[redacted]

Hi Lynette,

Following my meeting today with the Health and Ambulance Services Committee I have attached further information that was requested during the meeting

Regards,

Di

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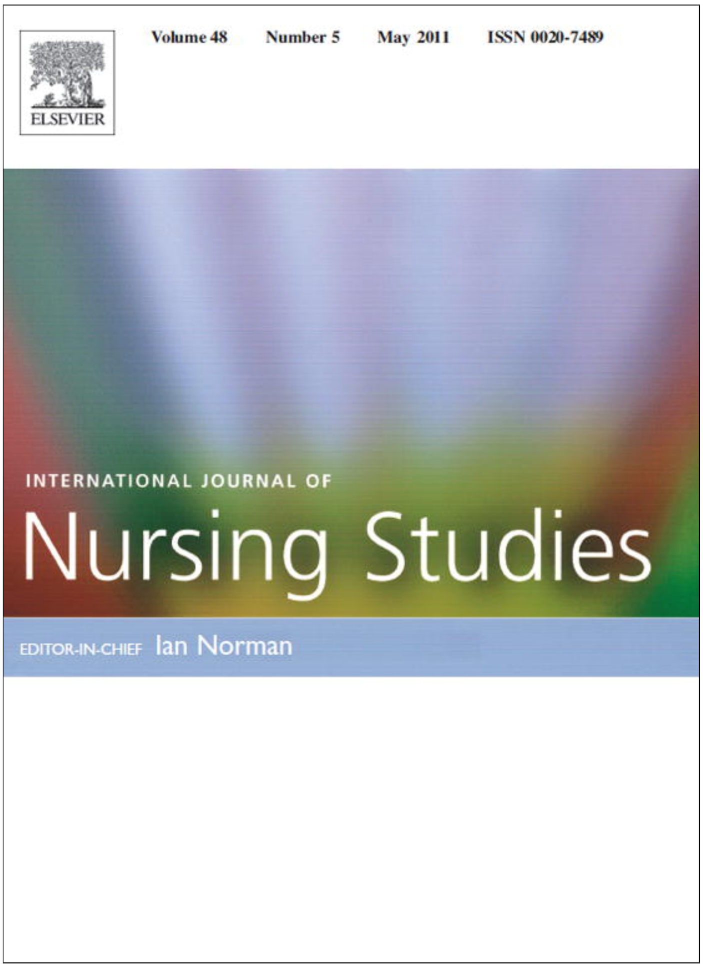

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The impact of the nursing hours per patient day (NHPPD) staffing method on patient outcomes: A retrospective analysis of patient and staffing data

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A B S T R A C T

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

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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.
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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,b). 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,b, 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,b; 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

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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 km^2, 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; 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)

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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, 2007). The ICD-9 to ICD-10 Crosswalks[c] 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

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

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; 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).

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.

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.

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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)				
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)
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.
* $p \le 0.05$.
** $p \le 0.01$.
*** $p \le 0.001$.

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.

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

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

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

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(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, 2002; Needleman et al., 2002; 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; 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; 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; 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; 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; 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,b). 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

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refine them and to understand what might be driving the variations in some nursing-sensitive outcomes.

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ORIGINAL RESEARCH

Impact of skill mix variations on patient outcomes following implementation of nursing hours per patient day staffing: a retrospective study

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Abstract

Aims. This article is a report of a study of the association between skill mix and 14 nursing sensitive outcomes following implementation of the nursing hours per patient day staffing method in Western Australian public hospitals in 2002, which determined nursing hours by ward category but not skill mix.

Background. Findings from previous studies indicate that higher nurse staffing levels and a richer skill mix are associated with improved patient outcomes. Mea suring skill mix at a hospital level for specific staffing methods and associated nursing sensitive patient outcomes are important in providing staffing for optimal patient care.

Design. The research design for the larger study was retrospectively analysing patient and staffing administrative data from three adult tertiary hospitals in metropolitan Perth over 4 years.

Methods. A subset of data was used to determine the impact of skill mix on nursing sensitive outcomes following implementation of the staffing method. All patient records (*N* 103,330) and nurse staffing records (*N* 73,770) from nursing hours per patient day wards from October 2002 June 2004 following implemen tation were included.

Results. Increases in Registered Nurse hours were associated with important decreases in eight nursing sensitive outcomes at hospital level and increases in three nursing sensitive outcomes. The lowest skill mix saw the greatest reduction in nursing sensitive outcome rates.

Conclusions. The skill mix of nurses providing care could impact patient outcomes and is an important consideration in strategies to improve nurse staffing. Levels of hospital nurse staffing and skill mix are important organizational characteristics when predicting patient outcomes.

Keywords: healthcare quality, health policy, nurse, nurses, patient outcomes, skill mix, staffing

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Introduction

The nurse hours per patient day (NHPPD) staffing method was introduced in the Western Australian (WA) public sector in March 2002 and it remains in effect today. This method used a 'bottom up' approach to classify each hospital ward into one of seven categories using characteristics such as patient complexity, nursing intervention levels, the presence of a high dependency unit, the emergency/elective patient mix and patient turnover. Once wards were classified, average NHPPD values were prescribed for each ward. Shift to shift variations in nursing hours were still possible under the method as it focussed on average hours for a ward or unit over time (Twigg & Duffield 2009).

Evaluation of the NHPPD staffing method found impor tant decreases in the rates of nine nursing sensitive outcomes when examining hospital level data following its implemen tation. These were mortality, central nervous system compli cations, pressure ulcers, deep vein thrombosis, sepsis, ulcer/gastritis/upper gastrointestinal bleed shock/cardiac arrest, pneumonia and average length of stay (Twigg & Duffield 2009, Twigg *et al.* 2011). At the ward level, important decreases in the rates of five nursing sensitive outcomes; mortality, shock/cardiac arrest, ulcer/gastritis/upper gastro intestinal bleed, length of stay and urinary tract infections (UTIs) were found.

In its order to implement NHPPD, the Australian Industrial Relations Commission, however, was silent on nursing skill mix. Since the order was given in 2002, a systematic review identified higher Registered Nurse (RN) staffing as an important determinant of patient safety (Kane *et al.* 2007a). It suggested that the proportion of total nursing hours provided by RNs (skill mix) should have been included in the staffing method. The purpose of this article is to report on the association between skill mix, defined as the proportion of total nurse hours provided by RNs (Needleman *et al.* 2002) and nursing sensitive outcomes following implementation of the NHPPD staffing method.

Background

Several studies have explored the relationship between skill mix and patient outcomes. A review of the quality of care for the treatment of acute medical conditions in hospitals in the USA examined quality of care for acute myocardial infarction, congestive heart failure and pneumonia (Landon *et al.* 2006). This study found that higher RN staffing patterns were associated with higher quality of care. In contrast, increased licensed practical nurse staffing was associated with lower quality of care. RN hours and the proportion of RNs were also found to have an important inverse relationship with the incidence of pneumonia (Cho *et al.* 2003). An increase of one RN hour resulted in a 0·23% decrease in the risk of pneumonia and a 10% increase in the proportion of RNs was associated with a 9·5% drop in the risk of pneumonia.

The growing body of evidence was mostly produced in the USA and was less accepted outside the USA healthcare system until several international studies were published. Estabrooks *et al.* (2005) examined 18,142 patient outcomes from 49 acute care hospitals in Alberta, Canada and found mortality varied significantly across hospitals. Age and patient co morbidities explained 44·2% of the variation in mortality and four nursing characteristics explained a further 36·9%. The four nursing characteristics were: nurse education hospitals with a higher proportion of baccalaureate prepared nurses were associated with lower rates of 30 day mortality; skill mix hospitals with a higher proportion of RNs compared to non RNs were associated with lower rates of 30 day mortality; employment status hospitals with a higher proportion of casual and temporary nurses were associated with higher rates of 30 day mortality; and nurse physician relationships hospitals with higher scores on collaborative nurse physician relationships were associated with lower rates of 30 day patient mortality. Higher per centages of RN staff, higher percentages of baccalaureate prepared nurses and higher nurse reported adequacy of staffing and resources were also associated with lower 30 day mortality rates in medical patients in Canada (Tourangeau *et al.* 2007). A higher proportion of RNs in the staff mix was associated with lower medication error rates and lower wound infection rates (Hall *et al.* 2004). These studies support the USA findings and give additional evidence that baccalaureate prepared nurses and a higher proportion of RNs are associated with improved patient outcomes (Hall *et al.* 2004, Estabrooks *et al.* 2005, Tourangeau *et al.* 2007).

In Australia, a study in Queensland surveyed 2800 nurses with a response rate of 53%. The study showed that over 50% of aged care nurses, 32% of nurses working in the public sector and 30% of nurses working in the private sector

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identified difficulties in meeting patient needs because of insufficient staffing levels and a poor skill mix (Hegney *et al.* 2003). More recently, a large New South Wales study (Duffield *et al.* 2007) undertaken over 5 years examined 80 hospitals and 286 wards to determine the association of nursing workload and skill mix with patient outcomes. This study found that a higher proportion of RNs was associated with important decreases in pressure ulcers, gastrointestinal bleeding, sepsis, shock, physiological/metabolic derangement and pulmonary failure. In contrast, this same study found increased rates of deep vein thrombosis with improved skill mix. It could be argued that this finding may relate to better assessment and detection with a richer skill mix. Skill mix was more critical than hours of care in regard to improvements in nursing sensitive outcomes (Duffield *et al.* 2007).

Finally, a recent comprehensive systematic review found that every additional RN full time equivalent per patient day was associated with a 16% reduced risk of mortality in surgical patients (Kane *et al.* 2007a). One additional RN hour per day was also associated with reductions in hospital acquired pneumonia (4%), pulmonary failure (11%), failure to rescue in surgical and medical patients (1%) and deep vein thrombosis in medical patients (2%). On the other hand, every additional patient per RN per shift was associated with a 7% increase in pneumonia, a 53% increase in pulmonary failure and a 17% increase in medical complications (Kane *et al.* 2007a). This systematic review suggests that the association between skill mix and patient outcomes is an international phenomenon and policy should give consider ation to skill mix when mandating nursing hours.

The study

Aim

The aim of the study was to determine any association between skill mix and patient outcomes following implemen tation of the NHPPD staffing method in three adult tertiary hospitals in Western Australia.

Design

The research design was an interrupted time series using retrospective analysis of patient and staffing administrative data.

Participants and data collection

The study was set in the capital city of Perth, WA and the sample consisted of all multi day patient separations and all patient days related to those separations in three adult tertiary teaching hospitals. Details of the study setting, data sources and procedures, data inclusion and exclusion criteria and measurement of patient outcomes have been published previously (Twigg *et al.* 2011). This component of the larger study involved the analysis of a retrospective cohort of all multi day stay patients admitted to the study hospitals following implementation of the NHPPD staffing method over 20 months (October 2002 June 2004) utilizing hospital morbidity data to identify nursing sensitive outcomes.

Study variables

Nursing sensitive outcome variables

The nursing sensitive outcome variables were: (1) central nervous system (CNS) complications; (2) wound infections; (3) pulmonary failure; (4) UTI; (5) pressure ulcer; (6) pneu monia; (7) deep vein thrombosis; (8) ulcer/gastritis/upper gastrointestinal bleed; (9) sepsis; (10) physiological/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, pulmo nary failure and physiological/metabolic derangement were examined only for surgical patients.

Predictor variable

The predictor variable of interest in this aspect of the study was skill mix. Skill mix was defined as the proportion of total nurse hours provided by Registered Nurses expressed as a percentage. Changes in rates of nursing sensitive outcomes following implementation of the NHPPD staffing method were examined to determine if skill mix had a statistically significant association.

Ethical considerations

The study was approved by the ethics committees of the university and the hospitals.

Data analysis

In preparation for inferential analysis a time series data file was created containing the incidence rate of nursing sensitive outcomes for each of the three tertiary hospitals (Twigg *et al.* 2011). Each time period was one calendar month. SPSS for Windows Graduate Student Version, Rel, 15.0.0 2006; SPSS Inc., Chicago, IL, USA was used for data analysis and the significance level was set at 0·05. A regression approach was used to analyse the time series. The basic goal of the

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regression was to find a formula that forecast each rate in the time series accurately from the preceding entries. A Poisson Generalized Estimating Equations (GEE) approach was used to estimate the parameters because this method took into account the correlation of data in each hospital. Poisson regression is the most appropriate multiple regression to use when the dependent variable is a rate and there is a need to adjust for other covariates (Katz 2006). Correlation over time of each nursing sensitive outcome was checked using auto correlation plots to determine whether it was more appro priate to use a regression model with first order autoregressive errors (AR1) or an independent correlation structure and the appropriate structure was entered into the Poisson GEE model specification. The GEE models were used to model the number of cases of each nursing sensitive patient outcome 1 13 (the dependent variable) using the total number of patients in each time period as an offset variable. As is customary in all types of regression, the Poisson models also included a constant term plus a term for time (time period), potentially fitting a linear function (or trend line). This assumes equal differences between the rates for consec utive time points. In addition, a squared term for time (time period squared) was included to also allow modelling of changes in a trend that followed a parabolic shape, that is, when rates trend up, then down, then up again (or *vice versa*). To account for cyclical fluctuations in the incidence of nurse sensitive outcomes such as pneumonia, which occurs more frequently in winter, a categorical variable called season was also included in the regression model. December, January and February were allocated to the summer season. March, April and May were allocated to the autumn season. June, July and August were allocated to the winter season. September, October and November were allocated to the spring season. Adjusting by season is well established in the analysis of case mix data where patient numbers and severity of illness varies across seasons. As there was no important interaction between skill mix and NHPPD (total hours) and total patients and total hours were significantly correlated, the variable total hours was not included in the final modelling.

