

1 *Background:* Inconsistent findings in over 100 studies have made it difficult to build a body of
2 knowledge explaining how variation in nurse staffing affects patient outcomes. Nurse dose,
3 defined as the level of nurses required to provide patient care in hospital settings, draws on
4 variables used in staffing studies to describe the influence of all staffing variables on outcomes.

5 *Objectives:* The purpose of this study was to provide initial quantitative validity of the nurse
6 dose concept by determining its association with MRSA infections and reported patient falls on a
7 sample of inpatient adult acute care units.

8 *Method:* Staffing data came from 26 units in Ontario Canada and Michigan. Financial and
9 human resource data were data sources for staffing variables. Sources of data for MRSA came
10 from Infection Control departments. Incident reports were the data source for patient falls.
11 Data analysis consisted of bivariate correlations and poisson regression.

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13 *Results:* Bivariate correlations revealed that nurse dose attributes (active ingredient and intensity)
14 were significantly associated with both outcomes. Active ingredient (education, experience, skill
15 mix), and intensity (FTE, RN-patient ratio, RN-HPPD) were significant predictors of MRSA.
16 Coefficients for both attributes were negative and almost identical. Both attributes were
17 significant predictors of reported patient falls and coefficients were again negative, but
18 coefficient sizes differed.

19
20 *Discussion:* By conceptualizing nurse and staffing variables (education, experience, skill mix,
21 FTEs, RN-patient ratio, RN-HPPD) as components of nurse dose, and by including these in the
22 same analysis, we were able to determine their relative influence on MRSA infections and
23 reported patient falls. Key Words: Outcome assessment, personnel staffing, nursing theory

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Introduction

It is unclear how nurse staffing contributes to good outcomes for hospitalized patients.(Authors, 2008) A large body of research has attempted to link nurse staffing variables to patient outcomes, using staffing variables as proxies for actual nursing care. However, efforts to accumulate and synthesize evidence of the influence of nurse staffing on patient outcomes have been hampered on several fronts. Most staffing research to date has been atheoretical,(Mark, Hughes, & Jones, 2004) results across staffing studies have been inconsistent and contradictory,(Jiang, Stocks, & Wong, 2006) and staffing definitions - even for the same term - vary conceptually and operationally. Finding a consistent link between nurse staffing and patient outcomes is needed to guide staffing decisions and demonstrate the influence of nursing care on patient outcomes. Until such a link is found, the wrong number or type of nurse can be assigned to a unit with the potential for adverse consequences for patient care(Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Mark et al., 2007) and increased healthcare costs.(Cho, Ketefian, Barkauskas, & Smith, 2003)

We embarked on a program of research to address some of the deficits mentioned above, beginning by conceptualizing various staffing variables as elements of nurse dose.(Authors, 2008) Then, we refined the nurse dose concept through a concept validation study and exploration of the factorial structure of nurse dose.(Authors, 2010) In this paper we report on the next step of our program of research, where we used staffing data from 26 nursing units to provide initial quantitative evidence of nurse dose's validity by linking nurse dose to two outcomes: methicillin-resistant staphylococcus aureus (MRSA) infections and reported patient falls. We are not the first researchers to use the term nurse dose.(Brooten & Naylor, 1995;

1 Brooten & Youngblut, 2006) In our version, nurse dose is a unit level variable and the attributes
2 of nurse dose reflect the contribution of registered nurses (RNs) to patient outcomes.

3 Literature Review

4 Over 100 studies (Kane, Shamliyan, Mueller, Duval, & Wilt, 2007) attempting to link
5 staffing variables to outcomes have operationalized staffing as: nurse-patient ratio, the number of
6 full-time equivalents (FTEs), hours per patient day (HPPD), and skill mix: the ratio of registered
7 nurses (RNs) to licensed practical nurses (LPNs) and unlicensed health care personnel.
8 Inconsistent findings across studies have made it difficult to build a body of knowledge
9 explaining how variation in nurse staffing affects patient outcomes.

