} = \left(\sum_r \overline{K}_r K_r\right) RIW_{TOT.} \tag{7}$$

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

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

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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