Results for separate hospitals were obtained by including in the model a categorical (or dummy) variable for hospital with an interaction term for hospital and skill mix. To allow different trend lines (or curves) for each hospital, models also included interaction terms between hospital and time period and hospital and time period squared. This method used all the data, which provides a more powerful analysis than a stratified analysis where each hospital is analysed separately. The rate ratios (RR) indicated changes in the rates of nursing sensitive outcomes 1 13 associated with a 1 percentage point increase in skill mix, net of other predictors in the model. For nursing sensitive outcome 14, length of stay, Generalized Linear Models were used with the same covariates to determine the mean changes in average length of stay associated with a 1 percentage point increase in skill mix.

In keeping with other studies, the analysis of nursing sensitive outcomes was undertaken in three groupings: all patients (Needleman *et al.* 2002), the subset of medical patients (Tourangeau *et al.* 2007) and the subset of surgical patients (Aiken *et al.* 2003). Previous studies (Needleman *et al.* 2001) identified two methods for adjusting for patient characteristics or risk factors that might influence the complication rates. The simplest method was to stratify all hospitals into groups with similar case mix and then analyse each group. The second more complicated method was to develop a measure of individual patient risk, then aggregate the risk of patients in each hospital, to estimate an expected rate of complications in each health service. The expected rate of complications would then be incorporated into the analysis to adjust for case mix differences across hospitals. In this study, however, the first method was used as the case mix data from the study hospitals were similar and they were routinely grouped together for comparative purposes.

Validity and reliability

All data were collected and recorded by the Department of Health, WA, independent of the researchers. As secondary data is reliant on the accuracy of the coding from the medical record, it is subject to error. Studies of secondary case mix data in WA, however, found such data have very high levels of accuracy and reliability (Brameld *et al.* 1999, Teng *et al.* 2008).

Results

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 103,330 patients post implementation of the NHPPD staffing method; gender ranged between 50·5 54·1% male and 49·5 45·9% female; 19·9 28·2% were admitted electively and 71·8 80·1% were admitted as emergencies. Age ranged from 18 to 106 and the average was between 58·91 and 62·71 years. The Diagnostic Related Group (DRG) cost weights, a relative measure of the average cost of care for patients in a DRG, were similar across hospitals. A summary of the patient demographics can be found in Table 1. Given the similarities in the gender proportions, mean ages and DRG cost weights between

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Table 1 Patient demographic variables post implementation NHPPD staffing method.

	Gender			Admission type (%)		
Patient records	Male (%)	Female (%)	Mean age (years)	Elective	Emergency	DRG cost weight
Hospital 1						
31,475	50·5	49·5	62·71	28·2	71·8	2·94
Hospital 2						
26,592	52·2	47·8	61·64	28·4	71·6	2·63
Hospital 3						
45,263	54·1	45·9	58·91	19·9	80·1	3·04

Table 2 Mean skill mix percent following implementation of the NHPPD staffing method.

	Post implementation	
Hospital	Mean	Range
Hospital 1	88·5	87·5 89·8
Hospital 2	81·5	78·5 83·5
Hospital 3	84·1	79·9 88·7

hospitals, additional adjustments were not made for patient characteristics in this analysis.

Staffing demographics, skill mix

The mean, minimum and maximum skill mixes (percentage of RNs) in each hospital following implementation of the NHPPD staffing method are shown in Table 2. Hospital 1 had the highest skill mix and Hospital 2 the lowest skill mix.

The impact of skill mix changes on nursing-sensitive outcomes following implementation of the NHPPD staffing method

The extent to which nursing sensitive patient outcomes were associated with skill mix following implementation of NHPPD in three adult tertiary hospitals is presented in Table 3. As there are 14 outcomes that are considered to be potentially associated with nursing (Needleman *et al.* 2001) and it is possible that the sensitivity of these outcomes may be different in medical and surgical settings, all results are presented.

In Hospital 1 the rate of pneumonia increased significantly for all patients with each percentage point increase in skill mix. There were no important changes for the other 13 nursing sensitive outcomes. In Hospital 2 skill mix was significantly associated with six nursing sensitive outcomes. Rates of pneumonia, deep vein thrombosis, shock/cardiac arrest and failure to rescue decreased significantly in the all patients' analyses with each percentage point increase in skill mix. However, the rate of urinary tract infection increased significantly as the skill mix percentage increased. In medical patients the rates of deep vein thrombosis and shock/cardiac arrest also decreased significantly when the skill mix per centage increased. In surgical patients the rates of pneumonia and sepsis decreased significantly as the skill mix percentage increased. For the other eight nursing sensitive outcomes there were no important changes.

Skill mix was significantly associated with five nursing sensitive outcomes for Hospital 3. The rates of pressure ulcer, gastritis and upper gastrointestinal bleeds decreased in all patients with each percentage point increase in skill mix. In medical patients, rates of pressure ulcer, pneumonia, gastritis and upper gastrointestinal bleeds and mortality decreased significantly with each percentage point increase in skill mix. However, the rate of shock/cardiac arrest in medical patients increased significantly with every percentage point increase in skill mix. There were no important trends for the remaining nine nursing sensitive outcomes.

Discussion

This study found that skill mix was significantly associated with several nursing sensitive outcomes following implemen tation of the NHPPD staffing method. As the hospitals had different levels of skill mix (Table 2), it is not surprising that the study did not find consistently important results across hospitals. Nonetheless, increases in skill mix were associated with important decreases in the rates of eight nursing sensitive outcomes: pressure ulcer, pneumonia, deep vein thrombosis, ulcer, gastritis and upper gastrointestinal bleeds, sepsis, shock/cardiac arrest, mortality and failure to rescue in the three hospitals. On the other hand, there were significantly increased rates of three nursing sensitive outcome indicators: urinary tract infections at Hospital 2, pneumonia at Hospital 1 and shock/cardiac arrest at Hospital 3.

Patients in Hospital 2, which had a post implementation average skill mix of 81·5%, experienced improvements in five nursing sensitive outcomes. Patients in Hospital 3, with an average skill mix of 84·1%, experienced improvements in four. These improvements are in contrast to Hospital 1 (skill mix 88·5%) where nursing sensitive outcomes did not improve significantly. This suggests that a skill mix of between 88% and 90% may be an appropriate target in terms of future policy development. That is, a richer RN skill mix may reduce several adverse events, including failure to rescue.

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Table 3 Rate ratios (95% confidence interval) comparing the effect of skill mix following implementation of NHPPD for nursing sensitive outcomes 1 13 and changes in average length of stay for nursing sensitive outcome 14 for hospitals all, medical and surgical patients.

Patient	Hospital 1	Hospital 2	Hospital 3
CNS complications (NSO 1)			
All	0·83 (0·57, 1·21)	0·88 (0·74, 1·04)	0·94 (0·89, 1·00)
Medical	0·89 (0·57, 1·39)	0·91 (0·75, 1·09)	0·95 (0·89, 1·01)
Surgical	0·70 (0·34, 1·45)	0·80 (0·51, 1·25)	0·91 (0·79, 1·04)
Surgical wound infections (NSO 2)			
Surgical	1·15 (0·89, 1·49)	0·98 (0·84, 1·13)	1·02 (0·98, 1·06)
Pulmonary failure (NSO 3)			
Surgical	0·74 (0·51, 1·08)	0·88 (0·71, 1·09)	0·95 (0·89, 1·01)
Urinary tract infections (NSO 4)			
All	1·02 (0·92, 1·12)	1·07** (1·02, 1·13)	0·99 (0·97, 1·00)
Medical	1·02 (0·92, 1·12)	1·07 (0·99, 1·15)	0·99 (0·97, 1·01)
Surgical	1·00 (0·83, 1·22)	1·10 (0·99, 1·23)	0·97 (0·94, 1·01)
Pressure ulcer (NSO 5)			
All	0·95 (0·72, 1·24)	1·08 (0·94, 1·23)	0·98 (0·92, 1·03)
Medical	0·96 (0·68, 1·36)	1·03 (0·89, 1·20)	0·91** (0·86, 0·97)
Surgical	0·92 (0·59, 1·42)	1·08 (0·87, 1·32)	1·04 (0·97, 1·12)
Pneumonia (NSO 6)			
All	1·16* (1·01, 1·33)	0·90** (0·85, 0·97)	0·98 (0·96, 1·00)
Medical	1·18 (0·97, 1·43)	0·92 (0·84, 1·01)	0·96* (0·93, 0·99)
Surgical	1·13 (0·92, 1·40)	0·88** (0·80, 0·97)	1·00 (0·96, 1·03)
DVT (NSO 7)			
All	1·01 (0·76, 1·34)	0·81** (0·70, 0·93)	0·96 (0·91, 1·02)
Medical	1·11 (0·79, 1·57)	0·80* (0·68, 0·95)	0·99 (0·92, 1·06)
Surgical	0·83 (0·50, 1·36)	0·83 (0·65, 1·05)	0·91 (0·83, 1·01)
Ulcer/Gastritis/UGI bleed (NSO 8)			
All	0·92 (0·73, 1·17)	0·95 (0·84, 1·08)	0·95* (0·90, 0·99)
Medical	0·98 (0·73, 1·23)	0·97 (0·84, 1·13)	0·93* (0·88, 0·99)
Surgical	0·72 (0·44, 1·19)	0·91 (0·89, 1·21)	0·96 (0·87, 1·06)
Sepsis (NSO 9)			
All	0·94 (0·78, 1·13)	0·89 (0·79, 1·00)	0·98 (0·95, 1·02)
Medical	0·92 (0·67, 1·26)	0·95 (0·81, 1·13)	0·96 (0·96, 1·01)
Surgical	0·99 (0·76, 1·30)	0·83* (0·71, 0·98)	1·01 (0·96, 1·06)
Physiological/Metabolic derangement (NSO 10)			
Surgical	0·99 (0·82, 1·21)	1·08 (0·95, 1·22)	1·01 (0·98, 1·05)
Shock/Cardiac arrest (NSO 11)			
All	0·76 (0·50, 1·16)	0·73*** (0·60, 0·88)	1·02 (0·95, 1·09)
Medical	0·69 (0·38, 1·24)	0·66** (0·50, 0·87)	1·10* (1·00, 1·22)
Surgical	0·84 (0·46, 1·55)	0·78 (0·59, 1·04)	0·95 (0·86, 1·06)
Mortality (NSO 12)			
All	0·92 (0·82, 1·03)	0·97 (0·92, 1·03)	0·98 (0·96, 1·00)
Medical	0·94 (0·83, 1·06)	0·97 (0·91, 1·03)	0·98* (0·96, 0·99)
Surgical	0·83 (0·64, 1·07)	0·99 (0·86, 1·13)	0·98 (0·94, 1·03)
Failure to rescue (NSO 13)			
All	0·91 (0·73, 1·13)	0·88* (0·79, 0·99)	0·99 (0·96, 1·04)
Medical	0·95 (0·72, 1·25)	0·88 (0·77, 1·00)	1·00 (0·95, 1·05)
Surgical	0·83 (0·58, 1·18)	0·91 (0·75, 1·10)	0·99 (0·73, 1·05)
Average length of stay (NSO 14)			
All	0·11 (−0·29, 0·51)	−0·03 (−0·23, 0·17)	−0·03 (−0·10, 0·04)
Medical	0·03 (−0·47, 0·41)	0·01 (−0·21, 0·22)	−0·05 (−0·13, 0·04)
Surgical	0·36 (−0·14, 0·86)	−0·07 (−0·31, 0·18)	0·01 (−0·09, 0·10)

NSO, nursing sensitive patient outcome.
$^{*}P \leq 0{\cdot}05$, $^{**}P \leq 0{\cdot}01$ and $^{***}P \leq 0{\cdot}001$.