10 Inconsistent findings may be the result of several factors. For example, a putative link
11 between full-time equivalents (FTEs) and the adverse outcome of urinary tract infections (UTIs)
12 has not emerged, perhaps as the result of differences in construction of the FTE variable.(Cho et
13 al., 2003; Kovner & Gergen, 1998) Similar variation in construction of hours per patient day
14 (HPPD) and the related RN-HPPD (to isolate the registered nurse component only) may account
15 for contradictory or inconsistent findings in other studies.(Cho et al., 2003; Needleman,
16 Buerhaus, Mattke, Stewart, & Zelevinsky, 2002) The level at which data are collected and
17 analyzed may also account for inconsistent findings. In a unit-level study, Blegen and colleagues
18 found no relationship between RN-HPPD and outcomes such as mortality and pressure
19 ulcers,(Blegen, Goode, & Reed, 1998) while both Cho and Needleman, in separate hospital-level
20 studies, found an inverse relationship between RN-HPPD and pneumonia. A skill mix
21 characterized by a high proportion of RNs was associated with fewer pressure ulcers in Blegen's
22 unit-level study,(Blegen et al., 1998) but not in Needleman's hospital-level study.(Needleman et
23 al., 2002) Finally, the majority of studies have assumed that a specific staffing variable may be

1 equally associated with all outcomes, when such an assumption may not be valid, contributing to
2 inconsistent findings. For instance, while Cho and colleagues reported an increase in pressure
3 ulcers as a result of increasing HPPD,(Cho et al., 2003) Needleman and colleagues did not find
4 any relationship between HPPD and adverse outcomes other than pressure ulcers (i.e., longer
5 length of stay, urinary tract infection, upper gastrointestinal bleeding, hospital-acquired
6 pneumonia).(Needleman et al., 2002)

7 Besides staffing variables, certain characteristics of RNs themselves may be important in
8 achieving excellent patient outcomes.(Aiken, Clarke, Cheung, Sloane, & Silber, 2003)
9 Researchers have investigated the effects of education and experience on patient outcomes.
10 Some researchers have reported a positive relationship between education and outcomes while
11 others have been unable to demonstrate a link between these variables.(Aiken et al., 2003;
12 Blegen, Vaughn, & Goode, 2001) The little that is known about the relationship of nurse
13 experience to outcomes suggests that experienced nurses contribute to positive outcomes.(Blegen
14 et al., 2001) No study has reported the combined effect of education, experience, and skill mix
15 although collectively these three variables represent the concentration of nursing knowledge on a
16 unit, which can be applied to improve the quality of patient care.(Authors, 2008)

17 The Development and Evolution of the Nurse Dose Concept

18 In developing a theory to explain nursing's influence on outcomes, we use the concept of
19 nurse dose, defined as the level (i.e., number and type—RN, LPN, unlicensed aide) of nurses
20 required to provide patient care in hospital settings. Nurse dose draws on variables used in
21 staffing studies and provides a unified approach to describe the influence of all staffing variables
22 on patient outcomes. We briefly review the development and evolution of nurse dose below.

1 We first conducted a concept analysis and concept derivation exercise, identifying 4
2 critical attributes of nurse dose: purity, amount, frequency, and duration. Next, we validated the
3 4 attributes of nurse dose with a panel of experts in nurse staffing research, resulting in some
4 changes to the attributes and indicators of nurse dose.(Sidani et al., 2010) Based on feedback
5 from the experts, the combination of education, experience, and skill mix was renamed “active
6 ingredient” instead of purity. This change was consistent with dose terminology in other
7 healthcare disciplines. The attributes of amount and frequency of nurse dose were both validated
8 by the experts, but duration was not, so that at the end of this phase of research nurse dose had 3
9 attributes: active ingredient, amount, and frequency.

10 We then explored the factorial structure of nurse dose using staffing data from 26
11 medical, surgical, and mixed medical/surgical inpatient units. Using principal axis factoring
12 analysis two factors emerged. One factor, active ingredient, consisted of 3 empirical indicators:
13 nurse education, experience and unit skill mix (factor loadings: 0.37, 0.36, 0.84 respectively).
14 The second factor, a combination of amount and frequency, also consisted of 3 empirical
15 indicators: FTEs, nurse-patient ratio, and RN-HPPD (factor loadings: 0.63, -0.66, 0.75,
16 respectively).(Sidani et al., 2010) As anticipated, FTE and RN-HPPD had positive factor
17 loadings whereas nurse-patient ratio had a negative factor loading. The factor pattern created by
18 these 3 indicators suggests that when FTEs and RN-HPPD are high, the nurse-patient ratio is
19 low, as would be expected on nursing units where patients are more acutely ill, such as intensive
20 care. We called this second factor intensity, which is consistent with the dose literature, and
21 reflects the interaction between amount and frequency.

