THE RELATIONSHIP BETWEEN NURSE STAFFING AND INPATIENT COMPLICATIONS

ABSTRACT

AIM. To compare characteristics of hospitalisations with and without complications and examine the impact of nurse staffing on inpatient complications across different unit types.

BACKGROUND. Studies investigating the relationship between nurse staffing and inpatient complications have not shown consistent results. Methodological limitations have been cited as the basis for this lack of uniformity. Our study was designed to address some of these limitations.

DESIGN. Retrospective longitudinal hospitalisation-level study.

METHOD. Adult hospitalisations to high intensity, general medical and general surgical units at three metropolitan tertiary hospitals were included. Data were sourced from Western Australian Department of Health administrative data collections from 2004 - 2008.

We estimated the impact of nurse staffing on inpatient complications adjusted for patient and hospital characteristics and accounted for patients with multiple hospitalisations.

RESULTS. The study included 256,984 hospitalisations across 58 inpatient units. Hospitalisations with complications had significantly different demographic characteristics compared with those without. The direction of the association between nurse staffing and inpatient complications was not consistent for different inpatient complications, nurse skill mix groups, or for hospitalisations with different unit movement patterns.

CONCLUSION. Our study design addressed limitations noted in the field, but our results did not support the widely held assumption that improved nurse staffing levels are associated with decreased patient complication rates. Despite a strong international focus on improving nurse staffing to reduce inpatient complications, our results suggest that adding more nurses is not a panacea for reducing inpatient complications to zero.

KEYWORDS

adult nursing, medical record linkage, nursing methodology research, outcome assessment, quality indicators

SUMMARY STATEMENT

Why is this research needed?

- Research linking nurse staffing levels and inpatient complications has not shown consistent results.
- The lack of uniform results has been attributed to methodological limitations.

What are the key findings?

- Our results did not support the widely held assumption that improved nurse staffing levels result in decreased patient complication rates.
- Baseline nurse staffing levels and patient complication rates impact on the effect of increasing nurse staffing levels.
- Increasing nurse staffing alone may not reduce patient complications in all situations.

How should these findings be used to influence policy, practice and future research?

- Policy makers should recognise that implementation of legislation mandating specific minimum staffing levels is not associated with significantly fewer patient complications.
- Innovative ways of defining, measuring and evaluating nursing care quality beyond the staffing proxy should be developed.
- Patient outcome measures that can be temporally linked to nursing care should be investigated.

INTRODUCTION

Nursing care is thought to directly influence inpatient health outcomes independent of other health professional's interventions and patient factors, such as, diagnosis and demographic or socioeconomic characteristics (International Council of Nurses 2007). However, there is limited or inconsistent evidence that increases in two common staffing measures of nursing care (nursing hours of care and nurse skill levels) are associated with decreases to inpatient complications; this has been attributed to study design limitations (Dimick *et al.* 2001, Curtin 2003, Stone *et al.* 2003, Garretson 2004, Haberfelde *et al.* 2005, Blegen 2006, Lake & Cheung 2006, Numata *et al.* 2006, Tourangeau *et al.* 2006, Ayre *et al.* 2007, Needleman *et al.* 2007, Thungjaroenkul *et al.* 2007, Garrett 2008, Unruh *et al.* 2008, West *et al.* 2009, Twigg *et al.* 2011). We present a study that addressed several of these design limitations and discuss other factors which may contribute to inconsistent findings on the relationship between nurse staffing and inpatient complications.

Background

The association between nurse staffing and inpatient complications has been a topic of research interest for nearly three decades. A 2007 systematic review reported an association between increased RN (Registered Nurse) staffing and decreased likelihood of hospital related mortality and patient complications in acute care hospitals (Kane *et al.* 2007). Some commonly measured complications in this area of research include: pressure ulcer, shock or myocardial infarction (MI) and hospital acquired infections (Kane *et al.* 2007, Van den Heede *et al.* 2007, Griffiths *et al.* 2008).These inpatient complications, sometimes known as 'nursing sensitive outcomes' or 'outcomes potentially sensitive to nursing', can be theoretically linked to nursing care (Subirana *et al.* 2014). Staffing is measured as a proxy for a hospital or unit's capacity to provide nursing care. Greater numbers or better skilled nurses may improve capacity to provide nursing care and prevent nursing sensitive complications (Kutney-Lee *et al.* 2009).

