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Abstract

Background

In March 2002 the Australian Industrial Relations Commission ordered the introduction of a new staffing method – nursing hours per patient day (NHPPD) – for implementation in Western Australia public hospitals. This method used a "bottom up" approach to classify each hospital ward into one of seven categories using characteristics such as patient complexity, intervention levels, the presence of high dependency beds, the emergency/elective patient mix and patient turnover. Once classified, NHPPD were allocated for each ward.

Objectives

The objective of this study was to determine the impact of implementing the NHPPD staffing method on 14 nursing-sensitive outcomes: central nervous system complications, wound infections, pulmonary failure, urinary tract infection, pressure ulcer, pneumonia, deep vein thrombosis, ulcer/gastritis/upper gastrointestinal bleed, sepsis, physiologic/metabolic derangement, shock/cardiac arrest, mortality, failure to rescue and length of stay.

Design and setting

The research design was an interrupted time series using retrospective analysis of patient and staffing administrative data from three adult tertiary hospitals in metropolitan Perth over a 4-year period.

Sample

All patient records (N = 236,454) and nurse staffing records (N = 150,925) from NHPPD wards were included.

Results

The study found significant decreases in the rates of nine nursing-sensitive outcomes when examining hospital-level data following implementation of NHPPD; mortality, central nervous system complications, pressure ulcers, deep vein thrombosis, sepsis, ulcer/gastritis/upper gastrointestinal bleed shock/cardiac arrest, pneumonia and average length of stay. At the ward level, significant decreases in the rates of five nursing-sensitive outcomes; mortality, shock/cardiac arrest, ulcer/gastritis/upper gastrointestinal bleed, length of stay and urinary tract infections occurred.

Conclusions

The findings provide evidence to support the continuation of the NHPPD staffing method. They also add to evidence about the importance of nurse staffing to patient safety; evidence that must influence policy. This study is one of the first to empirically review a specific nurse staffing method, based on an individual assessment of each ward to determine staffing requirements, rather than a "one-size-fits-all" approach.

What is already known about the topic?

• Higher nurse staffing levels have been linked with improved patient outcomes.

• This evidence has resulted in some states and jurisdictions legislating or mandating nurse staffing.

• The available evidence does not provide specific guidelines for nurse staffing, either in terms of the amount of care required or skill mix of the nurses providing care at a unit level.

What this paper adds

• This study empirically reviews a specific nurse staffing method, based on an individual assessment of each ward to determine staffing requirements, rather than a "one-size-fits-all" approach.

• It provides evidence that implementation of the NHPPD staffing method decreased nursing-sensitive outcomes and improved patient safety.

1. Introduction

One of the prime responsibilities of nurse leaders is to determine the most appropriate number and mix of nurse staffing to ensure safe patient care, while also maintaining an efficient and cost-effective nursing service. There is a growing body of evidence that implicates nurse staffing decisions in patient safety ([Kane et al., 2007a] and [Kane et al., 2007b]). The scrutiny under which these decisions are made has also intensified in the wake of decisions by funding bodies such as Medicare and Medicaid Services in the US, which no longer reimburse hospitals for patients who develop certain types of nursing-sensitive outcomes such as pressure ulcers, falls with injuries or nosocomial infections, i.e. conditions that did not exist when patients were admitted (Welton, 2008). In addition, no studies to date have "primarily empirically examined specific nurse staffing policy" ([Kane et al., 2007a] and [Kane et al., 2007b], p. 1).

In the late 1990s nurse staffing and workloads became a major industrial issue in Australia (2002, Australian Industrial Relations Commission, 2000). Nurses argued that they were unable to provide adequate patient care because poor staffing levels caused excessive workloads. This resulted in nursing workload becoming a key focus in negotiations around pay and employment conditions. Unions representing nurses argued for improved staffing levels to improve nursing workload (Australian Industrial Relations Commission, 2000) which led to the introduction of nurse-to-patient ratios in Victoria. In Western Australia (WA) these respective issues aligned in 2001 when nurses undertook unprecedented strike action. This industrial unrest initiated an arbitrated process to resolve the dispute and to address nurses' workloads in WA's public hospitals (Australian Industrial Relations Commission, 2002). In March 2002, the Australian Industrial Relations Commission (AIRC) ordered the implementation of the NHPPD staffing method to resolve the dispute between the government health industry and the Australian Nurses' Federation, representing public sector nurses in WA (Australian Industrial Relations Commission, 2002). The Commission's order was silent on skill mix.

The NHPPD staffing method used a "bottom up" approach to classify each hospital ward into one of seven categories. Characteristics such as patient complexity, intervention levels, the presence of high dependency beds, the emergency/elective patient mix and patient turnover were used to determine categories and the method has been described in detail previously (Twigg and Duffield, 2009). Once wards were classified, NHPPD were allocated. Improvements in staffing levels under the NHPPD method were substantial. There was an increase of 313.2 full time equivalent (FTE) nurses in wards across the state's public hospitals with most in the adult tertiary hospitals (88.9% of the total FTE nurses allocated) (Department of Health, 2005). Productive hours (nursing hours excluding annual leave, sick leave and other on costs) of permanent nurse staffing increased by 3.65% and use of agency nurses declined by 16.8% (Department of Health, 2006). The literature would suggest that such a significant increase in nursing hours would be associated with a decrease in nursing-sensitive outcomes ([Kane et al., 2007a], [Kane et al., 2007b] and [Pearson et al., 2006]). Interest in the method from other Australian State governments has resulted in the NHPPD staffing method being implemented in Tasmania and the Northern Territory. Its implementation in the Northern Territory was in direct response to a patient's death (Coroner's Court, 2008) where the coroner identified the need to determine nurse staffing using an evidence based-methodology. The cost of increase in FTE staffing following implementation of NHPPD in WA was estimated at AU$18,065,788 based on the average total cost of a nurse in June 2002 (Department of Health, 2006). Given this significant cost and the recognised international nursing shortage (Buchan and Aiken, 2008), it was crucial to determine how well the staffing method addressed patient safety (Twigg and Duffield, 2009).