22 At the present time nurse dose consists of two attributes, active ingredient (education,
23 experience, skill mix) and intensity (FTEs, nurse-patient ratio, RN-HPPD). The purpose of this

1 study was to provide initial quantitative validity of the nurse dose concept by determining its
2 association with MRSA infections and reported patient falls on a sample of inpatient acute care
3 units.

4 Methods

5 Sample and Data Sources

6 Staffing data came from a health system in Ontario, Canada (14 units) and from a health
7 system in Michigan (12 units) for a total of 26 units. Financial and human resource data were
8 used as sources for constructing the staffing variables. We collected data from adult medical,
9 surgical, and mixed medical/surgical units. Staffing variables were annualized and came from
10 fiscal year 2007. The same data were obtained based on clear definitions shared with all units. To
11 promote data uniformity we requested variables as presented in Table 1. Approval to conduct the
12 study from the institutional review boards of respective institutions in both the United States and
13 Canada was granted.

14 Conversion of all staffing variables to attributes of nurse dose. Several steps were
15 necessary before we could determine if nurse dose was associated with MRSA infections and
16 reported patient falls. We constructed the variables of FTEs, nurse-patient ratio, skill mix, and
17 RN-HPPD as delineated in Table 1: Empirical indicator column. While constructing the FTE
18 variable, we had to account for differences in labor laws between the United States and Canada
19 to derive productive hours. We used a standard of 1768 productive hours/year for the US nurses,
20 and 1527 worked hours/year for the Canadian nurses. Others have reported 2080 hours as a
21 standard year (40 hours/week for 52 weeks),(Needleman et al., 2002) which over counts
22 productive time because it includes benefits such as sick and vacation hours.

1 Next, we created scatter plots to examine the nature of relationships between outcomes
2 and the independent variables (education, experience, skill mix, FTE, RN-patient ratio, RN-
3 HPPD). This step was necessary to make sure that in categorizing nurse dose variables, we did
4 not alter their relationships with the outcomes. Next we examined histograms and, based on the
5 distribution of cases within each variable, 4 categories for each variable were generated. Scores
6 (range: 1 – 4) were assigned to the four categories so that low scores corresponded to the lower
7 end of the distribution on the respective nurse dose indicator and indicated lower levels on:
8 education, experience, skill mix, FTE, and RN-patient ratio. We reverse scored RN-HPPD
9 because its association with both outcomes was positive.

10 Construction of active ingredient. Since active ingredient is a combination of 3
11 variables (education, experience, skill mix), we summed and averaged categorized scores (range
12 of 1 – 4) for education, experience, and skill mix to create a composite score reflective of the
13 active ingredient attribute of nurse dose. Although there are other methods of combining
14 variables to derive a single score, such as constructing Z-scores, we preferred a method that
15 would be simple to use and easily interpreted.

16 Construction of intensity. Scores for each indicator of intensity: amount (FTE),
17 frequency (RN-patient ratio), and RN-HPPD ranged from 1 – 4, similar to those given to the
18 active ingredient variable. We summed and averaged scores for FTE, RN-patient ratio, and RN-
19 HPPD to create a composite score reflecting the intensity of nurse dose.

20 Outcome measures. Sources of data for MRSA came from Infection Control
21 departments in participating hospitals. MRSA was calculated as the rate of MRSA infection per
22 1000 patient days. Data for patient falls both with and without injury came from incident reports
23 submitted to the Risk Management department. Reported patient falls were calculated as the rate

1 of reported patient falls per 1000 patient days. Both outcomes' distributions clustered around
2 zero with a positive skew, resembling a Poisson distribution.(Hutchinson, 2005)

3 Data Analysis

4 Data analysis consisted of bivariate correlations and poisson regression, to account for
5 the skewed distribution of outcome variables. We generated a correlation matrix to determine if
6 there were significant associations between each nurse dose attribute (i.e., active ingredient and
7 intensity) and patient outcomes. Then we tested 2 poisson regression models, one with MRSA
8 infections as the dependent variable, and another with reported patient falls as the dependent
9 variable. Nurse dose attributes were independent variables in both models.