Despite theoretical links between nurse staffing levels and inpatient complications, studies investigating the association have not yielded consistent results (Stone *et al.* 2003, Haberfelde *et al.* 2005, Blegen 2006, Lake & Cheung 2006, Numata *et al.* 2006, Tourangeau *et al.* 2006, Ayre *et al.* 2007, Needleman *et al.* 2007, Thungjaroenkul *et al.* 2007, Unruh *et al.* 2008, West *et al.* 2009). Study design limitations have been cited as potential reasons for this, including: differences in risk adjustment variables and measures of nurse staffing and inpatient complications (Mark 2006, Van den Heede *et al.* 2007); masking of true associations through aggregation of heterogeneous groups of individual patient data (Sales *et al.* 2008); hospital-level analysis despite wide variation in staffing levels between individual units (Minnick & Pabst 1998, Van den Heede *et al.* 2009a, Twigg *et al.* 2011); difficulty estimating individual patient exposure to nurse staffing (Harless & Mark 2006, Mark 2006, Sales *et al.* 2008, Penoyer 2010); difficulty distinguishing pre-existing patient complications from those potentially related to nursing care (Mark & Harless 2010, Schreuders *et al.* 2014); and finally, that the effect of an increase in nurse staffing may depend on the baseline staffing (Jelinek 1967, Blegen *et al.* 1998, Hendrix 2003, Mark *et al.* 2004a).

This study of the relationship between nurse staffing and nursing sensitive inpatient complications in Western Australian (WA) public hospitals was designed to address several methodological limitations commonly cited in the field. All analyses were conducted at the hospitalisation-level, to avoid grouping patients with discordant characteristics and to enable a fine-grained estimate of actual patient exposure to nurse staffing (Harless & Mark 2006, Mark 2006, Sales *et al.* 2008, Penoyer 2010). The choice of analysis variables was guided by recommendations in the literature (Mark 2006, Van den Heede *et al.* 2007, Griffiths *et al.*

2008). Our method of identifying complications was designed to minimise the likelihood that pre-existing complications were attributed to nursing care (Mark & Harless 2010, Schreuders *et al.* 2014).

THE STUDY

Aims

We aimed to: firstly, describe the nurse staffing characteristics of study units; secondly, compare patient characteristics of hospitalisations with and without complications; and finally, examine the impact of patient exposure to nurse staffing on the odds of eight patient complications for different patient unit movement patterns.

Study design and participants

This was a retrospective longitudinal study of inpatient hospitalisations between 1 January 2004 - 31 December 2008 at three adult tertiary hospitals in WA. These hospitals offered the 'cleanest' nurse staffing data in terms of identifying nursing hours that provided direct patient care on inpatient units. All three are teaching hospitals, based in the metropolitan area, government-owned, large (≥200 beds) and provide high technology services (e.g. organ transplantation, cardiac catheterisation, trauma care). Hospitalisations of patients younger than 18 years and those admitted to paediatric, maternity, rehabilitation, or psychiatric care units were excluded. Repeat hospitalisations were included in analysis because the five year study period meant it was possible for the same person to be hospitalised multiple times for unrelated reasons and be at risk of different nursing sensitive patient complications. The way that nursing sensitive patient complications were identified ensured that none could be counted twice in the same complication group.

Data collection and analysis variables

Administrative nurse and patient data were sourced from three branches in the WA Department of Health (WADOH): the Health Corporate Network (HCN); the WA Data Linkage Branch (WADLB); and the Health Information Network (HIN). Brief descriptions of the data from each branch follow.

Nurse staffing data

The total number of nursing hours was sourced from government hospital payroll records maintained by the HCN and used to estimate each patient's average exposure to nursing hours and skill mix. Using hospital payroll records to calculate nurse staffing has the advantages of being quantifiable at the unit-level and counts only productive hours (i.e. hours paid as leave were excluded). The data were used to calculate total nursing hours worked on each unit per fortnight during the study period, both overall and by RNs or other types of nurses (as described below). At all three hospitals, nurses who provided direct inpatient care were paid from separate cost centres to nurses who provided non-direct patient care (i.e. those in management or educational roles) or outpatient care. This enabled us to estimate hours of direct patient care without having to adjust for a proportion of hours being used for outpatient care.