The objective of this study was to determine the impact of implementing the NHPPD staffing method on the incidence of nursing-sensitive outcomes. This paper reports on the analyses of data from three adult tertiary hospitals in WA and provides evidence of the impact of the NHPPD staffing method on nursing-sensitive outcomes.

2. Methods

This study involved the analysis of a retrospective cohort of all multi-day stay patients admitted to the study hospitals over a 4-year period from July 2000 to June 2004 financial years, utilising hospital morbidity data to identify nursing-sensitive outcomes. The research design was an interrupted time-series study. A time-series study allows the researcher to determine the effect of a change to a system by evaluating what happened within the system after a change is implemented. An interrupted time series is used to determine if the interruption had an impact (Cook and Campbell, 1979). The interruption in this study occurred in March 2002 when approval was given for implementation of NHPPD in the public sector in WA. Implementation began in earnest in July 2002 at the commencement of a new financial year.

2.1. Setting

This study was set in the capital city of WA which is the largest state in Australia covering 2,645,600 km2, approximately four times the size of Texas. The population of WA was 2,204,000 in 2008, with over 1.2 million residing in metropolitan Perth, the capital (Australian Bureau of Statistics, 2008). The metropolitan area has three adult tertiary teaching hospitals with a total of 1449 beds. Collectively they provide a comprehensive range of clinical services including; trauma, emergency (except obstetrics), critical care, neurosurgery, interventional neuroradiology, cardiac, lung and liver transplants, orthopaedics, general medicine, general surgery, cardiac care, cancer services, hyperbaric services and rehabilitation services.

2.2. Data sources and procedures

The sample consisted of all multi-day patient separations and all patient days related to those separations in the three adult tertiary hospitals' NHPPD ward categories A, B, C and D. The sample also included nursing hours (total hours of nursing care) in the three adult tertiary hospitals' NHPPD ward categories A, B, C and D combined. In addition, one adult tertiary hospital provided ward level data that enabled the individual NHPPD ward category analysis. When patients were admitted to more than one ward, a fraction of the nursing-sensitive patient outcome was calculated based on the time spent in each ward, and outcomes were attributed to the wards proportionally.

Patient data were sourced from patient discharge abstracts extracted from the hospitals morbidity systems. Staff data were sourced from the Department of Health, Western Australia Human Resource Data Warehouse. All data were from the period 1st July 2000 until 30 June 2004, covering four financial years.

The sample was limited to three adult tertiary teaching hospitals as these hospitals received 88.9% of the staffing increases. As the study included all patients admitted to the study hospitals as a multi-day stay and all nursing hours on those wards it was not necessary to establish the study sample using power analysis. These hospitals were similar in nature and infrastructure, with comparable nursing support and commitment to teaching and research. In addition, these hospitals' funding arrangements were the same, and they shared the same issues in regard to government initiatives and reform (Health Reform Committee, 2004). The major adult tertiary teaching hospitals also had a high level of accuracy of case-mix data and data on nursing hours worked. The ward level analysis was limited to one hospital as it was the only one able to provide patient ward transfer data.

2.2.1. Data inclusion criteria

The study analysed patient outcome data derived from the coded patient discharge abstracts for multi-day patients in the study hospitals. Staff data analysed included all nursing hours (total hours of nursing care) by category of nurse in an associated cost centre broken down by registered and enrolled nurse (similar to a licensed practical or vocational nurse).

2.2.2. Data exclusion criteria

The patient data request excluded patient discharge abstracts with the following Major Diagnostic Category (MDC): Maternity (MDC 14), paediatric (age < 18 years), newborns (MCD 15), mental health (MDC 19) and substance abuse (MDC 20). The exclusion of these MDCs follows the processes used by Needleman et al. (2001) and McCloskey (2003). Separations and associated patient days, where the length of stay was greater than 90 days, were also excluded from the analysis as nursing-sensitive outcomes in this study related to adult acute tertiary separations. Separations with a length of stay greater than 90 days would not typically be considered as acute care stays (McCloskey, 2003). The staffing data request excluded all non-productive hours such as annual leave, long service leave and leave without pay.