10 Results

11 Ten units were classified as “adult medical”, eight as “adult surgical”, and another 8 as
12 combined “adult medical/surgical”. Total number of beds per unit ranged from 12 – 64; 9 units
13 had 32 beds. Patient length of stay ranged from 1.5 – 13.1 days, with a mean of 7 days. On
14 average, 44% of RNs on a unit had a BSN or higher degree (range 2 - 86%; S.D. 18) and had 7.5
15 years' experience within the organization (range 3 – 16 years; S.D. 3.0). The mean number of
16 RN FTEs was 62 (range 20 - 147; S.D. 26), mean RN- patient ratio was 3 (range 2 – 5; S.D. 0.6),
17 and the mean RN-HPPD was 7.73 (range 5.2 – 12.9; S.D. 2.0). Skill mix varied from a low of
18 64% of RNs of the total nursing personnel, to a high of 98% RN staff (mean 78%; S.D. 7.8). The
19 mean patient fall rate was 6.8 falls/1000 patient days (range 0.2 – 17.9); 2 units had less than 1
20 reported patient fall/1000 patient days. The mean MRSA rate was 1.0 case/1000 patient days
21 (range 0 – 3.8); 9 units had no MRSA cases.

22 Bivariate correlations revealed that the two nurse dose attributes were significantly
23 associated with both outcomes. Active ingredient was significantly correlated with MRSA

1 infections ($r = -0.43$, $p = .03$) and reported patient falls ($r = -0.44$, $p = .03$), as was intensity:
2 MRSA ($r = -.70$; $p = .001$) and reported falls ($r = -.44$, $p = .03$). In the regression model with
3 MRSA as the outcome, active ingredient (education, experience, skill mix), and intensity (FTE,
4 RN-patient ratio, RN-HPPD) were significant predictors. Coefficients for both attributes were
5 negative, as would be expected, and almost identical. In the second regression model, both
6 attributes were significant predictors of reported patient falls and coefficients were again
7 negative, but coefficient sizes differed. Table 2 provides results of poisson regression analyses.

8 Discussion

9 The long term objective of this program of research is to consider nurse dose as a
10 prescriptive tool to identify the nurse staffing required to prevent pressure ulcers, urinary tract
11 infections, and other adverse patient outcomes thereby improving patient safety. The findings
12 provide preliminary evidence supporting the validity of the nurse dose concept. Our results are
13 significant for two reasons.

14 First, we were able to demonstrate strong inverse associations between nurse dose
15 attributes and both outcomes, in the hypothesized direction. By conceptualizing nurse and
16 staffing variables (education, experience, skill mix, FTEs, RN-patient ratio, RN-HPPD) as
17 components of nurse dose, and by including these in the same analysis, we were able to
18 determine their relative influence on MRSA infections and reported patient falls. These results
19 suggest that, contrary to the bulk of staffing research done to date, more than one staffing
20 variable should be measured when attempting to demonstrate the influence of staffing on patient
21 outcomes.

22 Second, by providing conceptual coherence around the meaning of various staffing
23 variables, we inform the selection of staffing indicators to consider in outcomes effectiveness

1 studies. The finding that both active ingredient and intensity were practically identical
2 contributors to MRSA suggests that both attributes of nurse dose may be equally important in
3 influencing this adverse patient outcome. Yet for reported patient falls, differences in the size of
4 coefficients suggest that both attributes may not make an equal contribution.

5 Our results suggest that a nurse dose approach to staffing variables offers promise in a
6 couple of areas. Research using multiple staffing variables in the same study and investigating
7 the relative influence of one predictor over others provides additional knowledge about nurse
8 staffing variables and their effect on patient outcomes. When multiple studies by different
9 authors use the same measures consistently, knowledge is built in an area.