Exposure to nurse staffing was estimated by measuring nursing hours per patient day (NHpPD) and skill mix (i.e. proportion of total nursing hours worked by RNs). These are thought to improve nursing care capacity by increasing total nurse hours available per patient and/or having care delivered by nurses with a more comprehensive educational preparation (Kutney-Lee *et al.* 2009). Data on number of nursing hours were combined with inpatient unit movement data to construct the NHpPD staffing measure. This measure achieved the highest level of consensus among international experts in a study about the usefulness of different nurse staffing, patient outcome and background variables (Van den Heede *et al.*

2007) and has been employed internationally (Needleman *et al.* 2002, Van den Heede *et al.* 2009b) and in Australia (Duffield *et al.* 2011, Twigg *et al.* 2011). The nurse skill mix measure was defined as the proportion of total nursing hours provided by RNs, where total nursing hours also included Enrolled Nurses (ENs) and Nursing Assistants (NAs). In Australia ENs and NAs receive vocational training that is less comprehensive than RN university-level education; they are analogous to licensed practical nurses and nurse aides.

Hospitalisations with incomplete nurse staffing data were excluded; for example when there were no or very few nursing hours recorded for a fortnight on a particular unit. Of a potential 7,598 fortnights of data, 1,168 were excluded for this reason.

Inpatient unit movement data

The HIN manages stored inpatient unit movement data from the patient information management system, which tracks patient locations in the hospital from admission to discharge. 'Inpatient units' were those with patients admitted for multiple days including Intensive Care Unit (ICU), Coronary Care Unit (CCU), High Dependency Area (HDA) and general and specialty medical and surgical units. Day surgery units, outpatient units and areas where inpatients attend diagnostic or other procedures (e.g. dialysis or imaging) were excluded. Inpatient unit movement data provided admission and discharge times from any patient care area (e.g., emergency department, inpatient units, operating theatres). These data were used to calculate the amount of nursing exposure for each patient (the time each patient spent on different units), the total number of patient days that were spent on a unit and the total number of unit movements per hospitalisation.

Patients often spend time on more than one unit during a hospitalisation and there may be wide variation in staffing levels between units; for example, when comparing ICU and a general medical unit. Rather than assuming a single staffing level, we calculated a composite nurse staffing exposure for each inpatient episode by combining the staffing levels on all the units that patients attended and weighting them by the length of time spent on each unit. These weighted values were summed and divided by the total length of stay (LOS) to quantify the average exposure to nurse staffing per day of hospitalisation. We stratified our analysis by time spent on a high intensity unit and at which time point during the hospital episode that it occurred; because higher staffing levels in those units led to inflated average daily exposure to nurse staffing. We have used the term ‘high intensity units’ to encompass ICU, HDA (i.e. similar to ICU step-down) and CCU; the term ‘low intensity units’ refers to general and specialty medical and surgical units. The following criteria were applied to stratify hospitalisations with similar unit movement patterns: none of the LOS in high intensity; the whole LOS in high intensity; high intensity at the beginning of the stay followed by low intensity, high intensity after theatre and low intensity at the beginning of the stay followed by high intensity.

Mortality and inpatient morbidity data

The WADLB connects mortality (WA death records), inpatient morbidity (WA hospitalisation records) and socioeconomic status data collections; records in each collection that refer to the same person are linked into chains of person-specific records. In addition to demographic details, the inpatient morbidity data include a principal diagnosis code and up to 21 additional diagnoses coded using the ICD-10, Australian Modification (ICD 10 AM) (National Centre for Classification in Health 2008). Linked mortality and inpatient morbidity data allowed us to track a single individual’s events over time, including death within 30 days of admission, even when it occurred out of hospital. A standardised index of relative socioeconomic disadvantage (IRSD), based on patient’s residential location immediately prior to hospital admission, was linked to the person-specific chain as an indicator of socioeconomic status (Adhikari 2006, Pink 2006). The IRSD uses census data to score the economic and social resources of a residential area and groups them into deciles, with the first decile representing greatest relative disadvantage (i.e. many households with low income and/or with lower educational attainment) and the tenth representing least relative disadvantage. Data linkage was used to determine when the primary outcomes, nursing sensitive patient complications, had occurred and to generate the demographic variables used in statistical risk adjustment.