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What is already known about this topic

- Higher nurse staffing levels and a richer skill mix have been associated with improved patient outcomes.
- In light of the evidence, some Australian states and jurisdictions have legislated or mandated nurse staffing.
- The available evidence does not give 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

- The effect of skill mix at a hospital level following implementation of the nursing hours per patient day staffing method is variable depending on ward type and patient characteristics.
- In acute care, a relatively small increase in skill mix is associated with important improvements in some nursing sensitive outcomes.
- Increases in skill mix are associated with improved patient outcomes even at higher skill mix concentrations.

Implications for practice and/or policy

- Nursing skill mix can have a major impact on some patient outcomes and hence should be considered when devising staffing methods, particularly where new models of care propose used less skilled patient care workers.
- A skill mix of between 88% and 90% Registered Nurses may be an appropriate target in future policy development.
- Additional research is needed to determine skill mix ratios that meet the requirements of specific ward types and patient characteristics.

Although these findings support earlier work undertaken in Australia and overseas (Aiken *et al.* 2003, Cho *et al.* 2003, Hall *et al.* 2004, Estabrooks *et al.* 2005, Duffield *et al.* 2007, Mark *et al.* 2007, Thungjaroenkul *et al.* 2007, Tourangeau *et al.* 2007), they also extend and expand the skill mix argument. Findings show that a relatively small (1 percent age point) increase in skill mix is associated with important improvements in some nursing sensitive outcomes. The RN provides surveillance of patients and the resultant early detection and rescue from complications are critical in improving patient outcomes (Aiken *et al.* 2002). These findings suggest that relatively small increases in skill mix may continue to benefit patients in acute care. A very recent study (Needleman *et al.* 2011) also identified that changes in skill mix on a shift by shift basis can be important to patient outcomes.

The findings raise questions in regard to the argument that the benefits of increased RN staffing diminish as the hours of care increase (Mark *et al.* 2007, Sochalski *et al.* 2008). These authors found hospitals with initial lower RN staffing levels were more likely to demonstrate improvement in patient outcomes when compared to hospitals with higher RN staffing levels (Sochalski *et al.* 2008). One question that arises is whether hospitals with higher RN staffing levels already had better patient outcomes and then demonstrated further improvements with further gains in RN staffing. The pre existing benefit of improved outcomes cannot be easily measured. Although these approaches give estimates of the marginal value of adding another nurse, this marginal approach underestimates the average value per nurse added (Dall *et al.* 2009). The Dall *et al.* study identified that the benefits of additional RN staffing changed little between low and high nurse hours per patient day hospitals. It suggests that there are only modest variations in staffing levels across hospitals once adjustments are made for case mix (Dall *et al.* 2009). In the NHPPD study, increases in skill mix continued to benefit patients at higher skill mix than those previously reported. This finding, combined with the evidence in the literature (Kane *et al.* 2007a), has important implications for policy development, especially in WA where the NHPPD staffing model is still in effect. It is also pertinent more widely throughout Australia as new models of care aim to maximize the use of less skilled workers to assist in patient care (Productivity Commission 2005). Using fewer skilled workers is not congruent with evidence to hand (Estabrooks *et al.* 2005, Tourangeau *et al.* 2007, Duffield *et al.* 2011). The association with improved patient outcomes evident in the literature supports the notion that policy should maximize the RN nursing workforce to improve skill mix.

Limitations of the study

The sample in this study was limited to the three adult tertiary teaching hospitals in Western Australia as these hospitals received 88·9% of the staffing increases under the NHPPD staffing method. This represented 36 39% of the states multi day patient separations during the study period. These hospitals were similar in nature, had similar infra structure and with similar nursing support and commitment to teaching and research (Health Reform Committee 2004). Hence, this lack of variation may have limited the ability of

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our study to assess the effect of skill mix. Another limitation of the study was that adjustment for patient characteristics was only undertaken in identifying nursing sensitive out comes. Although there were similar case mix weights in the study hospitals, adjustment for patient risk using a more complex individual measure aggregated by the hospital would have strengthened the study.

Conclusion

In conclusion, the findings of this Australian study add further evidence to a recent systematic review that found levels of RN staffing in hospitals remain the most persistent and prominent nursing organizational characteristics for predicting patient outcomes (Kane *et al.* 2007b). This study suggests that the skill mix of nurses could have a major impact on some patient outcomes and is an important consideration in developing staffing methods. However, the findings of this study were not consistent across all nursing sensitive outcomes or across all hospitals with their different levels of skill mix. There is a need for additional large scale studies that focus on ward types and patient characteristics.

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Conflict of interest

No conflict of interest has been declared by the authors.

Author contributions

All authors meet at least one of the following criteria (recommended by the ICMJE: http://www.icmje.org/ethi cal 1author.html) and have agreed on the final version:

- substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;
- drafting the article or revising it critically for important intellectual content.

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A review of workload measures: A context for a new staffing methodology in Western Australia

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Abstract

Objectives: This paper critically reviews various approaches to measuring nursing workload to provide a context for the introduction of a different approach to staffing. Nurse hours per patient day (NHPPD), which classifies wards into various groupings, was applied to all public hospitals in Western Australia.
Results: This method was introduced in response to industrial imperatives to determine reasonable workloads for nurses. As a result, the limited evaluation has focused only on the impact on workload management; reporting target versus actual nurse hours, staff retention and nurse feedback. This method improved ward staffing significantly without imposing restrictive nurse to patient ratios and facilitates the use of professional discretion within ward groupings to enable diversion of resources to match reported acuity changes.
Conclusion: While successful in attracting nurses back into hospitals and increasing nursing numbers, there is no empirical evidence of the impact this method had on patient outcomes or whether the guiding principles used in the development of this method are appropriate. The model would also benefit from further refinement to be more sensitive to direct acuity measures.
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Keywords: Workload measures; Nursing hours per patient day; Staffing

What is already known about the topic?

- To staff a unit effectively and safely requires a method of measuring nursing workload.
- Many methods of measuring nursing workload are in use such as nursing hours per patient day, nurse patient ratios and several commercially available software packages.
- The association between patient outcomes and adequate nurse staffing makes the challenge of effectively measur ing nursing workload critical.

What this paper adds

- A new staffing method was developed in Western Aus tralia, a modification of the nursing hours per patient day (NHPPD) method.
- This staffing method groups wards into seven categories based on a range of indicators such as patient turnover, emergency/elective patient mix and intervention levels, all of which influence nurse workload.

1. Introduction

Determining a sufficient number and mix of nursing staff to ensure safe patient care remains one of the most funda mental and important decisions made by nurse managers

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at all levels in an organisation. In more recent times, these decisions have received greater attention with several land mark studies clearly establishing the impact that nurse staffing can have on patient outcomes (mortality and mor bidity) (Aiken et al., 2002; Estabrooks et al., 2005; Needle man et al., 2002; Rafferty et al., 2007; Aiken, 2002). Work such as this should now lead to more attention being given to the design and implementation of staffing methods which ensure patient safety and an appropriate workload for nurses. However, there remains very little evidence to support and guide staffing decisions and staffing methods have not been evaluated from a patient outcome perspective (Kane et al., 2007).

2. Background and literature review

Measuring nursing workload, a prerequisite to identify ing adequate nurse staffing levels, is difficult and complex. Despite over three decades of research and discussion in the literature there is not a widely accepted workload measure. The invisible nature of nursing, where work once performed disappears, makes it difficult to measure (Duffield et al., 2006). Early and subsequent reviews of the literature have identified that a number of broad approaches to determining nurse demand have developed (Arthur and James, 1994; Duffield et al., 2006; Hurst, 2003). Hurst (2003) identified five nursing workforce planning systems in general use. The first method, *professional judgement,* is similar to the con sensus approach described by Arthur and James (1994). This approach involves intuitive or consultative methods which rely on professional judgement and making subjective deci sions about the appropriate number and mix of nurses (Hurst, 2003). This method utilises the experience and professional knowledge of the manager and is quick and simple to use, but it also provides opportunities for significant variation between wards and hospitals. However it does not make the link between quality and staffing levels transparent.

The second method is *nurses per occupied bed*, the top down approach. Again this is a relatively simple and quick method of calculating staff needs. However it relies on the initial establishment of base staffing having been appropri ate. Top down management approaches were also described by Arthur and James (1994) as the utilisation of staffing norms or a staffing formula, generally determined by pro fessional groups or national bodies. Hours of care per patient day (Holcomb et al., 2002) and nurse to patient ratios (AIRC, 2000; Hodge et al., 2004) have also been used as top down approaches: Both of these tend to reflect minimum staffing requirements which lack sensitivity to local situa tions (Arthur and James, 1994). The underlying staffing formulae establish a statistical relationship between vari ables that measure activity such as throughput, bed numbers, patient case mix and nurse staffing requirements (Hurst, 2003). While this approach is more consistent and less subjective, the major concern is that the model assumes current or mandated staffing levels are an appropriate base from which to project future needs. In addition, while relatively simple and quick to use, not all hours worked by nurses are used to provide direct patient care. Conse quently these approaches tend to be more of a method of allocating nursing resources to each patient without regard to patient need or complexity (Hodge et al., 2004).

The third method is the *acuity quality method* utilising patient dependency systems. A recent example of this method is the AUKUH Acuity/Dependency Tool developed by the Association of UK University Hospitals (AUKUH, 2007). This tool was launched in November 2007 to help National Health Service hospitals measure patient acuity and dependency. Over time the goal is to have sufficient data to measure changes and trends due to seasonality, changing demographics and health needs. This in turn would enable evidence based decision making on nurse staffing and work force planning. The acuity quality method relies on patients being classified by 'dependency' from which nursing requirements are then determined. The model relies on the premise that patient dependency is an accurate measure of the need for nursing time and as before, that the initial staffing requirements based on dependency are accurate. Also, patient classification methods tend to be task oriented and based on nursing activity analysis which are time consuming and expensive to develop (Adomat and Hewison, 2004; McGillis Hall and Doran, 2004). While this method can incorporate professional nursing judgment, a large number of dependency categories can make it a complex and potentially inaccurate process. It is also feasible that nurses could 'manipulate' the patient category to reflect the level of care nurses think the patient should have (Adomat and Hewison, 2004; McGillis Hall and Doran, 2004).

The fourth method is *timed task/activity method*. The type and frequency of nursing interventions documented in nursing care plans become the predictor of nurse staffing requirements (Hurst, 2003). This approach underpins the various commer cial software packages available such as Excel Care, E care, TrendCare® and GRASP. However, nurses experience a number of unanticipated delays, such as waiting for responses from others which often leads to the re sequencing of work, or changes in patient acuity requiring immediate but unantici pated additional attention from nurses. Changes in the nursing team composition or skill mix can also result in unanticipated delays. Collectively these complexities make it difficult for nurses to provide the interventions and care identified by the nursing care plan in a timely manner (Duffield et al., 2006).

The fifth and final method is *regression analysis*. Regres sion methods predict the number of nurses required for any given level of activity. For example increased bed occupancy would drive the need for more nurses which in turn, would be modelled in the regression. While this model does provide some independent evidence, it is difficult to include all variables that might predict nursing requirements as they are likely to be great in number (Hurst, 2003). In addition more recent work (Hurst, 2005, 2008) has identified that ward design and size have a major impact on nursing workload and also, the quality of outcomes for patients. Nightingale and racetrack ward designs support higher levels of direct care than do other types of ward design (Hurst, 2008). Larger wards with fluctuating workloads tended to have poor quality of care (Hurst, 2005). Design and size also now need to be taken into account in the measurement of nurse workload. ''The future of nurse demand methods, like the past, will be determined by developments in government policy, nursing, the health ser vice and technology.. . .a perfect tool for measuring nursing work is unlikely to exist'' (Arthur and James, 1994, p. 564).

Edwardson and Giovannetti (1994) reviewed nursing workload measurement systems in some very early evalua tion work. All systems had one aim to estimate the total hours of nursing staff required to care for patients. However, they found there was a lack of rigor in reliability and validity testing in all the systems developed, a view supported later by Hughes (1999) who also questioned the theoretical base of most systems. A comparison of three methods of work load estimates, GRASP, Project Research in Nursing (PRN) and Medicus found PRN consistently gave higher estimates of total nursing hours required when compared to GRASP or Medicus (Hughes, 1999; O'Brien Pallas et al., 1988). These authors suggested that the weights assigned to particular activities were the major reason for the variation. This study became the impetus for one of the most carefully prepared and thorough analyses of different systems by Thibault (Edwardson and Giovannetti, 1994). Each of the developers of three systems PRN 76, GRASP and Medicus provided material in response to an evaluation grid consisting of scientific parameters such as operational definitions, relia bility, validity and sampling and administrative applications such as application to specialty areas and components of nursing workload measures. On the basis of this material the strengths and weaknesses of the three systems were deter mined. The degree of consistency among four workload measurement systems, PRN, GRASP, Medicus and Nursing Information System for Saskatchewan (NISS) was also examined (O'Brien Pallas et al., 1992). All systems pro duced statistically and clinically significant variations in the hours of care. These differences were up to half a nursing shift per day overall and greater than one shift per day in Intensive Care.