2.2.3. Study variables

2.2.3.1. Nursing-sensitive outcomes

Nursing-sensitive outcomes are defined as a variable patient or family caregiver state, condition, or perception responsive to nursing intervention ([Irvine et al., 1998], [Johnson and Lass, 1997] and [Mass et al., 1996]). The nursing-sensitive outcomes in this study were derived according to the methodology developed by Needleman et al. (2001). Using algorithms that specified inclusion and exclusion criteria specific for that adverse outcome in order to identify only those patients who experienced a truly preventable adverse outcome rather than one associated with the disease process, they determined risk-adjusted cohorts of patients using a combination of International Classification Diseases (ICD)-9 codes, Diagnostic Related Groups (DRG's) and MDC, presence of a surgical procedure and age. The nursing-sensitive outcomes were (1) central nervous system (CNS) complications, (2) wound infections, (3) pulmonary failure, (4) urinary tract infection (UTI), (5) pressure ulcer, (6) pneumonia, (7) deep vein thrombosis, (8) ulcer/gastritis/upper gastrointestinal bleed, (9) sepsis, (10) physiologic/metabolic derangement, (11) shock/cardiac arrest, (12) mortality, (13) failure to rescue and (14) length of stay. Failure to rescue was defined as death of a patient who experienced a hospital-acquired complication. Surgical wound infections, pulmonary failure and physiologic/metabolic derangement were examined only for surgical patients. These were the outcome variables utilised in the study.

Needleman et al. (2001, p. 37) reviewed the literature to identify variables potentially useful for measuring nursing-sensitive outcomes. This list was referred to experts in the field to further refine and develop the list of nursing-sensitive outcomes. Then Needleman et al. developed algorithms using American ICD-9 codes for each outcome specifying the coding language and procedures for detecting the outcomes and calculating the rate for each measure. McCloskey (2003) subsequently developed “crosswalks” for each algorithm to translate (map) the work of Needleman et al. from the American ICD-9 to Australian/New Zealand ICD-10. These crosswalks have been used in three studies, McCloskey and Diers (2005) and (Duffield et al., 2009) and (Duffield et al., 2007). The ICD-9 to ICD-10 Crosswalksc were used in this study with permission.

2.2.3.2. Predictor variables

The predictor variables in the study were those nurse staffing characteristics that changed following the implementation of NHPPD, specifically nurse hours of care and skill mix (percentage of registered nurse hours). Skill mix results are not reported in this paper.

2.3. Data analysis

2.3.1. Preparation for inferential analysis

Two time-series data files were created and the incidence rate of nursing-sensitive outcomes calculated. The first file contained total figures for each of the three tertiary hospitals. The second file contained total figures for each of the four ward categories, A, B C and D, at one tertiary teaching hospital. Category A (7.5 NHPPD) included four wards, category B (6.0 NHPPD) had seven wards, category C (5.75 NHPPD) had three wards and category D (5.0 NHPPD) had two wards. One ward changed category during the study period, resulting in additional nursing hours and the creation of a new category named A+B (6.8 NHPPD). The data relating to this ward was included in category B during the period when it was a category B ward. No analysis of the new category A+B was included owing to the limited time series. Sixteen wards in total were included in this part of the study. Except for the inclusion of a hospital variable in the first file and a ward variable in the second file, all other study variables were the same in both files. These variables included 'group' which distinguished between medical (non-surgical) and surgical patients; 'stage' which identified three time periods: stage-0 pre-NHPPD implementation (time period 1–20 or the months from July 2000 until February 2002), stage-1 transition (time period 21–27) and stage-2 post-implementation (time period 28–48 or the months from October 2002 until June 2004); and 'season' with the months of December, January and February coded as summer; March, April and May autumn; June, July and August winter; and September, October and November spring.

2.3.2. Data analysis

Analyses were performed using SPSS for Windows Graduate Student Version, Rel, 15.0.0 2006, Chicago: SPSS Inc., and significance was set at 0.05. Demographic characteristics of the cohort were compared pre- and post-implementation of the NHPPD staffing model using Pearson chi-square tests and t-tests.

To address correlation within hospitals (or ward categories) for nursing-sensitive outcomes indicators 1–13, generalised estimating equations (GEE) were applied to Poisson regression models, in which total numbers of patients were used as offsets. For nursing-sensitive patient outcome 14, the generalised linear equation method (GLM) was used. The correlation structure over time between successive counts of each nursing-sensitive outcome was determined by a statistician to be autoregressive lag 1 (AR1) or independent, based on analysis of autocorrelation function and partial autocorrelation function graphs. To address the time-series structure of the data, all models were adjusted for season, time period and the square of time period (to account for non-linearity), time period/hospital (or ward) and time period squared/hospital (or ward) interactions. No adjustment was made for patient characteristics given the similarity in the gender, mean age and case-mix weights between the study hospitals.

The Poisson GEE models for nursing-sensitive outcomes indicators 1–13 were used to determine rate ratios (RR) that compared nursing-sensitive outcome incidence rates after implementation of the

NHPPD staffing method (stage-2) to pre-implementation (stage-0) incidence rates. For average length of stay, nursing-sensitive patient outcome 14, the generalised linear equation method (GLM) was used to determine mean changes in average length of stay from pre-implementation to post-implementation.

These statistical procedures were applied to both data files. As well as fitting models for each nursing-sensitive outcome to the combined hospital data, models were produced for each of the hospitals separately to identify differences between hospitals. This was done to take into account potential work environment characteristics that may have influenced results. Using the second data file, models were fitted for each of the ward categories. In category D wards the surgical CNS complication and ulcer/gastritis/upper gastrointestinal bleed rates could not be calculated as no nursing-sensitive outcomes were observed in stage-2 for surgical patients. Crude rate ratios were calculated for surgical shock/cardiac arrest, mortality and failure to rescue because there was insufficient data to satisfy convergence criteria in the multivariate models.