Nursing sensitive patient complications

Our choice of outcome variables were informed by recommendations in the literature (Van den Heede *et al.* 2007, Griffiths *et al.* 2008). Six nursing sensitive patient complications were identified based on the presence or absence of specific ICD-10-AM diagnosis codes in the linked morbidity data: (1) surgical wound infection; (2) urinary tract infection; (3) pressure ulcer; (4) pneumonia; (5) deep vein thrombosis; and (6) shock or myocardial infarction. Two further complications used inpatient morbidity and mortality data, failure to rescue (i.e. death following pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis or deep vein thrombosis (Needleman *et al.* 2002)) and 30-day mortality (i.e. in or out of hospital deaths within 30 days of admission). Inpatient complications were assumed to be nursing sensitive only when the patient had no relevant disease codes recorded within 2 years prior to the episode captured by our study criteria. Therefore if an individual experienced the same inpatient complication on separate hospitalisations that were less than 2 years apart, only the first event was counted in our analysis. Our method for identifying nursing sensitive patient complications is described in greater detail elsewhere (Schreuders *et al.* 2014).

Ethical considerations

Ethics approval for this research was granted by the Government of Western Australia Department of Health Human Research Ethics Committee (reference: RA/4/1/2469) and The University of Western Australia Human Research Ethics Committee (Project #2009/56).

Data analysis

Risk adjustment

The inpatient morbidity data allowed us to risk adjust for: age, sex, relative decile of socioeconomic status (based on residential postcode) (Adhikari 2006, Pink 2006), month of admission, admission type (elective or emergency), whether their hospitalisation was an inter-hospital transfer, which of the three hospitals they attended, Charlson Comorbidity Score (CCS) (Charlson *et al.* 1987, Quan *et al.* 2005) calculated with 5 years of look-back and total number of complications detected for the hospitalisation. The CCS is a weighted measure of the number and severity of comorbid diseases an individual has recorded in their hospitalisation history (Charlson *et al.* 1987). Lower CCS values indicate an individual has fewer comorbid medical conditions. Data sourced from the HCN and HIN enabled risk adjustment of: percentage of the hospitalisation with below-target nurse staffing levels, the total number of inpatient unit movements and LOS. LOS is often included as an outcome variable but was included in risk adjustment here since longer total hospital LOS has been independently associated with increased risk of patient complications (Graves *et al.* 2005, Khan *et al.* 2006, Hauck & Zhao 2011) and it was not within the scope of the study to measure deviation from expected LOS (Tschannen & Kalisch 2009). Below-target staffing levels were ascertained based on whether units met the WA state government's mandated minimum nurse staffing levels for the fortnight during which the hospitalisation occurred (Western Australian Department of Health 2005). Appropriate risk adjustment has been recognised as essential to ensure the association between nurse staffing and inpatient complications is not confounded by extraneous variables (Needleman *et al.* 2007).

Analytic methods

Analyses were performed using IBM SPSS (Version 21, IBM SPSS Inc. 2010, Chicago, Il, www.spss.com) and statistical significance was set at 5%. Summary statistics were used to describe demographic and nurse staffing characteristics (NHpPD and skill mix). T-tests and chi-squared tests were used to compare differences in demographic characteristics of inpatients with and without complications.

We applied generalised estimating equation methodology to binomial logistic regression to account for correlation between the responses of patients who had multiple hospitalisations. An unstructured correlation structure was assumed. Preliminary analysis suggested stratifying because hospitalisations that included time in a high intensity unit had different nurse staffing distributions. Analysis was stratified by the pattern of unit movements during hospitalisation. Each nursing sensitive outcome was modelled separately with NHpPD, skill mix and the NHpPD:skill mix interaction as explanatory variables, adjusted for age, sex, Charlson Comorbidity Score, socioeconomic status, LOS, admission type, hospital transfer, hospital, percentage of hospitalisation on units with below-target NHpPD, number of unit movements per hospitalisation and total number of nursing sensitive inpatient complications per hospitalisation. NHpPD was included as a continuous variable and skill mix was separated into three categories based on the percentage of total nursing care hours provided by RNs: low (RNs provided <74% of hours), medium (RNs provided ≥74% and < 83% of hours) and high (RNs provided ≥83% of hours). The models estimated the changes in odds of each nursing sensitive complication at each level of skill mix with a one hour increase in NHpPD. The interaction between NHpPD and skill mix was included to reflect the complexity of the real-world situation in which additional hours by RNs may have a different effect than additional hours at a lower skill mix (Mark *et al.* 2004b).