Similar early work was also undertaken in the UK where four nursing workload measurement systems were reviewed. Again the estimates of nursing hours required were sub stantially different from each other for no apparent reason and the differences could not be explained in terms of any other aspect of the nursing process (Carr Hill and Jenkins Clarke, 1995). In addition there was a lack of understanding of the phenomenon being measured and no assessment of reliability or validity.

It is obvious that much of the literature related to work load management tools and their evaluation was published in the 1980s and 1990s. It is quite likely that drivers of nursing workload have changed significantly in the intervening years (Duffield et al., 2007). The application of these tools in the 21st century may be questionable. However there is little in the more recent literature to further inform the development of workload management tools.

Measuring demand for nursing services in Australia is further compounded by the fact that management informa tion routinely collected does not have detailed patient level information from which to do so. Consequently, several approaches have been taken to the measurement of workload including patient classification systems, DRG nurse costing models, hours of care per patient day, nurse to patient ratios and a number of commercial packages in use (Duffield et al., 2006). Early patient dependency (classification) systems attempted to identify the demand for nursing resources based upon completion of specific nursing activities. This 'task' approach to assessing the need for nursing resources was criticised for representing nursing as a series of time limited tasks rather than an iterative process of providing nursing care. In addition, this approach is very labour intensive and requires extensive data recording by nurses. More modern patient dependency systems attempted to recognise the process of nursing care provided, by not only measuring the nursing tasks, but by also applying weights to the tasks to include risk, skill mix and complexity factors. However despite these developments, widespread dissatisfaction with patient dependency systems remains (Gerdtz and Nelson, 2007). Nurses have found that computerised patient infor mation systems neither enhance clinical practice or patient care (Darbyshire, 2004). A phenomenological study invol ving 13 focus groups and 53 practitioners described primar ily negative experiences of computerised patient information systems. Nurses perceived the systems were unable to capture 'real nursing', were non responsive, difficult to use and irrelevant to patient care and meaningful clinical outcomes (Darbyshire, 2004).

Nursing costing models based on Diagnostic Related Groups (DRGs) provide a nursing service weight for a particular DRG estimating the typical nursing resources required for this type of patient. While these systems do not require direct data entry from nurses, they are criticised because they do not capture other determinants of nursing workload or any day to day variation in patient need (Duf field et al., 2006). Nurse hours per patient day and nurse to patient ratios as workload measures are also criticised. They tend to rely on historical data to determine staffing and consequently do not take into account changes in care practices or patient acuity. In addition, the underlying assumption that all patients and all patient days are equal is challenged (Graf et al., 2003). The need for nursing care varies significantly between different patients but also, as the patient progresses through their recovery. In addition the intensity of patient care increases as the length of stay is shortened. Consequently these measures may give inade quate estimates of nursing care requirements (Graf et al., 2003). Nurse staffing requirements are driven by a number of factors in addition to patient acuity. Length of stay, the number of admissions, discharges and transfers, the man ager's clinical judgement, staff competencies, ward geogra phy and medical practice patterns are multiple dimensions that influence any staffing system (Van Slyck, 2000).

In the absence of universally accepted workload mea sures, unit level managers have tended to utilise clinical judgement when making decisions about staffing (Arthur and James, 1994; Hurst, 2003). These decisions could be influenced by a myriad of factors including cost pressures, hospital accepted norms, patient acuity, ward turnover and availability of nursing staff. Senior nurse executives often find themselves in a position of defending what they believe are required nursing staffing levels without accepted work load measures to support these levels. In addition, many benchmarking activities focussed on reducing staffing levels to the lowest level rather than determining what was needed in any patient population (Aiken et al., 2000).

The many workload measures in use are yet to meet the needs of those nurses who have the day to day account ability for providing adequate nurse staffing to secure appro priate patient outcomes. Questions remain about the theoretical base from which the workload measures are derived and there is too often a lack of understanding of the phenomenon being measured (Carr Hill and Jenkins Clarke, 1995; Edwardson and Giovannetti, 1994; Hughes, 1999). Nevertheless, the literature demonstrates a continued proliferation of systems designed to measure nursing work load despite the discussion and concerns in regard to relia bility, validity and comparability (Fagerstrom, 1999; Graf et al., 2003; Harrison, 2004; Rauhala and Fagerstrom, 2004; Walts and Kapadia, 1996; Yamase, 2003). However, the association between patient outcomes and adequate nurse staffing (Aiken et al., 2002; Estabrooks et al., 2005; Kane et al., 2007; Needleman et al., 2002; Rafferty et al., 2007) makes the challenge of effectively measuring nursing work load vitally important. In Western Australia, a nurse hours per patient day staffing method was developed which attempted to address some of the concerns identified in the literature in regard to workload management while also responding to industrial and political imperatives.

3. The context

Western Australia is the largest State in Australia cover ing 2,529,875 square kilometres. The population is 2,003,800 with over 1.2 million residing in metropolitan Perth, the capital city. The Department of Health has overall responsibility for funding and managing the public hospitals in this State. The metropolitan area has three adult teaching hospitals with 1449 beds, specialist women's and children's hospitals, (398 beds) specialist mental health (199 beds) and six general hospitals (1020 beds). These hospitals are man aged under an Area Health Service Structure. Country health services cover all areas in Western Australia outside of metropolitan Perth and face the difficulty of providing services over vast stretches of land with low density popula tion. There are also a number of private hospitals providing services to those with private health insurance.

A feature unique to Australia is the means by which Australian public sector employees' wages and working conditions, including those for nurses, are determined by the Australian Industrial Relations Commission (AIRC). The AIRC was established by the Australian Government and functions under principal legislation of the Workplace Relations Act 1996. The main objective of the Act was to "provide a framework for cooperative workplace relations which promotes the economic prosperity and welfare of the people of Australia..." (AIRC, 1999, p. 2). The Act gave the AIRC a range of powers of which most relevant for this paper is to prevent and settle disputes, preferably by con ciliation or as a last resort by arbitration (AIRC, 1999). It is through such an arbitrated process that the Western Aus tralian NHPPD staffing method evolved.

4. Australia and the WA model

Nurses' workload was given greater prominence fol lowing the release of several state and national reports on its impact on workforce retention (Australian Industrial Relations Commission, 2000, 2002; Commonwealth of Australia, 2002; Department of Education Science & Training, 2002). Victoria was the first State required to address the issue. In 2000, the industrial body for nurses, the Australian Nurses Federation (ANF), made nurse to patient ratios a major part of their negotiations and under took prolonged industrial action as part of their campaign. The ANF cited California, the first state in the United States to adopt legislation mandating minimum unit based licensed nurse to patient ratios (Donaldson et al., 2005) as an example of a suitable staffing method. The Victorian Department of Health could not reach agreement with the ANF. Consequently an arbitrated outcome by the AIRC resulted in the introduction of nurse to patient ratios as a method of measuring nursing workload. In acute care hospitals a ratio of one registered nurse to four patients was established at ward level on the morning and afternoon shifts and one nurse to eight patients on the night shift. Nurses also have the ability to close beds if the staffing ratio is not reached. However, as indicated earlier, a weakness of this model is that ratios themselves cannot identify the precise nursing hours required at any particular time in any particular setting (Duffield et al., 2006; Gerdtz and Nelson, 2007). Nor are ratios sensitive to other vari ables that impact on nurse staffing needs such as ward turnover, staff competencies, geography of the ward and medical practice patterns (Duffield et al., 2006; Hurst, 2008). Many of these dimensions are addressed in the WA nurse hours per patient day staffing method.

In WA, the government and its publicly funded hospitals were concerned about the disruption caused to the health system in Victoria and the likelihood that ratios would also be mandated in this State. In its findings the Victorian AIRC commented that the hospital networks had opportunities to provide alternatives to the nurse to patient ratios proposed by the nurses' union but had failed to do so (AIRC, 2000). This limited the options available to the AIRC in handing down a decision. In a proactive response a working party of senior nurse leaders was formed in WA to provide an alternative staffing approach. As the result of an arbitrated process, the nurse hours per patient day (NHPPD) staffing method, but with an approach (described below) never used before, was mandated for use in this State's public hospitals (AIRC, 2002). The Union had made nursing workload a key political and industrial issue and the AIRC decision was arrived at in this context. Patient care and patient outcomes were not considered in the development of the NHPPD staffing method or the AIRC decision to mandate its use. Nevertheless, this approach remains the primary means of determining nurse staffing requirements in the State.

The working party established guiding principles to determine safe staffing by category of ward utilising three sources of information, some of which were based on earlier work (Van Slyck, 2000). Firstly, national bench mark data were provided by a consultant to determine nursing staffing levels in metropolitan and country (rural or regional) services in WA. These data established the relative position of WA's staffing levels in public hospitals compared to other states. Utilising national benchmark data assisted in addressing the concern expressed pre viously by avoiding reliance on historical local hospital data (Arthur and James, 1994; Hurst, 2003). The second source of information was expert opinion involving nurse executives and the work of the Metropolitan Directors of Nursing Council. This approach enabled tapping into the professional judgement of senior nurses, not only in regard to historical trends but also current identified pressures and future needs (Arthur and James, 1994; Hurst, 2003; Van Slyck, 2000). However, this consensus approach was prone to significant variation between wards and hospitals. The third source of information was reference to published literature available at the time. Patient related activities, patient acuity, emergency and elective patient admissions were also examined when considering the drivers of nur sing workload utilised by others in developing staffing methodologies (Beglinger, 2006). Unfortunately, what is now a clear link between nurse staffing and patient out comes was less apparent at the time of development of the model. It was not until 2004 that the quality literature fully recognised the importance of nursing in patient safety. The landmark report commissioned by the U.S. Department of Health and Human Services' Agency for Healthcare Research and Quality, titled Keeping Patients Safe: Trans forming the Work Environment of Nurses (Page, 2004) identified the central role nurses play in patient safety. However, this work was published after the development of the staffing method. Consequently, patient outcomes were not included in the development of this method or in its future evaluation.

The NHPPD staffing method grouped wards and allo cated nurse hours based on a number of factors such as the presence or absence of high dependency beds, the mix between emergency and elective services and in mental health wards, characteristics such as risk of self harm and aggression. Berlinger (2006) has since identified a number of similar variables as drivers of nurse workload which include: length of stay; admission, discharge and transfer activity (ward turnover); age of patients; clinical conditions and interventions, high dependency care within the ward; and 'sitters' for patients who would be unsafe if left alone.

Seven ward groupings were developed (refer to Table 1) with each category allocated average nurse hours per patient day. The NHPPD staffing method different ward groupings were derived from a mix of descriptive attributes and quantifiable and measurable attributes. The staffing method was then tested using the benchmark data collected previously.

Table 1 outlines the ward categories with descriptors and the nursing hours per patient day allocated to each. Category A wards had high complexity patients with a high level of nursing interventions, high dependency units within the ward and received patients as an immediate step down from Intensive Care. Category B wards were very similar to Category A except they did not have a high dependency unit within the ward. A ward could also fall into Category B if it had an average daily patient turnover of greater than 50%. Category C wards were also categorised as acute high complexity wards with moderate patient turnover of greater than 35% or emergency admissions greater than 50%. Category D wards were characterised as moderate complex ity, often involving acute rehabilitation. They were expected to have emergency patient admissions of greater than 40% or moderate patient turnover of greater than 35%. Category E wards were characterised as having moderate complexity, often being sub acute and with moderate patient turnover of less than 35%. Category F wards were characterised as moderate to low complexity with low patient turnover such as patients awaiting placement into residential care units. The final Category G was related to ambulatory care settings such as day surgery and renal dialysis units.

All public hospitals were advised about the approved full time equivalent (FTE) increase in nursing positions resulting from application of this staffing method. As this was a solution to an industrial problem (nurses' workload) it is not surprising that subsequent evaluation has been limited to the impact on staff numbers and recruitment.