10 Moreover nurse dose may have practical applicability as a valuable tool for nurse
11 administrators to help them make evidence-based staffing decisions. Depending on what specific
12 nurse-sensitive adverse event is plaguing a particular unit, nurse managers may be able to titrate
13 their staffing in a way that helps to reduce that adverse outcome. Thinking about staffing in nurse
14 dose terms may allow nurse managers to make their case in a way that is understood by non-
15 nurse finance personnel. For example, nurse managers may be able to argue that an emphasis on
16 FTEs or skill mix alone may be insufficient to make an impact on outcomes. They can use dose
17 language to point out that since prescribing a medication effectively requires attention to both the
18 medication's active ingredient and intensity (amount and frequency), similarly for nurse dose
19 both the active ingredient (of which skill mix is a part) and intensity (of which FTE is a part)
20 should be considered.

21 There were several limitations to our study. Although we were able to demonstrate
22 significant relationships between several staffing variables and outcomes, because of the cross-
23 sectional nature of our investigation we cannot claim that the staffing variables caused a

1 reduction in adverse outcomes. Longitudinal studies wherein changes in nurse dose are tracked
2 over time are needed to determine the causal relationship between nurse dose attributes and
3 outcomes. There was a wide variety of staffing patterns among units providing data, but our
4 small sample means that findings cannot be generalized beyond the health care systems in
5 Ontario Canada and in the United States that participated in the study. The rarity of both adverse
6 outcomes represents a final limitation, but we were constrained in the outcomes we investigated
7 because of what comparable outcome data were available in both Canadian and American sites.

8 Earlier work by members of this research team contributed to conceptual coherence and
9 clarification of the nurse dose concept, and by empirically validating nurse dose with actual
10 staffing and outcome data this study extends our knowledge of nurse dose. In future research
11 outcomes other than MRSA infections and reported patient falls should be studied. Outcomes
12 such as urinary tract infections and pressure ulcers may be more sensitive to variations in staffing
13 because of designation as being “nurse sensitive” and thus more consistent with the
14 conceptualization of nurse dose. Adverse outcomes with known or anticipated variability in a
15 variety of settings would facilitate more thorough testing of nurse dose attributes.

16 In summary, this study represented the next logical step in a program of research aiming
17 to determine how staffing data can be configured in a unique way known as nurse dose and
18 linked to patient outcomes. Nurse staffing variables in their various permutations represent an
19 indirect measure of nurses’ capacity to prevent adverse outcomes and promote quality care.
20 Using nurse dose terminology to tease out the influence of staffing variables in multiple
21 combinations on adverse outcomes is crucial because some nursing processes may very well
22 depend on a specific nurse dose for optimal patient outcome achievement.

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Table 1

Nurse Dose Attributes: Theoretical and Empirical Indicators

Attribute	Theoretical Indicator	Empirical Indicator
Active Ingredient	Education: Percentage of RNs with BSN Degree or higher	number of RNs <u>with BSN or higher</u> total number of RNs
	Experience: Average years of RN organizational experience	RN organizational <u>experience total</u> total number of RNs
	Skillmix: Percentage of RNs to other nursing personnel	RN earned hours <u>(productive and nonproductive)</u> Total earned hours (RN + RPN/LPN + nonprofessional productive and nonproductive hours)
Intensity	# of RN FTEs	<u>RN worked (productive) hours</u> number of worked hours per year (Canada 1527; US 1768)
	RN to patient ratio	<u>RN worked (productive) hours</u> patient days x 24
	RN-HPPD	<u>RN worked (productive) hours</u> patient days

Table 2

Multiple Regression Models

Independent variables	Dependent variables	Coeff	Std. error	z	p value	95% conf. interval	Pseudo R ²
Model 1 – $p = .001$	MRSA						.25
LR $\chi^2(2) = 19.97$							
Active ingredient (ed/exp/sk)		-1.12	.51	-2.22	0.03	-2.13 - .13	
Intensity (fte/rnpratio/RN-HPPD)		-1.15	.31	-3.73	0.001	-1.76 - .55	
Model 2 – $p = .001$	Reported Falls						.18
LR $\chi^2(2) = 40.52$							
Active ingredient (edexpsk)		-.66	.15	-4.31	0.001	-.97 - .36	
Intensity (fte/rnpratio/RN-HPPD)		-.48	.12	-4.16	0.001	-.71 - .26	