Validity and reliability

Data were routinely collected by the WA Department of Health. Validation studies of the diagnosis coding of the Western Australian hospital morbidity data report high levels of reliability and validity of this source (Holman *et al.* 1999, Teng *et al.* 2008, Mnatzaganian *et al.* 2012). Payroll data has been demonstrated to provide complete information for nurse staffing measures (Jiang *et al.* 2006).

RESULTS

Over the five year study period there were 256,984 inpatient hospitalisations for 144,319 individuals across 58 inpatient units in the three hospitals; 36,773 (14%) of these hospitalisations included time in ICU or HDA. Of the 144,319 hospitalised individuals, 65% had only one hospitalisation during the study period (n=93,539), 18% had two hospitalisations (n=26,427), 8% had three hospitalisations (n=10,988) and the remaining 9% were hospitalised four or more times (n= 13,365). Approximately 20% of individuals experienced a complication during at least one hospitalisation (n=28,789).

The NHpPD range of 3.3 to 18.8 hours in low intensity units was markedly lower than the 10.3 to 48.2 hour range in high intensity units (24 NHpPD is equivalent to a nurse to patient ratio of 1:1, Table 1). Although both high and low intensity units had a maximum RN skill mix of 100%, the minimums dropped to 32% and 55% respectively (Table 1).

One or more inpatient complication was identified during 11% of hospitalisations (n=27,280). Patient demographic characteristics were significantly different during hospitalisations with complications compared with those without ($p \leq 0.001$). Patients were approximately 10 years older, more likely to be female and to have comorbid health conditions during hospitalisations with complications compared with those without (Table 2).

Table 3a shows the relationship between NHpPD and inpatient complications at each level of skill mix for hospitalisations in only low intensity units. Significant associations between the outcome and NHpPD were demonstrated in the lowest skill mix category, where each additional NHpPD was associated with a 29% increase in odds of surgical wound infection and a 19% decrease in odds of failure to rescue. In the medium skill mix category, there was a 17% increase in odds of pressure ulcer for each additional NHpPD.

Table 3b shows the relationship between skill mix-adjusted NHpPD and inpatient complications for hospitalisations with the whole LOS on high intensity units. Fourteen of the estimated associations between the outcome and NHpPD were significant. Increased NHpPD were associated with decreased odds of surgical wound infection across all three skill mix categories and urinary tract infection across the mid and high skill mix categories. In the lowest skill mix category, the odds of shock or MI decreased with increased NHpPD but this association was reversed in the medium and high skill mix categories. Increased NHpPD were associated with increased odds of 30-day mortality across skill mix categories and failure to rescue in the lowest and highest skill mix categories.

Table 4 shows the relationship between skill mix-adjusted NHpPD and inpatient complications when only part of the LOS was on high intensity units. Although estimated associations varied across models and skill mix categories, odds of surgical wound infection and urinary tract infection complications tended to decrease, while shock or MI and 30-day mortality tended to increase with additional NHpPD.

DISCUSSION

We found that the direction of the association between nurse staffing and patient complications was not consistent across different patient complications, nurse skill mix categories, or for hospitalisations with different unit movement patterns. Surgical wound infection and urinary tract infection were the only complications that consistently decreased with improved staffing levels. In contrast, improved staffing levels tended to be associated with increased odds of pressure ulcer, pneumonia, shock or myocardial infarction (MI) and 30-day mortality. In some models, failure to rescue decreased with improved staffing, but when all or the first part of the hospitalisation was on a high intensity unit, the odds increased.

It is currently accepted that improvements in nurse staffing are associated with decreased rates of certain patient complications and mortality. Our study's results were not in keeping with this, despite addressing some recognised previous limitations, such as risk adjustment. Others have acknowledged a similar lack of consistency (Jiang *et al.* 2006, Mark 2006, Needleman *et al.* 2007), particularly for mortality (Penoyer 2010), which suggests there are key challenges that require discussion before policy decisions draw on this evidence.