5. The impact

Significant staffing increases resulted from the introduc tion of NHPPD which was phased in over a 6 month period after the method was mandated in March 2002 (Department

Table 1
NHPPD guiding principles (incorporating mental health inpatient units)

Ward category	NHPPD	Criteria for measuring diversity, complexity and nursing tasks required
A	7.5	High complexity High dependency Unit @ 6 beds within a ward Tertiary step down ICU High intervention level Specialist unit/ward tertiary level 1:2 staffing Tertiary paediatrics Mental health high risk of self harm and aggression Intermittent 1:1/2 Nursing Patients frequently on 15 minutely observations
B	6.0	High complexity No high dependency unit Tertiary step down CCU/ICU Moderate/high intervention level Special unit/ward including Mental Health Unit High Patient Turnover[a] >50% Paediatrics[b] Secondary paediatrics Tertiary maternity Mental health high risk of self harm and aggression Patients frequently on 30 min observations Occasional 1:1 nursing a mixture of open and closed beds
C	5.75	High complexity acute Care unit/ward Moderate patient turnover >35%, OR Emergency patient admissions >50% Mental health moderate risk of self harm and aggression Psycho geriatric mental health unit
D	5.0	Moderate complexity Acute rehabilitation secondary level Acute unit/ward Emergency patients admissions >40% OR Moderate patient turnover >35% Secondary maternity Mental health medium to low risk of self harm and aggression
E	4.5	Moderate complexity Moderate patient turnover >35% Sub acute unit/ward Rural paediatrics
F	4.0	Moderate/low complexity Low patient turnover <35% Care awaiting placement/age care Sub acute unit/ward Mental health slow stream rehabilitation
G	3.0	Ambulatory care including: Day surgery unit and renal dialysis unit

[a] Turnover admissions + transfers + discharges divided by bed number.
[b] Paediatrics additional formulae: birth; neonates; emergency; and operating room.

of Health, 2006). Most hospitals placed greater emphasis on recruitment including strategies such as overseas recruitment, offering flexible rostering patterns and provision of family friendly initiatives. In the short term hospitals also supplemented any staffing shortages with casual and agency nurses on a shift by shift basis (Department of Health, 2006). As a result of these strategies metropolitan health services were at or within 10% of target staffing levels within 6 months of the introduction of the staffing method (Department of Health, 2003).

Hospital recruitment initiatives were also supported by a policy change whereby the Department of Health established its own agency to supply short term relief staff using a contracted provider and a fixed fee structure. As a consequence the financial incentive for many nurses to work for an agency was minimised. Wards that experienced ongoing difficulties recruiting permanent staff were also able to access short term relief staff from the Department of Health agency until permanent nursing staff could be recruited. Country health services had more difficultly in recruiting additional staff and took a longer period to reach the new staffing levels (Department of Health, 2003). The AIRC was silent about skill mix (AIRC, 2002) unlike the Victorian decision which mandated the staffing ratios based on a registered nurse workforce (AIRC, 2000). The only other experience of mandating skill mix as part of ratios was in California which allowed for up to 50% of the mandated licensed nurses to be licensed vocational nurses, the equivalent of an enrolled nurse (Donaldson et al., 2005). Consequently the mix between registered and enrolled nurses was not mandated in WA. However the decision did require staffing increases to consist of nurses licensed to practice rather than carers or non licensed roles (AIRC, 2002).

Importantly, the staffing method provided nurse executives with an agreed and mandated staffing profile based on more than historical data or professional judgement. An increase of 313.18 FTE nurses was approved for implementation in ward areas across the State's public hospitals (Department of Health, 2005). This increase equated to a 3.47% increase in staffing with the majority of the increased staff numbers occurring in the teaching hospitals (86.10% of the total FTE allocated) (Department of Health, 2005). To put this in context, there were 7136 productive nursing FTE in WA public hospitals at the time these changes occurred. The skill mix of the nursing workforce remained relatively unchanged over a 2 year period before and after implementation of NHPPD with 88.7% registered nurses and 11.3% enrolled nurses (AIHW, 2004).

These agreed staffing increases did deliver improved staffing outcomes. They helped reverse a worrying trend of very high agency usage with nurses leaving the public hospital system because of significant workload pressures (Department of Health, 2006). Vacancy rates within public hospitals began to decline. Productive hours of permanent nurse staffing increased by 3.65%. Agency usage initially increased to meet demand: However within 2 years this had declined by 16.82% as nurses returned to the permanent workforce (Department of Health, 2006). At this time the average cost of an agency nurse was $A89, 415 compared to the average cost of a nurse employed by the health services ($A57, 685). Consequently, a 16.82% reduction in agency usage during a period when there was significant growth in the nursing workforce, represented significant savings to the Government and its hospitals.

Introduction of this staffing method also assisted in staff retention as nurses experienced increased staffing levels which in turn, impacted positively on workload and their capacity to provide quality care. For nurse executives, this method also enabled them to increase the number of FTE nursing staff in an environment where the Government was seeking increased efficiency and cost reductions. This approach has since been expanded into other areas of practice such as the Emergency Department, Intensive Care, Coronary Care and Operating Theatres.

6. Review of the staffing method, nurse hours per patient day

The nurse hours per patient day staffing method did address some but not all of the concerns about workload measures identified in the literature. It did remove subjective determinations of adequate staffing identified as a concern (Arthur and James, 1994; Hurst, 2003; Van Slyck, 2000) by quantifying and grouping wards around similar patient types and workload drivers such as high dependency, occupancy, ward turnover and emergency and elective mix. This has ensured similar staffing levels for all 'like wards' across hospitals. This approach also addressed to some extent the concern about a lack of sensitivity to specific ward circumstances (Graf et al., 2003). Every ward was reviewed on its individual data and descriptive detail. Consequently, if a unique set of ward characteristics such as turnover, emergency/elective split, and patient type existed in a ward, it was assessed as part of the determination of nursing hours. In addition, because the nurse hours per patient day utilised average staffing requirements it avoided the pitfall of being seen as setting a minimum or maximum staffing level, giving much greater day to day staffing flexibility (Gerdtz and Nelson, 2007). Also, the utilisation of national benchmarking staffing data prevented the model assuming current staffing levels were an appropriate base from which to project future needs (Arthur and James, 1994; Hurst, 2003). Given the staffing increases achieved this clearly was not the case (Department of Health, 2006).

However, the development and introduction of nurse hours per patient day failed to address two key areas. The acuity and intervention level was primarily determined by descriptive means relying on the Director of Nursing from the hospital and the implementation team reaching agreement. The staffing method would be enhanced if regular patient acuity and intervention levels were measured by a standardised tool such as the AUKUH Acuity Dependency Tool (AUKUH, 2007). The other major limitation of the staffing method is that there has not been any attempt at this stage to evaluate its impact on patient outcomes. This method would not be alone in that regard. No studies to date have 'primarily empirically examined specific nurse staffing policy' (Kane et al., 2007, p. 1).

7. Conclusion

The Western Australia Nursing Hours per Patient Day staffing method recognises that ward acuity and 'business', both of which impact on nurses' workload and hence staffing needs, relate to more than just individual patient needs (Twigg, 2001). Its introduction improved staffing levels, reduced reliance on agency nurses and increased staff reten tion, outcomes which are monitored and reported at 6 monthly intervals in compulsory meetings between the Government and relevant industrial organisations.

Importantly for nurse executives, this method offers some assurance that sufficient resources are provided with out imposing a restrictive shift by shift nurse to patient ratio. In this way it facilitates the use of professional discretion over 24 h 7 days a week to enable diversion of resources to areas of greatest need. It does this within general parameters set by capturing drivers of nurses' workload from a number of sources. Predicted shortages of nurses and the aging of the workforce make it imperative that appropriate and validated tools for measuring nursing workload are in place to ensure patient and nurse safety. The Western Australia staffing method is a key feature of Government policy and continues to be utilised to demonstrate ongoing management of nurses' workload and patient care require ments. However, evaluation of this staffing method is requi red, particularly with respect to the different ward categories and the decision rules built into the model. Any such evaluation needs to examine the impact on patient out comes such as satisfaction or nursing sensitive outcomes.

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Conflict of interest

The authors (Di Twigg and Christine Duffield) have no actual or potential conflict of interest including any financial, personal or other relationships with other people or organi sations within 3 years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Informing Practice and Policy Worldwide through Research and Scholarship

REVIEW PAPER

Is there an economic case for investing in nursing care – what does the literature tell us?

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Abstract

Aim. To determine the cost effectiveness of increasing nurse staffing or changing the nursing skill mix in adult medical and/or surgical patients?

Background. Research has demonstrated that nurse staffing levels and skill mix are associated with patient outcomes in acute care settings. If increased nurse staffing levels or richer skill mix can be shown to be cost effective hospitals may be more likely to consider these aspects when making staffing decisions.

Design. A systematic review of the literature on economic evaluations of nurse staffing and patient outcomes was conducted to see whether there is consensus that increasing nursing hours/skill mix is a cost effective way of improving patient outcomes. We used the Cochrane Collaboration systematic review method incorporating economic evidence.

Data sources. The MEDLINE, CINAHL, SPORTDiscus and PsychINFO databases were searched in 2013 for published and unpublished studies in English with no date limits.

Review methods. The review focused on full economic evaluations where costs of increasing nursing hours or changing the skill mix were included and where consequences included nursing sensitive outcomes.

Results. Four cost benefit and five cost effectiveness analyses were identified. There were no cost minimization or cost utility studies identified in the review. A variety of methods to conceptualize and measure costs and consequences were used across the studies making it difficult to compare results.

Conclusion. This review was unable to determine conclusively whether or not changes in nurse staffing levels and/or skill mix is a cost effective intervention for improving patient outcomes due to the small number of studies, the mixed results and the inability to compare results across studies.

Keywords: acute care, economic evaluation, literature review, nurse sensitive outcomes, nurse skill mix, nurse staffing, nursing, patient outcomes

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Why is this review needed?

- Nurses are often the target for cost cutting measures in hospitals despite the literature that shows adverse patient outcomes are associated with reduced nursing numbers.
- Nurses need to show they are a cost effective health care intervention.
- There are no recent reviews that cover the international literature on economic evaluations of nurse staffing/skill mix and patient outcomes.

What are the key findings?

- We could not determine whether changing nurse staffing levels is a cost effective intervention for improving patient outcomes due to the variable results and the inability to compare results across studies.
- It appears that increasing nurse staffing has a beneficial effect on patient outcomes, but this effect comes at a cost. It is up to funders to determine whether or not this cost is acceptable.
- There is some evidence that changing the skill mix may be more cost effective than increasing nursing hours although this requires further investigation.

How should the findings be used to influence policy/practice/research/education?

- We recommend the development of a reference case to define the costs and consequences that should be included in cost effectiveness studies of nurse staffing to allow for meaningful comparison and synthesis.
- Future studies should include a sensitivity analysis due to the uncertainty surrounding the effectiveness estimates and other variables.
- The evidence would benefit from cost utility studies to allow for comparison with other health care interventions.

Introduction

Today's healthcare environment is one where there are numerous interventions competing for limited healthcare dollars. Nurses are often seen as one of the most expensive components of any healthcare system, because of their large numbers when compared with other staff. For example in Australia in 2011, there were three times as many nurses employed as there were doctors, 214,321 nurses compared to 73,980 doctors (Health Workforce Australia 2013). These figures are reflected internationally, such as in the National Health Service in the UK where there were 347,944 nurses, 110,957 doctors and 76,163 allied health professionals working in hospital and community health services (Health & Social Care Information Centre 2013); and in the USA there is a 4:1 ratio of nurses to doctors (3,528,000 nurses compared with 806,000 doctors) (Deloitte Centre for Health Solutions 2012). As a consequence of their numbers, nurses are often the target for cost cutting measures (Behner *et al.* 1990, Dubois *et al.* 2006, Needleman *et al.* 2006, Twigg & Duffield 2009). However, it is unclear whether cutting nursing numbers to save money, actually does so, or whether it costs the hospital and society more in terms of patient adverse events and concomitant lost productivity and diminished quality of life.

Extensive research over several years has demonstrated that nurse staffing levels and skill mix (the proportion of hours of care provided by registered nurses) are associated with acute care patient outcomes, including mortality, failure to rescue and other adverse outcomes (Aiken *et al.* 2002, 2014, Needleman *et al.* 2002, Cho *et al.* 2003, Duffield *et al.* 2011, Twigg *et al.* 2011). Although a limitation of studies into the effectiveness of nurse staffing on reducing adverse outcomes is that they are observational rather than experimental, the number of studies and size of the patient populations is generally accepted as sufficient to establish association between staffing levels/skill mix and outcomes, even if it is not possible to show causality (Kane *et al.* 2007a,b, Shamliyan *et al.* 2009).

To strengthen the case for maintaining or increasing nurse staffing and skill mix at a level that will promote patient safety, it is also necessary to consider the cost effectiveness of nursing as an intervention. If increased nurse staffing and/or a richer skill mix can be shown to be cost effective hospitals are more likely to staff at appropriate levels. Nurses must make a case for their cost effectiveness as an intervention that saves lives and prevents adverse outcomes. This requires economic evaluations of nurse staffing and skill mix (Michigan Nurses Association 2004).

Economic evaluation in health care has been defined as 'a comparison of alternative options in terms of their costs and consequences' (Drummond *et al.* 2005). Alternatively, it can be defined as an assessment of which treatments, including increased patient to nurse ratios and richer nursing skill mix, represent 'value for money', that is, how much does it cost to achieve better health outcomes with a new treatment when compared with an existing treatment (Pharmaceutical Benefits Advisory Committee (2013). Any economic evaluation should therefore include a consideration of both the costs (of treatment) and consequences (health outcomes) of a new treatment compared with an existing treatment. There are four main types of economic evaluation in health care: cost minimization, where the consequences are assumed to be the same so only the costs are compared; cost effectiveness, where a ratio of the

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differences in costs and outcomes is calculated, that is, an incremental cost effectiveness ratio or ICER; cost utility, where the ICER is based on cost per quality adjusted life years (QALY); and cost benefit, where both costs and out comes are valued in monetary terms (Simoens 2009, Gray *et al.* 2012).