For both data files, the analysis of nursing-sensitive outcomes was undertaken in three groupings. Firstly, all patients were examined (all patients). Secondly, the medical subset of patients (medical patients) was examined and finally the surgical subset of patients (surgical patients) was examined. For the second data file, these analyses were repeated for each of the four ward categories A, B, C and D. These groupings were used as previous studies suggest differences between medical and surgical patients or the studies were limited to only one type of patient ([Aiken et al., 2002], [Needleman et al., 2002] and [Tourangeau et al., 2006]).

3. Results

3.1. Patient demographic data

All multi-day stay patients from the NHPPD multi-day ward categories A, B, C and D in the three adult teaching hospitals were included (52 wards). There were 236,454 patients in the study; 52.5% were male and 47.5% female; 23.8% were admitted electively and 76.2% admitted as emergencies. Age ranged from 18 to 106, and the average was 60.6 years. There were no significant differences in gender proportions between stage-0 and stage-2 ($p = 0.827$). However, the percentage of patients admitted as emergency admissions reduced significantly between stage-0 and stage-2 ($p < 0.001$). There were statistically significant increases in mean ages of patients between stage-0 and stage-2 (for combined hospitals, $p < 0.001$). However, the difference of 0.6 years overall would not be considered clinically relevant. There were also significant increases in DRG cost weights when comparing stage-0 and stage-2 (for combined hospitals $p < 0.001$) (refer Table 1).

Table 1. Comparison of patient demographic variables between stage-0 and stage-2.

Stage	Patient records	Gender		Mean age (years)	Admission type (%)		
		Male (%)	Female (%)		Elective	Emergency	DRG cost weight
Combined Hospitals							
Stage-0	98,215	52.5	47.5	60.2	22.9	77.1	2.08
Stage-2	103,330	52.5	47.5	60.8***	24.6	75.4***	2.16***
Hospital 1							
Stage-0	30,853	50	50	62.1	27.2	72.8	2.78
Stage-2	31,475	50.5	49.5	62.7***	28.2	71.8**	2.94***
Hospital 2							
Stage-0	25,336	52.4	47.6	60.9	27.4	72.6	2.37
Stage-2	26,592	52.2	47.8	61.6***	28.4	71.6**	2.63***
Hospital 3							
Stage-0	42,026	54.3	45.7	58.5	16.9	83.1	2.76
Stage-2	45,263	54.1	45.9	58.9***	19.9	80.1***	3.04**

Key: DRG cost weight = Diagnostic Related Group cost weight.

** $p \leq 0.01$.
*** $p \leq 0.001$.

3.2. Staffing demographics, nursing hours

The total nursing hours in the study wards increased over the 4-year period from 58,420 h in 2000/2001 to 69,327 h in 2003/2004, an increase of 10,907 h. The total registered nurse (RN) hours also increased over the 4 years; however, when RN hours were examined as the percentage of the total nursing hours (skill mix), they fell from 87.0% to 83.8%, a decrease of 3.2%. Although the nursing hours increased for all three hospitals in stage-2, the changes were not statistically significant ($p = 0.616$). Further analysis of the NHPPD by ward category in one adult tertiary hospital demonstrated an increase in nursing hours in stage-2 in category A, B and D. Category C wards experienced a decrease in hours in stage-2 however, these changes were not statistically significant.

3.3. The impact of NHPPD staffing method on nursing-sensitive outcomes

Changes in nursing-sensitive outcomes were examined comparing the pre-NHPPD implementation stage-0 (the months from July 2000 until February 2002) and the post-implementation stage-2 (the months from October 2002 until June 2004) (refer Table 2). For all patients and for medical and surgical patients the death rate decreased significantly post-interruption in stage-2, i.e. the death rate for all patients was 25% lower (RR 0.75) in stage-2 compared to stage-0. In surgical patients CNS complication, pneumonia and ulcer/gastritis/upper gastrointestinal bleed rates significantly decreased in stage-2.

Table 2. Rate ratios comparing rates in stage-2 to stage-0 for nursing-sensitive outcomes 1–13 and the changes in average length of stay for nursing-sensitive outcome 14 for hospitals all, medical and surgical patients.

Patient	Combined hospitals	Hospital 1	Hospital 2	Hospital 3
CNS complications (NSO 1)				
All	1.03 (0.74, 1.44)	0.71 (0.38, 1.33)	1.31 (0.67, 2.57)	1.03 (0.62, 1.69)
Medical	1.31 (0.89,1.92)	0.76 (0.36, 1.61)	1.90 (0.91, 3.96)	1.40 (0.80, 2.46)
Surgical	0.46* (0.23, 0.92)	0.58 (0.18, 1.86)	1.31 (0.67, 2.57)	0.42 (0.15, 1.18)
Surgical wound infections (NSO 2)				
Surgical	1.20 (0.94, 1.54)	1.32 (0.85, 2.04)	0.87 (0.52, 1.45)	1.31 (0.92, 1.88)
Pulmonary failure (NSO 3)				
Surgical	1.02 (0.73, 1.44)	0.77 (0.45, 1.32)	1.14 (0.50, 2.60)	1.34 (0.79, 2.27)
Urinary tract infections (NSO 4)				
All	1.00 (0.87, 1.15)	0.90 (0.76, 1.08)	1.01 (0.83, 1.24)	1.07 (0.88, 1.29)
Medical	1.00 (0.84, 1.19)	0.87 (0.72, 1.04)	0.94 (0.74, 1.20)	1.06 (0.86, 1.32)
Surgical	1.07 (0.89, 1.30)	0.97 (0.70, 1.33)	1.02 (0.83, 1.25)	1.10 (0.80, 1.56)
Pressure ulcer (NSO 5)				
All	0.98 (0.68, 1.41)	1.65 (0.99, 2.73)	0.73 (0.47, 1.15)	0.67 (0.44, 1.03)
Medical	1.06 (0.67, 1.66)	1.69 (0.87, 3.29)	1.00 (0.57, 1.78)	0.51* (0.29, 0.91)
Surgical	0.84 (0.56, 1.26)	1.62 (0.74, 3.54)	0.46* (0.23, 0.91)	0.96 (0.51, 1.82)
Pneumonia (NSO 6)				