The mechanism of action by which patient complication rates are associated with improvements in nurse staffing is not yet fully understood. Many conceptual frameworks have been suggested to elucidate these mechanisms (Holzemer 1994, Mark *et al.* 1996, Aiken *et al.* 1997, Irvine *et al.* 1998, Mitchell *et al.* 1998, Lee *et al.* 1999, Cho 2001, Duffy & Hoskins 2003, Yen & Lo 2004, Tourangeau 2005, Meyer & O'Brien-Pallas 2010, O'Brien-Pallas *et al.* 2011, Subirana *et al.* 2014). No consensus has been reached but many frameworks feature complex relationships between multiple factors and are based on a structure-process-outcome paradigm (Donabedian 1966). Nursing processes of care, effectiveness of health professional communication, nursing care delivery models, clinical judgement and timely interventions are some of the process factors that have been proposed as mediating the relationship between staffing and complications (Irvine *et al.* 1998, Duffy & Hoskins 2003, Sidani *et al.* 2004, Tourangeau 2005, O'Brien-Pallas *et al.* 2011, Subirana *et al.* 2014). Like other researchers, we were unable to overcome the challenges of adequately measuring nursing process factors.

In the framework recently published by Subirana *et al.* (2014), clinical judgement, nurse surveillance, early detection of complications, timely intervention, expertise and tasks left undone are processes identified as mediating the relationship between nurse staffing and patient complications. However, only the last two have been research-tested and the others are ‘suggested variables’. Theoretically, adequate staffing hours and skill mix result in improved patient outcomes because processes of care can be carried out unimpeded. These process factors are difficult to measure, but are important since they mediate the relationship between nurse staffing and patient complications. It is possible that unmeasured structure or nursing process variables in our study are the reason for our unexpected results.

Another reason for our contrary results may be that baseline staffing levels and complication rates have a greater impact than previously understood. There is often an implicit assumption that the relationship between nurse staffing and patient complications is always linear. For example, Kane *et al.* (2007) reported that if the association between staffing and complications was causal, a one unit increase in staffing would result in seven fewer cases of hospital-acquired pneumonia per 1,000 hospitalised patients. However, as early as 1967 it was noted that nurse staffing increases would eventually result in gradually smaller changes to the actual amount of time spent on patient care (Jelinek 1967). Despite decades of research, few have acknowledged that as nurse staffing levels increase, progressively smaller reductions in patient complications should be expected (Blegen *et al.* 1998, Hendrix 2003, Mark *et al.* 2004a). Our results are consistent with the idea that nurse staffing level and patient complication rates have thresholds after which further improvements to nurse staffing have little or no effect.

It is plausible that nurse staffing levels and patient complication rates in this study had already reached a threshold level. The hospitals in the study were operating under a government mandated minimum nurse staffing policy, introduced approximately two years prior to commencement (Twigg & Duffield 2009). Implementation of the policy resulted in a state-wide 3.47% increase in nurse staffing in 2004, 86% of which went to the three study hospitals (Western Australian Department of Health 2005). Even though attainment of mandated staffing levels on units was high and approximately 80% of unit-fortnights met or exceeded targets (Table 2: 'Percentage of length of stay with below-target staffing') the odds of several patient complications increased with higher NHpPD and improved skill mix. Similarly, analysis of the impact of Californian minimum staffing legislation demonstrated significant increases to nurse staffing but no concomitant reductions in patient complication rates (Cook *et al.* 2012, Spetz *et al.* 2013). This adds weight to assertions that there is still insufficient evidence to support the efficacy of specific minimum staffing levels (Shullanberger 2000, Lang *et al.* 2004, Blegen 2006, Ayre *et al.* 2007, Hyun *et al.* 2008, Donaldson & Shapiro 2010).

Finally, finer complication measures may be needed to accurately assess the impact of nursing care. Nurses provide 24 hour care and their role is one of surveillance, assessment, planning, action and re-assessment. For a missed task or lack of surveillance to lead to a reportable complication, the oversight would have to coincide with unfavourable patient characteristics, multiple missed tasks and lack of identification of the missed tasks by subsequent shifts of nurses, or by any other health care professionals with patient contact. As others have found, measuring the missed tasks themselves, rather than complications arising from an unlikely sequence of omissions, may provide a more sensitive response to changes of a single hour of nursing care (Kalisch *et al.* 2009). The complications that have been commonly measured thus far have been useful in progressing the field to this point, but now it may be necessary to refine the methodology. Staffing levels and baseline complication rates in some populations have improved to the extent that existing outcome measures are not sufficiently sensitive to detect incremental decreases associated with changes to already adequate staffing. Considering the inability to establish a causal relationship with nurse staffing levels, we join others in concluding that it may be time to identify and develop more sensitive outcome measures (Mark *et al.* 2004a, Flynn & McKeown 2009). In reality, as well as the adjustment variables included in this study, unmeasured nursing process variables, high baseline staffing and low patient complication rates, insufficiently sensitive outcome measures and possibly other factors we have not considered are likely to have contributed to nursing sensitive patient complications.