Background

Over the last 10 years, there have been six reviews that have either focused on or included a review of economic evaluations of nurse staffing and skill mix. The most recent review was conducted by Shekelle (2013), who reviewed the literature published between 2009 2012 on nurse staff ing ratios and in hospital death and reported on 15 studies, four of which were economic evaluations. The author con cluded that it was not possible to calculate the cost of increasing the nurse patient ratio due to the lack of inter vention studies in this area. Goryakin *et al.* (2011) con ducted a scoping review of economic evaluations of nurse staffing, including the years 1989 2009 and reviewed 17 articles. They found that the cost effectiveness of nurse staffing was not easy to assess due to mixed results. Addi tionally, they identified several methodological issues for consideration in future studies to allow comparability across studies. These methodological issues included the need for: more intervention studies of nurse staffing, increased use of Markov modelling to extend the time hori zon of studies, examination of societal perspectives, inclu sion of post discharge costs and economic evaluations using QALYs.

Unruh (2008) also conducted a literature search on nurse, patient and financial outcomes of nurse staffing, covering the years 1980 2006 discussing 117 articles, 12 of which were economic studies of nurse staffing and patient out comes and concluded that the results were inconclusive. Thungjaroenkul *et al.* (2007) completed a systematic review of the literature on nurse staffing, hospital costs and length of stay covering the years 1990 2006. They reviewed 17 studies and also found that results were mixed, with variables measured in different ways across studies. They recommended standardizing measures of cost and using micro costing methods. The authors also recommended the use of prospective rather than retrospective designs and concluded that hospitals should be encouraged to use a richer skill mix, while acknowledging that it was not possi ble to draw strong conclusions due to the issues identified. Spetz (2005) focused on cost effectiveness studies in an overview of the literature and commented on five studies of cost effectiveness of nurse staffing, identifying a lack of comparison to alternate staffing approaches as a weakness of the studies and a general low level of quality in the nurs ing economic literature. Lang *et al.* (2004) reviewed the lit erature between 1980 2003 to assess whether there was support for specific minimum nurse patient ratios and included nine papers focused on hospital financial out comes. The authors reported that better staffing was cost neutral or cost saving, however, they dismissed eight of the nine studies as being too dated to be useful. In summary, none of the reviews answered the question of whether or not increasing nurse staffing or skill mix was cost effective due to the quality or variability of the published literature.

The review

Aim and review question

This review examined the literature on economic evalua tions of nurse staffing and patient outcomes to see whether increasing nursing hours or changing the skill mix is a cost effective way of improving patient outcomes. The question for this review was: what is the cost effectiveness of increas ing nurse staffing or changing the nursing skill mix in adult medical and/or surgical patients?

Design

The systematic review was conducted using the Cochrane Collaboration systematic review method incorporating eco nomics evidence, to develop search strategies, define inclu sion and exclusion criteria and address risk of bias and synthesize findings (Higgins & Green 2011). The Agency for Healthcare Research and Quality (AHQR) recom mended that systematic reviews of economic evaluations be used for 'comparing and contrasting how different investi gators have chosen to structure their models and estimate key variables' and how the results differ based on these dif fering structures and assumptions (Walker *et al.* 2012, p. 1). This advice was incorporated into the review.

Search methods

The MEDLINE, CINAHL plus with full text, SPORTDiscus with full text and PsychINFO databases were searched in 2013 for published and unpublished studies in English with no date limits. In the MEDLINE database, we used combi nations of the keywords: personnel staffing and scheduling, nursing staff, nursing skill mix, nurses, nursing hours per patient day, models of nursing, nursing intensity, costs and cost analysis, economics, business case, cost saving, patient

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outcomes, mortality, pressure ulcer, infection, pneumonia, falls, venous thrombosis, central nervous system, gastrointestinal haemorrhage, heart arrest, cardiac shock, metabolic disease, respiratory insufficiency and length of stay. In the CINAHL, SPORTDiscus and PsychINFO databases the key words used were personal staffing and scheduling, nursing hours per patient day, nursing care delivery systems, nursing staff, nurses, nursing education, models of care, health care delivery, nursing intensity, healthcare systems, nurse staffing models, costs and cost analysis, cost saving, business case, economic*, outcome* health care, patient outcome*, mortality, pressure ulcer*, infection, pneumonia, fall*, venous thrombosis, central nervous system, gastrointestinal haemorrhage, cardiac shock, metabolic diseases, respiratory failure and length of stay. We also reviewed the reference lists of prior literature and systematic reviews. The full search strategy is available from the authors. The review protocol was not registered.

Inclusion and exclusion criteria

This review focused on full economic evaluations where the costs of increasing nursing hours or changing skill mix were included and where the consequences included patient outcomes that have been identified as responsive to nursing intervention, that is, the quality and type of nursing care provided can influence whether or not patients develop these adverse outcomes in their hospitalization. These are known in the literature as nursing sensitive outcomes (NSOs) and include length of stay (LOS), failure to rescue (FTR), mortality, sepsis, falls, pressure injuries, pneumonia, deep vein thrombosis (DVT), urinary tract infections (UTI), ulcer/gastritis/upper gastrointestinal bleeding, shock, cardiac arrest, central nervous system complications, surgical wound infections, pulmonary failure and physiological/metabolic derangement (Aiken *et al.* 2002, Needleman *et al.* 2002, Kane *et al.* 2007a,b, Rafferty *et al.* 2007).

Studies were included that either measured or modelled the variables of interest. Any studies that did not link costs, nursing sensitive patient outcomes and staffing and/or skill mix were excluded. We included studies regardless of the methodology used to measure the effectiveness of nurse staffing/skill mix on patient outcomes. There are no randomized control trial (RCT) study designs in this area of research, hence all of the studies were based on retrospective observational data (Kane *et al.* 2007a).

The review was limited to studies that included patients in medical and/or surgical acute care wards in their analysis. Studies in emergency settings, intensive care units, peri operative settings and long term care facilities were excluded, as were studies primarily focusing on maternity, newborn, paediatric, mental health or palliative care populations. We also excluded articles in languages other than English and articles describing health professionals other than nurses.

Search outcome

The search strategy produced 7994 papers, including duplicates. The title, abstract and keywords of these papers were scanned to see if they were relevant to the review. This scan identified 194 papers and the full text of these was obtained. Two authors read the full text of these articles to check if they met the inclusion/exclusion criteria. The main reasons for excluding articles at this stage were that they were conducted in a non acute setting, they did not measure one of the variables of interest, or they did not link nurse staffing, costs and outcomes. Six of the articles were literature/systematic reviews and 24 papers included measures of nurse staffing or skill mix, nurse sensitive outcomes and costs in the patient populations of interest. After further review nine articles met the selection criteria, that is, they were full economic evaluations linking costs, outcomes and staffing/skill mix and were retained in the final review. The search outcome is illustrated in Figure 1.

Prior reviews

As mentioned, there were six prior reviews, either literature or systematic reviews, that had analysed economic evaluations of nurse staffing/skill mix identified in the search (Lang *et al.* 2004, Spetz 2005, Thungjaroenkul *et al.* 2007, Unruh 2008, Goryakin *et al.* 2011, Shekelle 2013). These reviews did not necessarily review just economic evaluations but covered the more general area of nurse staffing and outcomes. These reviews are listed in Table 1 in descending date order, showing the number of relevant economic studies included in each and the number of articles in each which met the inclusion/exclusion criteria for this review. Between them the previous reviews covered 47 studies, however, the most that any single review covered was 17 and only five of these met the inclusion/exclusion criteria for this review. Additionally, four studies were identified that met the inclusion/exclusion criteria that were not included in a previous review. We therefore proceeded with this review of nine articles.

Quality appraisal

Walker *et al.* (2012) on behalf of the Agency for Healthcare Research and Quality conducted a systematic review of quality assessment tools for evaluating best practices in

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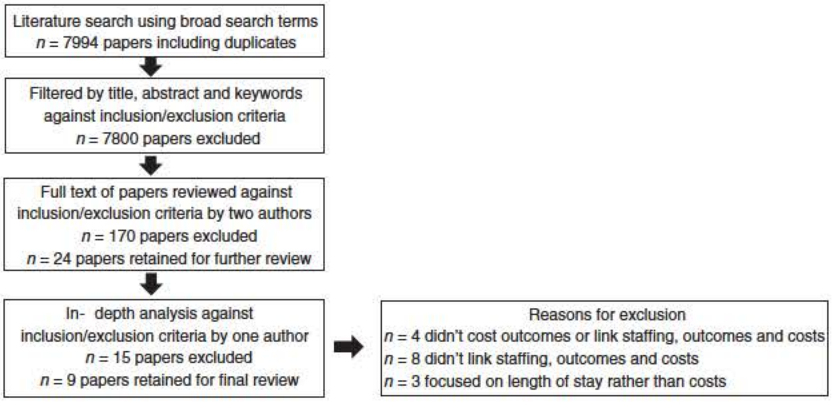

Figure 1 Search outcome.

Table 1 Details of previous systematic/literature reviews of economic evaluations of nurse staffing.

	Years covered	Number of economic articles reviewed	Number of reviewed articles which met our inclusion/exclusion criteria
Shekelle (2013)	2009 2012	4	3
Goryakin *et al.* (2011)	1989 2009	17	2
Unruh (2008)	1980 2006	12	3
Thungjaroenkul *et al.* (2007)	1990 2006	17	2
Spetz (2005)	No dates given	5	0
Lang *et al.* (2004)	1980 2003	9	1

conducting and reporting on economic evaluations in health care. They identified 10 checklists in the literature and found that although these checklists 'cannot guarantee that the results of an economic analysis are valid' (Walker *et al.* 2012, p. 15), with most aimed at the quality of reporting, rather than the quality of design, they are helpful in checking that the analysis has all the appropriate components. One of these tools was selected for use, the Quality of Health Economic Studies Checklist (QHES) developed by Chiou *et al.* (2003) which uses a weighted scoring system. It was used to assess the quality of the included studies, although no studies were excluded from the review on the basis of this checklist. Although the scoring system has not been validated, it allowed us to assess whether a study had the necessary components and allowed some indication of the relative merits of each study. We also used the Cochrane Collaboration advice for assessing the risk of bias in the effectiveness studies underlying the economic analyses (Higgins & Green 2011).

Data abstraction

Data were abstracted from each study to identify the type of economic analysis performed, the perspective taken by the authors (hospital or societal), whether the study was measured or modelled and if measured, details of the study population and setting. If the underlying effectiveness study used in the economic analysis was not detailed in the economic report, the effectiveness study was obtained and assessed for risk of bias using the Cochrane Collaboration advice. The source of the nurse, patient and cost variables and how they were measured was also summarized.

Synthesis

Due to a lack of consistency in methods and ways of reporting costs and outcomes it was not possible to analyse the data using meta analysis. Therefore, the data were summarized narratively, comparing results where applicable.

Results

Excluded studies

Several studies were excluded from the review because they did not meet the inclusion/exclusion criteria, specifically they did not measure one of the variables of interest or did not link costs, staffing and outcomes. For researchers interested in the area of economic evaluations of nurse staffing/

skill mix, these papers still aid understanding of the variables of interest. The excluded articles of note were Flood & Diers (1998), Cho *et al.* (2003), McCue *et al.* (2003), McGillis Hall *et al.* (2004), Pappas (2008) and Dall *et al.* (2009).

Types of economic evaluations

There were four cost benefit analyses identified (Behner *et al.* 1990, Needleman *et al.* 2006, Shamliyan *et al.* 2009, Weiss *et al.* 2011) and five cost effectiveness analyses (Rothberg *et al.* 2005, Newbold 2008, Van den Heede *et al.* 2010, Li *et al.* 2011, Twigg *et al.* 2013). There were no cost minimization or cost utility studies identified in the review. A summary of included studies, including the quality assessment score, is presented in Table 2. For the complete quality assessment please refer to supplementary information in Table 3.

Of the nine studies reviewed, seven were conducted in the USA, one in Australia (Twigg *et al.* 2013) and one in Belgium (Van den Heede *et al.* 2010). Four of the studies were economic analyses reported alongside an effectiveness study (Behner *et al.* 1990, Li *et al.* 2011, Weiss *et al.* 2011, Twigg *et al.* 2013), where many variables were measured, while the other five studies were modelled from various data sources. Eight studies were conducted from the hospital perspective and one from both a hospital and societal perspective (Shamliyan *et al.* 2009).