Patient	Combined hospitals	Hospital 1	Hospital 2	Hospital 3
All	0.95 (0.79, 1.14)	1.08 (0.82, 1.41)	0.98 (0.75, 1.28)	0.75* (0.60, 0.95)
Medical	1.07 (0.83, 1.36)	1.19 (0.83, 1.72)	1.22 (0.85, 1.76)	0.77 (0.56, 1.07)
Surgical	0.83* (0.70, 0.99)	0.96 (0.66, 1.37)	0.94 (0.73, 1.21)	0.79 (0.58, 1.07)
DVT (NSO 7)				
All	1.01 (0.75, 1.36)	1.29 (0.79, 2.10)	1.15 (0.68, 1.93)	0.63 (0.37, 1.07)
Medical	1.23 (0.85, 1.79)	1.39 (0.75, 2.57)	1.55 (0.83, 2.88)	0.91 (0.46, 1.79)
Surgical	0.70 (0.43, 1.15)	1.15 (0.52, 2.57)	1.15 (0.68, 1.93)	0.41* (0.17, 0.96)
Ulcer/gastritis/UGI bleed (NSO 8)				
All	0.76 (0.55, 1.04)	0.72 (0.49, 1.07)	0.89 (0.57, 1.38)	0.80 (0.51, 1.24)
Medical	0.83 (0.62, 1.11)	1.16 (0.71, 1.88)	0.73 (0.43, 1.22)	0.61 (0.37, 1.01)
Surgical	0.63* (0.43, 0.92)	0.41** (0.21, 0.80)	0.89 (0.56, 1.42)	1.06 (0.49, 2.28)
Sepsis (NSO 9)				
All	0.80 (0.64, 1.01)	1.15 (0.82, 1.62)	0.58** (0.37, 0.89)	0.68* (0.47, 0.96)
Medical	0.80 (0.57, 1.10)	1.20 (0.69, 2.11)	0.79 (0.43, 1.48)	0.54* (0.31, 0.92)
Surgical	0.82 (0.61, 1.10)	1.10 (0.68, 1.77)	0.58** (0.37, 0.89)	0.93 (0.59, 1.47)
Physiologic/metabolic derangement (NSO 10)				
Surgical	1.14 (0.93, 1.40)	1.04, (0.74, 1.46)	2.19*** (1.38, 3.48)	0.93 (0.68, 1.26)
Shock/cardiac arrest (NSO 11)				
All	0.91 (0.62, 1.35)	0.44** (0.24, 0.83)	1.84 (0.94, 3.6)	1.26 (0.74, 2.17)
Medical	0.82 (0.46, 1.45)	0.37* (0.16, 0.87)	0.97 (0.36, 2.62)	1.55 (0.68, 3.54)
Surgical	1.05 (0.64, 1.71)	0.55 (0.22, 1.37)	1.94 (0.69, 5.43	1.15 (0.52, 2.51)
Mortality (NSO 12)				
All	0.75*** (0.66, 0.87)	0.74** (0.59, 0.91)	0.81 (0.64, 1.02)	0.71*** (0.58, 0.86)
Medical	0.76*** (0.64, 0.90)	0.76* (0.60, 0.96)	0.84 (0.65, 1.09)	0.66*** (0.53, 0.82)

Patient	Combined hospitals	Hospital 1	Hospital 2	Hospital 3
Surgical	0.75* (0.59, 0.96)	0.66 (0.43, 1.04)	0.66 (0.41, 1.07)	0.89 (0.63, 1.28)
Failure to rescue (NSO 13)				
All	1.05 (0.85, 1.29)	0.91 (0.63, 1.32)	1.22 (0.82, 1.82)	1.10 (0.78, 1.55)
Medical	1.03 (0.78, 1.35)	1.05 (0.65, 1.68)	1.33 (0.82, 2.18)	0.85 (0.54, 1.31)
Surgical	1.08 (0.78, 1.52)	0.74 (0.41, 1.32)	0.98 (0.56, 1.93)	1.52 (0.91, 2.54)
Average length of stay (NSO 14)				
All	†−0.36 (−0.36, 0.25)	†0.44 (0.33, 0.91)	†−0.08 (−0.52, 0.36)	†−0.43 (−0.086, 0.01)
Medical	†0.06 (−0.32, 0.44)	†0.81** (0.17, 1.14)	†0.05 (−0.56, 0.66)	†−0.67* (−1.27, −0.06)
Surgical	−0.18 (−0.62, 0.27)	0.11 (−0.75, 0.54)	†−0.40 (−1.14, 0.34)	†−0.02 (−0.76, 0.71)

Key: Exp(B) = incidence-rate ratio; †B = maximum likelihood estimate; NSO = nursing-sensitive patient outcome.

* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

In Hospital 1 three nursing-sensitive indicators significantly decreased in stage-2 and one indicator increased significantly. In surgical patients the rate of ulcer/gastritis/upper gastrointestinal bleeds decreased. Shock/cardiac arrest and mortality rates decreased in all patients and the medical subset of patients post-interruption in stage-2. The average length of stay for medical patients increased by an average of 0.81 days. In Hospital 2 two outcomes decreased significantly in stage-2 while one outcome increased significantly. In all patients and the surgical subset of patients, sepsis rates decreased significantly post-interruption. Surgical patients also experienced significantly lower pressure ulcer rates. Hospital 2 had the highest overall rate of pressure ulcers when comparing hospitals. Surgical patients also experienced a significant increase in physiologic/metabolic derangement with a 2.19 fold increase in the rate. The rates of six nursing-sensitive outcomes in Hospital 3 decreased significantly. All patients had lower rates of pneumonia, sepsis and mortality. Medical patients had lower rates of pressure ulcers, sepsis, mortality and length of stay decreased by 0.67 days on average. Surgical patients had lower rates of deep vein thrombosis.

When examining ward categories A, B, C and D (refer Table 3), three nursing-sensitive outcome indicators changed significantly in category A ward (7.5 NHPPD) patients. Shock and cardiac arrest decreased in all patients and medical patients in stage-2. The rates of ulcer/gastritis/upper gastrointestinal bleeds also decreased in surgical patients in stage-2. The rate of pressure ulcers increased in all patients.

Table 3. Effect of stage summarised by nursing-sensitive outcome, incidence-rate ratio (95% CI) and change in average length of stay (†).

Patient	Category A	Category B	Category C	Category D
CNS complications (NSO 1)				
All	0.98 (0.42, 2.26)	0.62 (0.31, 1.24)	0.85 (0.39, 1.89)	0.82 (0.30, 2.21)
Medical	1.05 (0.37, 2.97)	0.64 (0.28, 1.44)	1.14 (0.42, 3.08)	0.85 (0.29, 2.49)
Surgical	0.64 (0.19, 2.17)	0.92 (0.31, 2.70)	1.55 (0.46, 5.24)	+
Surgical wound infections (NSO 2)				
Surgical	1.51 (0.93, 2.44)	1.20 (0.74, 1.96)	0.94 (0.52, 1.72)	1.83 (0.64, 5.25)
Pulmonary failure (NSO 3)				
Surgical	0.77 (0.43, 1.38)	0.56 (0.30, 1.05)	1.39 (0.63, 3.04)	0.70 (0.23, 2.12)
Urinary tract infections (NSO 4)				
All	0.82 (0.65, 1.03)	0.82 (0.67, 1.01)	0.97 (0.77, 1.22)	0.75* (0.59, 0.95
Medical	0.81 (0.60, 1.10)	0.78* (0.62, 0.98)	0.95 (0.71, 1.26)	0.68** (0.52, 0.90)
Surgical	0.84 (0.58, 1.23)	0.85 (0.58, 1.25)	0.99 (0.68, 1.44)	0.92 (0.54, 1.57)
Pressure ulcer (NSO 5)				
All	1.94* (1.01, 3.74)	1.40 (0.75, 2.61)	1.80 (0.99, 3.25)	0.82 (0.44, 1.53)
Medical	1.53 (0.60, 3.88)	1.17 (0.52, 2.64)	3.15** (1.37, 7.27)	0.71 (0.32, 1.54)
Surgical	2.41 (0.94, 6.19)	2.10 (0.78, 5.61)	1.12 (0.47, 2.69)	1.17 (0.32, 4.23)
Pneumonia (NSO 6)				
All	1.00 (0.74, 1.35)	0.92 (0.70, 1.20)	1.20 (0.86, 1.66)	1.48 (0.97, 2.26)
Medical	1.04 (0.63, 1.17)	0.91 (0.63, 1.32)	1.35, (0.86, 2.12)	1.50 (0.90, 2.49)
Surgical	1.03 (0.69, 1.54)	0.87 (0.57, 1.32)	0.99 (0.61, 1.60)	1.11 (0.44, 2.83)
DVT (NSO 7)				
All	0.98 (0.55, 1.76)	1.32 (0.78, 2.44)	1.58 (0.83, 2.99)	3.39 (1.15, 9.96)