One of the strengths of this work was that the study design addressed several common shortcomings in the nurse staffing and patient outcomes literature. To maximise comparability of our results, variable selection was guided by expert consensus on key risk adjustment variables and measures of nurse staffing and patient complications (Mark 2006, Van den Heede *et al.* 2007). The analysis was completed without aggregating patient data to minimise masking true associations by combining heterogeneous groups (Sales *et al.* 2008). Our threefold approach to measuring patient exposure to nurse staffing reduced measurement error bias and most closely emulated the reality of each patient's experience. We computed exposure to nurse staffing for every patient based on their actual unit movements, we measured nurse staffing per fortnight at unit level counting only productive hours of care and our analysis was stratified by the unit movement pattern of each patient hospitalisation (Harless & Mark 2006, Mark 2006, Sales *et al.* 2008, Penoyer 2010). Finally, our restrictive criteria for classifying complications as nursing sensitive distinguished those that were pre-existing from those potentially related to nursing care (Mark & Harless 2010, Schreuders *et al.* 2014).

Past rationales for inconsistencies in the relationship between nurse staffing and patient complications have suggested that study designs which address the above limitations may resolve ambiguous findings. We draw attention to the fact that, like the findings of this study, other studies which have addressed limitations have not yielded definitive results. Harless & Mark (2010) used a 'present on admission' indicator to distinguish pre-existing patient complications from those related to nursing care and found greater RN hours were associated with increases in all three post-operative complications investigated: pneumonia, septicaemia and urinary tract infection. Mark *et al.* (2004a) conducted a longitudinal hospital-level study and found that patient complication ratios increased when staffing was increased at low skill mix levels, but decreased at high skill mix levels. A pattern seems to be emerging that as study design becomes more sophisticated the associations between nurse staffing and patient complications do not continue to conform to currently accepted norms.

Limitations

We acknowledge some limitations. Firstly, process factors that may mediate the relationship between nursing care and inpatient complications have not been measured. For example: work environment, hospital commitment to inpatient safety, nurse-doctor collaboration and communication and RN satisfaction (Aiken & Patrician 2000, Lake & Friese 2006, Kane *et al.* 2007, O'Brien Pallas & Hayes 2008). Secondly, though offering several advantages, hospital payroll records are not perfect in their estimation of nurse staffing; we were unable to capture 'float' nursing to other units, staffing was averaged across fortnights despite per-shift staffing variations on individual days and monthly agency hours were distributed evenly over the fortnightly pay periods. Thirdly, although great care was taken to ensure data integrity was maintained, the datasets we used were large and complex and data preparation decisions may have impacted our findings. Finally, our non-experimental study design means a causal relationship between nurse staffing and inpatient complications cannot be inferred.

CONCLUSION

Our study was designed to address some commonly cited limitations in this field of research. Despite doing so, increases in nurse staffing were not consistently associated with reductions in the eight inpatient complications investigated. There has been a strong focus on improving nurse staffing to reduce inpatient complications, but adequate nursing hours and skill mix are just two of the factors that affect how nursing processes contribute to quality care. Likewise, inpatient complications are just one way that the delivery of quality nursing care can be measured. It is time to more seriously consider innovative ways of defining, measuring and evaluating nursing care quality beyond the staffing proxy. In addition, more sensitive patient outcome measures should be investigated. This study adds weight to the argument that reducing inpatient complications to zero cannot be achieved simply by adding more nurses in contexts where acceptable staffing levels have been achieved.

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TABLE 1: NURSING HOURS PER PATIENT DAY AND REGISTERED NURSE SKILL MIX FOR HIGH AND LOW INTENSITY UNITS

	No. units	No. fortnights with complete data	Mean	SD	Minimum	Maximum
Nursing hours per patient day						
High intensity units*	9	947	22.7	9.59	10.3	48.2
Low intensity units†	49	4,951	6.8	1.20	3.3	18.8
RN skill mix‡						
High intensity units*	9	947	86.5	8.94	55.0	100.0
Low intensity units†	49	4,951	75.8	11.15	32.0	100.0

*High intensity units included Intensive Care Units, High Dependency Areas and Coronary Care Units.
†Low intensity units included general and specialty medical and surgical units.
‡RN (Registered Nurse) skill mix was the percentage of nursing hours provided by RNs as a proportion of total nursing hours.