Effectiveness studies

There was a high risk for bias identified in all of the effectiveness studies associated with the economic evaluations included in this review due to the nature of the study designs used to estimate the relationship between nurse staffing/skill mix and patient outcomes. Behner *et al.* (1990), Li *et al.* (2011), Weiss *et al.* (2011) and Twigg *et al.* (2013) conducted their own effectiveness studies. In the studies based on modelling of variables, Rothberg *et al.* (2005) used effectiveness data from Aiken *et al.* (2002) for their mortality estimates and Needleman *et al.* (2002) for their length of stay estimates. Shamliyan *et al.* (2009) used data from a meta analysis of 27 published studies. Newbold (2008) used effectiveness data from the Aiken *et al.* (2003) study, Needleman *et al.* (2006) from their prior work in 2002 and Van den Heede *et al.* (2010) from a previous study by the authors in 2009. Of these, six were large cross sectional observation studies that measured the association between nurse staffing and/or skill mix and nurse sensitive patient outcomes (Aiken *et al.* 2002, 2003, Needleman *et al.* 2002, Van den Heede *et al.* 2009, Li *et al.* 2011, Weiss *et al.* 2011), one was a meta analysis of observational studies (Kane *et al.* 2007a), one was a small comparison study based on observational data (Behner *et al.* 1990) and one was a larger pre/post analysis of observational data following an organizational change in staffing levels (Twigg *et al.* 2013). Although the quality of these studies was generally high, with the authors including confounding variables in their regression models, the observational designs, use of administrative data sets, estimation rather than measurement of some important variables and analysis at the hospital rather than the patient level means there is a high risk of bias in these studies with the level of evidence mostly level 4, or at best level 3 (Joanna Briggs Institute 2013). Due to this risk of bias, it is important to perform sensitivity analyses around the effectiveness estimates. Although five of the studies included some type of sensitivity analysis only Rothberg *et al.* (2005) conducted a sensitivity analysis around the effectiveness estimates.

Rothberg *et al.* (2005) also conducted sensitivity analysis on hourly nurse compensation, cost per hospital day, supply elasticity and relative risk of nurse dissatisfaction. In addition, they performed a probabilistic sensitivity analysis where they varied all their estimates to put confidence intervals around the cost effectiveness estimates. This was the only study that used sensitivity analysis to derive confidence intervals. Other authors conducted limited sensitivity analysis in relation to the cost of an adverse event and effect of repeat NSOs in the same patient (Twigg *et al.* 2013), changes in the discount rate (Van den Heede *et al.* 2010), cost of adverse events in age categories, health insurance and patient residence (Shamliyan *et al.* 2009) and the final cost measure (Li *et al.* 2011).

Cost estimates

Costs calculated in the studies were primarily the cost of nurse staffing. For the cost effectiveness studies Twigg *et al.* (2013) costed actual nursing hours pre and post intervention; Rothberg *et al.* (2005) calculated daily nursing costs per patient for each patient to nurse (PTN) ratio and also included a calculation of nursing costs and savings from decreased length of stay; Van den Heede *et al.* (2010) calculated the additional nurse hours required to meet the 75th percentile of nursing hours per patient day (NHPPD) compared with a 'do nothing' approach. Newbold (2008) calculated the cost of nursing staff for three PTN ratios combined with three skill mix ratios. Li *et al.* (2011) estimated the contribution of nursing costs to inpatient costs to

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Table 2 Summary of included studies.

Article	Study group & country	Type of economic analysis, perspec tive & design	Nurse variables	Patient variables	Cost variables	Results
Behner *et al.* (1990) Quality Assessment 20/100	USA, 1 nursing unit, 132 patients with DRG 215	Hospital perspective Cost benefit Measured Two stage model, relationship between staffing levels and patient complications, then relationship between patient complications and length of stay	Staffing levels Ratio of required to actual hours	Length of stay Presence of complications Acuity level	Determined costs at the patient level by assigning patients to an acuity level based on their nursing resource needs and assigned a workload factor and cost to each of the acuity levels Used budget variance measures of rate variance, volume variance, efficiency variance	Understaffing 20% below required resulted in 30% increase in probability of patient having a complication. Those who experienced a complication had a mean length of stay of 3·5 days longer than those who did not. Additional costs associated with patients who develop complications are greater than the labour savings due to understaffing.
Li *et al.* (2011) Quality Assessment 59/100	USA, 139,360 admissions to 292 medical/surgical units at 125 Veterans Affairs medical centres	Hospital perspective Cost effectiveness Measured Retrospective cross sectional study Two step multi level mixed effects linear regression analysis Association between inpatient care costs and nurse staffing, controlling for other variables	From national databases Total Hours per patient day (HPPD) RN skill mix Used aggregated monthly data	Controlled for patient variables Serious complication (pulmonary failure, metabolic derangement, wound infection, deep vein thrombosis, pneumonia, urinary tract infection, pressure ulcer, sepsis, shock/cardiac arrest, gastrointestinal bleed) Transfer to Intensive Care Unit	From national databases Cost per hospital admission (CPHA) (patient) Cost per bed day of care (CPBDC) (patient) (cost of admission divided by the length of stay)	Surgical: neither a higher RN skill mix nor greater total HPPD were associated with CPHA after controlling for predicted inpatient costs. Both RN skill mix and HPPD were associated with CPBDC Medical: RN skill mix was not associated with higher CPHA, but higher total HPPD was associated. RN skill mix and HPPD were associated with CPBDC.

Table 2 (*Continued*).

Article	Study group & country	Type of economic analysis, perspec tive & design	Nurse variables	Patient variables	Cost variables	Results
Needleman *et al.* (2006) Quality Assessment 69/100	USA, 799 acute care hospitals (used data from earlier study)	Hospital perspective Cost benefit Modelled Regression analysis	Raising RN proportion to 75th percentile Raising nursing hours (RN/ LPN) to 75th percentile Raising both (nursing hours and RN proportion) to the 75th percentile where each is below	Avoided deaths Length of stay Avoided adverse outcomes	Costs of avoided adverse outcomes and avoided days estimated from regression models Estimated variable and fixed costs Wage data based on 1997 2002 Current Population Surveys Other costs based on American Hospital Association Annual Survey	Cost savings exceed cost increases for raising RN proportion but not for raising nursing hours or raising both the hours and RN proportion together Most cost savings come from decreased LOS
Newbold (2008) Quality Assessment 62/100	USA, used data from the Aiken *et al.* (2003) study	Hospital perspective Cost effectiveness Modelled Used production theory	From Aiken *et al.* (2003) study Nine combinations of nurse/ patient ratios and skill mixes	From Aiken *et al.* (2003) study Mortality (survival)	Bureau of Labour Statistics Wages of RNs and LPNs	Cost for each process ranged from a daily cost of $3280 for a survival rate of 976·2/1000 patients (8 PTN ratio/20% RNs) to a daily cost of $6305 for a survival rate of 983·5/1000 patients (4 PTN ratio/80% RNs). In all cases increasing the percentage of RNs or decreasing the PTN ratio increased the cost per day. The cheapest option to improve outcomes was to change the skill mix rather than the PTN ratio.

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Table 2 (*Continued*).

Article	Study group & country	Type of economic analysis, perspec tive & design	Nurse variables	Patient variables	Cost variables	Results
Rothberg *et al.* (2005) Quality Assessment 88/100	USA	Hospital perspective Cost effectiveness Modelled Included sensitivity analysis	Patient to nurse ratios	Used mortality data from Aiken *et al.* (2002) and length of stay data from Needleman *et al.* (2002) Lives saved	Bureau of Labour statistics for wages, research literature Cost per patient daily nursing labour cost + non nursing costs × LOS	Costs per life saved vary depending on the ratio To change from 8 7 PTN, cost per life saved $45,900 (or $24,900 with decreased LOS costs), to change from 5 to 4 PTN, costs per life saved $142,000 (or $70,700 with decreased LOS costs)
Shamliyan *et al.* (2009) Quality Assessment 76/100	USA	Hospital and societal perspective Cost benefit Modelled Random effects model and simulation models	RN full time equivalent (FTE)/patient day	From meta analysis of 27 published studies on staffing and outcomes LOS, mortality, FTR, cardiac arrest, shock, unplanned extubation, respiratory failure, DVT, upper GI bleeding, falls, pressure ulcers, nosocomial infection, UTI, pneumonia, nosocomial blood stream infection	Based on relative changes in LOS and avoided adverse events with different staffing ratios Used nationally available data to calculate costs of: Years of potential life saved Value of lives saved per 1000 hospitalized patients Value of avoided patient adverse events RN cost/1000 hospitalized patients Calculated hospital net savings and societal net savings Savings/cost ratio	Increasing RN staffing by one RN FTE/patient day was associated with a positive savings cost ratio and saved from between 210 683 and 604 169 years of life in medical and surgical patients with a productivity benefit of 2 10 billion Largest economic benefit corresponded to an 0·56 1·5 increase in RN FTE/patient day The hospital cost of increased nurse staffing exceeded the benefits
Twigg *et al.* (2013) Quality Assessment 72/100	Australia, All multi day patients admitted to 3 teaching hospitals over a 2 year period (107,253 patients in pretest and 107,026 in post test)	Hospital perspective Cost effectiveness Measured Longitudinal, retrospective study Pre/post implementation of NHPPD staffing method Logistic regression	Total nursing hours pre and post implementation Skill mix per cent Total nursing hours Total RN hours	Measured from hospital morbidity data Life years gained based on differences in FTR pre and post intervention	Hourly cost based on average nursing costs per hospital Cost of NSO prevented based on a published cost of an adverse event for a multi day admission corrected for age and morbidity	Cost per life year gained was $8907.

Table 2 (*Continued*).

Article	Study group & country	Type of economic analysis, perspec tive & design	Nurse variables	Patient variables	Cost variables	Results
Van den Heede *et al.* (2010) Quality Assessment 82/100	Belgium, general cardiac postoperative nursing units, 9054 patients, 75 nursing units, 28 surgery centres	Hospital perspective Cost effectiveness Modelled	From Belgian Nursing Minimum Dataset NHPPD sum of RN hours per nursing unit divided by the number of inpatient days per unit	From Belgian hospital discharge database Mortality Number of life years gained, multiplied number of avoided deaths × life expectancy of patients (determined from the literature)	Computed additional nurse hours required to meet 75th percentile of NHPPD, used the difference between the NHPPD of the unit and the NHPPD of the 75th percentile × number of postoperative inpatient days	Increasing staffing to the 75th percentile was associated with an ICER of €26,372 per avoided death and €2639 per life year gained
Weiss *et al.* (2011) Quality Assessment 59/100	USA, 4 Magnet hospitals, 16 units 1892 patients, randomly selected	Hospital perspective Cost benefit Measured Retrospective multi level regression analysis	Registered Nurse (RN) hours per patient day (RNHPPD) Non RN hours per patient day (Non RNHPPD) Split between overtime and non overtime hours RN vacancy rate	Unplanned readmissions in 30 days Emergency department (ED) visits in 30 days Quality of discharge teaching scale Readiness for hospital discharge scale	Costed nurses according to US Bureau of Labour Statistics data Used patient level financial data from the hospitals cost accounting database Calculated change in patient net revenue from reduced readmission/ED visit	RN non overtime and RN overtime were sig for readmission, RN overtime was sig for ED visits Increasing RN non overtime by 1SD (0·75 hours per patient day) cost hospitals $198 per patient but saved payers $607 per patient Reducing RN overtime by 1SD (0·07 hours per patient day) saved hospitals $8 per patient

calculate the change in cost for a one unit change in the staffing variable.

For the cost benefit studies Needleman *et al.* (2006) cal culated the cost of raising the proportion of registered nurse (RN) hours to the 75th percentile, raising the number of licenced practical nurse (LPN) hours to the 75th percentile and raising both to the 75th percentile. Shamliyan *et al.* (2009) calculated the RN cost per patient day. Weiss *et al.* (2011) measured the monthly nursing hours per patient day and costed them by multiplying the hourly cost by the stan dard deviation by the average LOS. Behner *et al.* (1990) measured the recommended to actual nursing hours expressed as a percentage based on patient acuity for each day of the patients' stay and calculated the cost savings from understaffing.

Various published salary data were used for the nurse staffing costs such as the Belgian Ministry of Public Health (Van den Heede *et al.* 2010), United States (US) Current Population Surveys (Needleman *et al.* 2006), US Bureau of Labor Statistics (Rothberg *et al.* 2005, Newbold 2008, Shamliyan *et al.* 2009, Weiss *et al.* 2011) and the US Cen ters for Medicare & Medicaid Services Wage Index File (Li *et al.* 2011). Twigg *et al.* (2013) and Behner *et al.* (1990) did not state the source of their salary data.