Patient	Category A	Category B	Category C	Category D
Medical	0.93 (0.43, 1.98)	1.30 (0.68, 2.49)	1.97 (0.84, 4.64)	3.00 (0.87, 10.28)
Surgical	1.05 (0.42, 2.61)	1.23 (0.49, 3.08)	1.09 (0.41, 2.87)	3.61 (0.33, 39.31)
Ulcer/gastritis/UGI bleed (NSO 8)				
All	0.85 (0.54, 1.34)	0.76 (0.51, 1.10)	0.87 (0.53, 1.42)	0.81 (0.39, 1.69)
Medical	0.90 (0.40, 2.07)	1.32 (0.79, 2.20)	1.49 (0.79, 2.82)	0.98 (0.43, 2.23)
Surgical	0.42* (0.18, 0.97)	1.16 (0.92, 1.31)	2.38* (1.03, 5.51)	+
Sepsis (NSO 9)				
All	1.56 (0.93, 2.62)	0.85 (0.53, 1.35)	1.19 (0.69, 2.05)	1.36 (0.66, 2.80)
Medical	1.38 (0.62, 3.08)	0.97 (0.51, 1.86)	1.25 (0.58, 2.69)	1.45 (0.61, 3.48)
Surgical	1.56 (0.88, 2.76)	0.79 (0.44, 1.42)	1.09 (0.51, 2.36)	1.57 (0.28, 8.74)
Physiologic/metabolic derangement (NSO 10)				
Surgical	1.28 (0.88, 1.85)	0.98 (0.66, 1.45)	0.94 (0.60, 1.47)	0.76 (0.31, 1.83)
Shock/cardiac arrest (NSO 11)				
All	0.42* (0.19, 0.89)	0.43** (0.22, 0.81)	0.61 (0.25, 1.50)	0.33 (0.07, 1.48)
Medical	0.16** (0.05, 0.59)	0.37* (0.15, 0.93)	0.50 (0.15, 1.65)	0.25 (0.04, 1.66)
Surgical	1.13 (0.34, 3.72)	1.81 (0.55, 6.00)	0.89 (0.27, 2.91)	++0.45 (0.04, 5.01)
Mortality (NSO 12)				
All	0.80 (0.61, 1.05)	0.72** (0.57, 0.91)	0.72* (0.55, 0.94)	1.01 (0.66, 1.55)
Medical	0.78 (0.56, 1.08)	0.74* (0.57, 0.97)	0.69* (0.51, 0.95)	1.09 (0.68, 1.74)
Surgical	1.06 (0.66, 1.69)	1.19 (0.74, 1.93)	0.95 (0.59, 1.51)	++0.52 (0.15, 1.77)
Failure to rescue (NSO 13)				
All	1.04 (0.66, 1.65)	0.81 (0.54, 1.22)	0.99 (0.61, 1.61)	1.27 (0.64, 2.52)
Medical	0.94 (0.48, 1.87)	0.97 (0.58, 1.62)	1.02 (0.54, 1.91)	1.66 (0.76, 3.64)
Surgical	1.29 (0.64, 2.57)	1.87 (0.92, 3.80)	0.78 (0.39, 1.56)	++0.61 (0.10, 3.62)

Patient	Category A	Category B	Category C	Category D
Average length of stay (NSO 14) (†)				
All	1.58 (−0.35, 3.5)	1.06 (−0.87, 2.98)	1.28 (−0.65, 3.20)	−2.19* (−3.91, −0.47)
Medical	0.88 (−1.21, 2.96)	0.74 (−1.35, 2.83)	1.27 (−0.82, 3.36)	−2.26* (−4.11, −0.41)
Surgical	1.98 (−0.60, 4.55)	−0.92 (−2.16, 3.99)	0.91 (−1.67, 3.48)	−3.47* (−6.54, −0.39)

Key: † = change in average length of stay; NSO = nursing-sensitive patient outcome.

Note: + unable to calculate as no nursing-sensitive outcomes were observed in stage-2. ++ crude (unadjusted) rate ratios were calculated as there was insufficient data to satisfy convergence criteria in the multivariate model.

* p ≤ 0.05.
** p ≤ 0.01.

In category B wards (6 NHPPD) three nursing-sensitive outcomes decreased significantly. Shock and cardiac arrest rates and mortality rates declined in all patients and medical patients. In medical patients, urinary tract infection rates decreased.

In category C wards (5.75 NHPPD) mortality rates decreased significantly in all patients and medical patients significantly. On the other hand, pressure ulcer rates increased significantly in medical patients. Surgical patients' ulcer/gastritis/upper gastrointestinal bleed rates also increased.

In category D wards (5 NHPPD) three nursing-sensitive outcomes changed. All patients and medical patients experienced significant decreases in urinary tract infection rates. Average length of stay decreased significantly in each patient group. On the other hand, deep vein thrombosis rates increased significantly in all patients.

4. Conclusions

This study demonstrates that the increases in nurse hours after implementation of the NHPPD staffing method, which was designed to address nursing workload, improved a number of patient outcomes. The increase in nursing hours following implementation was significantly associated with a 25–26% decrease in mortality rates. In addition, surgical patients had a 54% drop in central nervous system complication rates, a 17% decrease in pneumonia, and a 37% reduction in ulcer/gastritis/upper gastrointestinal bleed rates. These significant improvements in patient outcomes are also shown when each hospital's combined ward categories were analysed, with improvements in eight nursing-sensitive outcomes. Patients had significant decreases in the rates of mortality (26% Hospital 1, 29% Hospital 3), shock/cardiac arrest (56% Hospital 1), pneumonia (25% Hospital 3), and sepsis (42% Hospital 2, 32% Hospital 3) after implementation of the NHPPD staffing method. The medical subset of patients also had significant reductions in the rates of mortality (24% Hospitals 1 and 3), shock/cardiac arrest (63% Hospital 1), pressure ulcer rates (49% Hospital 3), sepsis (46% Hospital 3), and average length of stay (0.67 of a day Hospital 3). The surgical subset of patients also had a significant drop in rates of ulcers/gastritis/upper gastrointestinal bleeds (56%

Hospital 1), pressure ulcers (54% Hospital 2), sepsis (42% Hospital 2), and deep vein thrombosis (59% Hospital 3). These findings suggest increasing nursing hours may deliver better patient outcomes. Variability between hospitals also suggests other factors, such as the work environment, may also have an impact on the findings.