Consequences

Consequences of changes in nurse staffing/skill mix were measured in various ways. In the cost effectiveness studies, Twigg *et al.* (2013) calculated the difference between the

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expected and observed NSOs for the intervention and costed adverse events according to data published by Ehsani *et al.* (2006) to calculate the cost of the intervention. They also calculated life years gained from the 'failure to rescue' outcome, calculating the difference between the average age of those who experienced a 'failure to rescue' and the average Australian life expectancy based on OECD (2011) data, pre and post intervention. Rothberg *et al.* (2005) measured effectiveness as deaths averted for each PTN ratio. Van den Heede *et al.* (2010) calculated avoided deaths from observational patient data if increasing staffing to the 75th percentile and life years gained by multiplying avoided deaths by the life expectancy of patients, with survival rates determined from two studies (Sergent *et al.* 1997, Kvidal *et al.* 2000). Newbold (2008) mapped the survival rate for each of three PTN ratios combined with three skill mix ratios to give a cost per production process. Li *et al.* (2011) calculated the cost per hospital admission and cost per bed day of care based on inpatient costs derived from the VHA decision support system.

In the cost benefit studies many different consequences were costed. In Needleman *et al.* (2006) the cost of adverse outcomes and avoided days of stay, estimated with regression modelling, were calculated, with costs based on data from the American Hospital Association (AHA) annual survey and Medicaid cost reports separating variable costs from fixed costs. Shamliyan *et al.* (2009) calculated the net benefit of saved lives, net benefit of avoided adverse events and net benefit of decreased length of stay. The monetary cost of saved lives was estimated using average present value of future lifetime earnings from Haddix *et al.* (2003), the value of avoided adverse events was calculated from charge per case data from the Healthcare Cost and Utilization Project & United States Agency for Healthcare Research and Quality (2000) and the value of decreased LOS was given as the average cost of one patient day although the source of these cost data was not stated. Savings were reduced by 40% to account for variable costs. The authors calculated a savings/cost ratio for each outcome as the net benefit/RN cost. Weiss *et al.* (2011) calculated the impact for the hospital from changes in net revenue from reduced readmission/ED visits costed at the patient level from the hospital accounting system and calculated the impact on payers by costing the reimbursement payments to the hospital and physicians from hospital post discharge use. Physician payments were estimated using the Medicaid physician reimbursement formula. Behner *et al.* (1990) calculated the cost of adverse outcomes and increased length of stay at the patient level for those who experienced understaffing at 20% below the standard nursing hours, although the source of the costing data was not stated.

Is increasing nurse staffing cost effective?

Results of the economic benefit of increasing nurse staffing levels and changing skill mix in these studies were mixed. The cost values reported here are the costs reported in the included studies adjusted to 2013 USD using purchasing power parity and GDP deflator indices (Higgins & Green 2011, International Monetary Fund 2014). Behner *et al.* (1990) found that staffing at 20% below required was associated with additional costs from complications that were greater than the labour savings, costing an additional US $28,441 for the study sample. In contrast Weiss *et al.* (2011) found that payers save US$652 per admission, but the hospital loses US$213 per patient when the RN HPPD level is higher (by one standard deviation 0·75). Similarly, Li *et al.* (2011) found that costs per admission were positively associated with increased HPPD among medical admissions (US $202 per additional HPPD) but not among surgical admissions. Higher costs per hospital day were associated with higher HPPD and RN skill mix for medical admissions (US $97 per additional HPPD and US$7 per 1% increase in skill mix) and surgical admissions (US$138 per additional HPPD and US$16 per 1% increase in skill mix).

Two studies provided evidence that changing skill mix was more cost effective than increasing RN hours. Needleman *et al.* (2006) found that increasing the RN proportion to the 75th percentile was associated with a cost saving of US$303 million (across the whole sample 799 hospitals) while increasing licenced hours (RNs and LPNs) to the 75th percentile resulted in a cost of US$7·3 billion and increasing both nursing hours and proportion of RN hours to the 75th percentile cost US$7·1 billion. Similarly Newbold (2008) concluded that the cheapest option to improve outcomes was to change the skill mix rather than the nurse patient ratio, although unlike Needleman *et al.* (2006) he found that in all cases increasing the percentage of RNs or decreasing the nurse patient ratio (PTN) increased the cost per day with reported costs ranging from a daily cost of US $4,030 for a survival rate of 976·2/1000 patients (8 PTN ratio/20% RNs) to a daily cost of US$7,746 for a survival rate of 983·5/1000 patients (4 PTN ratio/80% RNs).

In the only study conducted from a societal perspective, Shamliyan *et al.* (2009) found that increasing RN staffing by one RN full time equivalent (FTE) per patient day was associated with a positive savings cost ratio and would save from between 210,683 (female medical patients) and 604,169 (male surgical patients) years of life in medical and surgical patients with a productivity benefit of US$3·6 to US$13 billion. However, they found that from the hospital perspective, the cost of increased nurse staffing exceeded the benefits.

In the three studies that calculated an incremental cost effectiveness ratio (ICER) there was a cost associated with saving lives, with all costs within reasonable levels for the funding of interventions (as reported by the authors through comparison to the cost of other interventions). These ICERs cannot be directly compared due to the differ ent nature of the staffing comparisons they used. Rothberg *et al.* (2005) estimated a cost per life saved of US$56,394 (or US$30,593 if decreased LOS costs are included) when changing the ratio from 8 7 patients per nurse and a cost per life saved of US$174,464 (US$86,864 if decreased LOS costs are included) while changing the ratio from five to four patients per nurse. Van den Heede *et al.* (2010) calcu lated that increasing NHPPD to the 75th percentile com pared with a 'do nothing' approach was associated with an ICER of US$25,702 per avoided death and US$2,572 per life year gained, while Twigg *et al.* (2013) calculated a cost per life year gained of US$14,123 when comparing an increase in NHPPD from pre to post intervention.

There is some evidence that the cost effectiveness of nurse staffing is not linear. Shamliyan *et al.* (2009) found that the largest economic benefit corresponded to a 0·56 1·5 increase in RN FTE/patient day, decreasing with a further increase to 2·5 RN FTE/patient day. Rothberg *et al.* (2005) also found a non linear relationship where the rate of incre mental cost increase accelerated while the rate of mortality decrease decelerated resulting in progressively higher ICERs for each one patient decrease in the PTN ratio. Newbold (2008) also reported diminishing returns for both increasing the RN ratio and for decreasing the PTN ratio.

Discussion

All the studies identified in this review were either cost ben efit or cost effectiveness analyses. The study authors used a variety of methods to conceptualize and measure costs and outcomes, making it difficult to directly compare results across studies. This variability was also identified by previ ous reviewers (Thungjaroenkul *et al.* 2007, Unruh 2008, Goryakin *et al.* 2011). The quality scores of the studies using the QHES Instrument ranged from 20 88 out of a possible 100, with the Rothberg *et al.* (2005) study meeting more of the quality criteria than the other studies. All but one of the studies were conducted from the hospital per spective, rather than a societal perspective. Weinstein *et al.* (1996) recommended that cost effectiveness studies be con ducted from the societal perspective, although hospitals may be more interested in the direct financial impact on themselves alone. The studies could have been improved by including the societal perspective as well as the hospital per spective, including incremental analysis, including or increasing the sensitivity analysis around variable estimates, increasing the time horizon of the studies and greater dis cussion of limitations and bias. Similar methodological limi tations were also identified by Spetz (2005) and Goryakin *et al.* (2011) in their reviews.

A major limitation of all the studies is the quality of the underlying effectiveness studies on which estimates of the relationship between adverse outcomes and staffing/skill mix levels are based. There are no RCTs in this area of research. In general studies are based on observational data, often with very large datasets (Kane *et al.* 2007a, Shekelle 2013). Correspondingly, there was a high risk for bias identified in all of the effectiveness studies associated with the economic evaluations included in this review. The high likelihood of bias in the effectiveness studies affects the validity of the economic evaluation. Due to this risk of bias it is important to perform sensitivity analyses around the effectiveness estimates. Although five of the studies included some type of sensitivity analysis, only Rothberg *et al.* (2005) conducted a sensitivity analysis around the effectiveness estimates.

Is increasing nurse staffing cost effective?

The results of the economic benefit of increasing nurse staff ing or changing nurse skill mix were mixed, with some stud ies showing a saving and some a cost with results dependent on how variables were measured, the population they were measured in and how nurse staffing or skill mix were con ceptualized. It was not possible to arrive at a clear conclu sion as to whether increasing nurse staffing or changing skill mix was a cost effective intervention to improve patient out comes. There is some evidence that the cost effectiveness of nurse staffing is not linear. This area requires further investi gation that would be aided by the development of a refer ence case for cost effectiveness studies.

Developing a reference case guideline

It is difficult to compare the results across studies because of the different ways costs and consequences were mea sured. It would be helpful to develop a reference case for determining the cost effectiveness of nurse staffing to ensure that any future studies are comparable. A reference case is a guideline for the conduct of cost effectiveness

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studies that presents a standard protocol or framework for how the nurse staffing or skill mix variable should be measured, which items should be included in costs, what discounting is required, how consequences should be measured, the time horizon that should be considered and the perspective that should be taken. Such studies should also include sensitivity analyses that incorporate different realistic changes to cost and benefit variables. The Panel on Cost Effectiveness in Health and Medicine provided some useful guidelines for how to achieve this (Weinstein *et al.* 1996). The reference guideline would ideally be able to be applied internationally, although variations in data available in different countries may lead to differences in what can be included. Nonetheless any reference case development should take into account ways to incorporate an international perspective to allow comparability between countries.

The development of a reference case guideline would also help to improve the quality of economic evaluations of nurse staffing. International standards in relation to the funding of new therapies and technologies recommend economic evaluations using ICERs based on quality adjusted life years (QALYs) and the development of a base reference case as the preferred methodology (Weinstein *et al.* 1996, Canadian Agency for Drugs & Technology in Health 2006, National Institute for Health and Care Excellence (2013), Pharmaceutical Benefits Advisory Committee 2013). Additionally, the use of ICERs based on QALYs and a well defined reference case allows interventions to be compared both in and across intervention types. Willingness to pay (WTP) thresholds for funding of new interventions are primarily published in terms of cost per QALY (with limited WTP thresholds based on life years gained) and so use of cost utility analysis would enable researchers to compare their study findings against generally accepted WTP thresholds (Kaplan & Bush 1982, George *et al.* 2001, Simoens 2009, Shiroiwa *et al.* 2010). Whether the use of QALYs in cost effectiveness studies of nurse staffing and skill mix is feasible is an area that requires further discussion when developing a reference guideline.

Limitations

This review was limited to English language studies; so the authors may have missed some studies of relevance. There were other studies that investigated some aspects of the economics of nurse staffing that were not included in this review because they did not comprise a full economic evaluation linking costs, outcomes and staffing, however, it may be that some of these papers would still aid an understanding of this topic. All of the studies that were identified are limited because of the design of the effectiveness studies that underpin the economic analyses. There were no effectiveness studies based on randomized controlled trials and therefore effectiveness estimates and the economic estimates based on these must be interpreted with caution. Only one study used sensitivity analysis to account for this limitation (Rothberg *et al.* 2005).

Conclusion

There is a large body of literature that demonstrates that nurse staffing levels and skill mix are important factors in ensuring the quality of care for patients in acute care settings. In comparison, there are only a small number of studies that have investigated the cost of changing staffing levels and skill mix in relation to the cost of adverse outcomes of care. Due to the small number of studies, the variable results and the inability to compare results across studies, the authors were unable to determine conclusively whether or not changes in nurse staffing levels is a cost effective intervention for improving patient outcomes. The way comparisons were made does not allow the identification of a nurse patient ratio or skill mix that is most cost effective. In general, it seems that although increasing nurse staffing and/or changing skill mix has a beneficial effect on patient outcomes, this effect comes at a cost. It is up to payers to determine whether or not this cost is acceptable. It may be that from a hospital perspective, increasing nurse staffing is not a cost effective intervention whereas from the societal perspective it is, however more high quality studies are required in this area, using a well defined reference base case. There is some evidence that changing the skill mix may be more cost effective than increasing nursing hours although this requires further investigation.

Recommendations

The authors recommended the development of a reference case guideline, with expert consultation, to define the cost and consequences that should be included in cost effectiveness studies of nurse staffing to allow for meaningful comparison and synthesis of future studies. Future studies should also include a sensitivity analysis due to the uncertainty surrounding the effectiveness estimates and other variables. Additionally, more studies from the societal perspective need to be conducted. We found no cost utility studies in the literature, which may be due to the difficulty of measuring variables due to the large scale nature of nurse staffing studies, however if feasible, the evidence would benefit from cost utility studies to allow for compari son with other healthcare interventions.

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Author contributions

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the IC MJE (http://www.icmje.org/ethical 1author.html)]:

- substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;
- drafting the article or revising it critically for important intellectual content.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site.

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