The analysis of ward categories demonstrates improved patient outcomes at ward level, with significant decreases in the rates of five nursing-sensitive outcome indicators in stage-2 following implementation of NHPPD. The increase in the rates of three nursing-sensitive outcome indicators may be a consequence of the significant increase in DRG weight experienced in stage-2 of the study and possible increasing patient complexity and co-morbidity over the study period. However, as the DRG weight was not included in the modelling this cannot be determined. Increases in nursing hours prescribed under the mandated NHPPD staffing method were associated with improved patient outcomes.

These findings support the value of increased surveillance of patients by nurses to reduce death and adverse events as found by others ([Aiken et al., 2003], [Aiken et al., 2002], [Needleman et al., 2002] and [Tourangeau et al., 2006]). Other published evaluations of the mandated nurse-to-patient ratios in California (where minimum ratios were established by type of unit, for example medical–surgical units), found no evident change in adverse events or patient length of stay ([Bolton et al., 2007], [Donaldson et al., 2005] and [Spetz et al., 2009]).

This study has a number of strengths including extensive and careful data cleansing, accurate and reliable case-mix data and accurate nursing hours allocated at ward level. The nursing-sensitive outcomes were based on a carefully considered methodology (Needleman et al., 2001). In addition, this study was able to match nursing hours to specific wards and then match wards to the NHPPD ward category. However, a more complex individual measure of patient risk aggregated by hospital may have strengthened the study. It may also have assisted in explaining the variation between hospitals and ward categories. Mortality in this study was defined as a death that occurred while admitted in hospital as part of the episode of care. If patients were discharged to other settings and subsequently died from a complication related to that admission, the death was not captured in the study. Consequently, the mortality rate may be lower than if 30-day mortality were utilised. However, it is the surveillance role of nurses providing acute care that, when required, rescues the patient from deterioration (Aiken, 2002). In this context, death outside the hospital is possibly less relevant to the study outcomes.

In conclusion, this study found an association between implementing the NHPPD staffing method in WA public hospitals (and the associated increase in nursing hours) and improvements in patient safety. Specifically, when examining hospital-level data, there have been significant reductions in the rates of nine nursing-sensitive patient outcome indicators following implementation of NHPPD. Seven significant reductions in the rate of mortality occurred following implementation of the NHPPD staffing method, four significant reductions in the rates of sepsis occurred, two significant reductions in the rates of pressure ulcers, pneumonia, ulcer/gastritis/upper gastrointestinal bleeds, shock/cardiac arrest, and length of stay occurred and one significant reduction in the rate of CNS complications and deep vein thrombosis occurred. At ward or unit level there have been significant reductions in the rates of five nursing-sensitive outcome indicators following implementation of NHPPD. Four significant reductions in mortality and shock/cardiac arrest occurred, three significant reductions in urinary tract infections and length of stay occurred, and two significant reductions in ulcer/gastritis/upper gastrointestinal bleeds and pressure ulcers occurred following implementation of NHPPD.

These findings are also consistent with other studies ([Duffield et al., in press] and [McCloskey and Diers, 2005]) where nursing-sensitive outcomes were used. Specifically these studies also found CNS complications, urinary tract infections, pressure ulcers, pneumonia, ulcer/gastritis/upper gastrointestinal bleeds, sepsis, physiologic/metabolic derangement and shock/cardiac arrest were significantly associated with changes in nurse staffing. These studies had similar variation and not all of the 14 nursing-sensitive outcomes had significant changes. Finally, the NHPPD method is silent on skill mix which is also an important determinant of patient outcomes ([Needleman et al., 2002] and [Tourangeau et al., 2006]) and warrants further examination.

While the debate continues in regard to the benefits or otherwise of mandated nurse staffing ([Bolton et al., 2007], [Donaldson et al., 2005], [Seago, 2002] and [Sochalski et al., 2008]), this study suggests that the introduction of minimum staffing levels through an arbitrated process, linked to individual ward categories developed in the NHPPD staffing method, may improved patient outcomes over time. From a policy perspective some authors have argued that it is premature to mandate minimum staffing levels ([Gerdtz and Nelson, 2007], [Lang et al., 2004] and [Mark et al., 2007]). Yet, the literature has demonstrated that the levels of nurse staffing and the skill mix of those nurses in hospitals remain the most persistent and prominent nursing organisational characteristics for predicting patient outcomes ([Kane et al., 2007a] and [Kane et al., 2007b]). This study supports increased nursing hours achieved through a mandated staffing method, NHPPD benefits patient safety even though the staffing method could be further refined. Accepted staffing norms, based on evidence, would improve patient safety. It is time to act and implement mandated staffing based on the evidence to date. These methods then need thorough evaluation over time to refine them and to understand what might be driving the variations in some nursing-sensitive outcomes.

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