TABLE 2: COMPARISON OF CHARACTERISTICS FOR HOSPITALISATIONS WITH AND WITHOUT NURSING SENSITIVE COMPLICATIONS DETECTED

	No inpatient complications	One or more inpatient complications
Hospitalisations, n	229,704	27,280
Age in years, mean (Range)	**61.5** (18-106)	**71.83** (18-107)
Sex (%)		
Male	**55**	**48**
Female	**45**	**52**
Admission type (%)		
Elective	**26**	**17**
Emergency	**74**	**83**
Charlson Comorbidity Score, mean (SD)	**2.0** (2.64)	**3.4** (3.18)
Socioeconomic status decile, mean (SD)	**7.0** (2.47)	**7.2** (2.47)
Transfer (%)		
Not transfer	**77**	**63**
Possible transfer	**23**	**37**
Source of referral (%)		
Home	**75**	**66**
Residential aged care facility	**3**	**8**
Another acute care hospital	**21**	**26**
Other*	**1**	**0**
Number of unit moves, mean (SD)	**2.7** (1.33)	**3.2** (2.04)
Number of inpatient complications per hospitalisation, mean (SD)	NA	**1.2** (0.54)
Length of stay in days, mean (SD)	**6.8** (7.92)	**13.5** (13.26)
Percentage of length of stay with below-target staffing, mean (SD)	**20.6** (38)	**21.3** (35)
Length of stay on high intensity units† in days, mean (SD)‡	**0.4** (1.72)	**1.5** (4.81)
Percentage of total length of stay on high intensity units†, mean (SD)‡	**63** (38)	**50** (36)

NB: Bold typeface indicates statistically significant difference of $p<0.001$ for t-test or chi-square test comparing values for hospitalisations with no inpatient complications recorded and hospitalisations with one or more inpatient complications recorded.
*Other referral sources included residential aged care facility, prison, psychiatric hospital and unspecified source.
†High intensity units included Intensive Care Units, High Dependency Areas and Coronary Care Units.
‡Calculated using the subset of hospitalisations that included time on high intensity units (n=36,773).

TABLE 3: NURSE STAFFING AND INPATIENT COMPLICATIONS FOR HOSPITALISATIONS WITH A) NONE OF THE LENGTH OF STAY ON A HIGH INTENSITY UNIT* OR B) WHOLE LENGTH OF STAY ON A HIGH INTENSITY UNIT*

a. Hospitalisations with none of the length of stay on a high intensity unit[a] (n=220,045)							
		NHpPD[b] & Low RN[c]%		NHpPD & Mid RN%		NHpPD & High RN%	
	n[d]	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Surgical wound infection	1,740	**1.29 (1.22,1.37)**	**<0.001**	1.01 (0.93,1.09)	0.833	0.94 (0.85,1.03)	0.192
Urinary tract infection	6,259	0.98 (0.94,1.02)	0.293	0.98 (0.93,1.03)	0.428	1.03 (0.96,1.10)	0.418
Pressure ulcer	680	1.06 (0.97,1.17)	0.195	**1.17 (1.05,1.32)**	**0.007**	0.85 (0.71,1.02)	0.074
Pneumonia	3,304	1.01 (0.96,1.07)	0.688	0.99 (0.92,1.06)	0.788	0.96 (0.87,1.05)	0.340
Deep vein thrombosis	1,113	0.96 (0.87,1.06)	0.438	1.02 (0.92,1.14)	0.658	1.05 (0.94,1.17)	0.415
Shock or myocardial infarction	153	1.13 (0.93,1.37)	0.209	0.94 (0.73,1.21)	0.627	0.93 (0.65,1.32)	0.690
Failure to rescue	1,053	**0.81 (0.70,0.94)**	**0.004**	0.82 (0.66,1.01)	0.065	0.88 (0.72,1.08)	0.227
30-day mortality	8,325	1.00 (0.96,1.04)	0.970	0.98 (0.93,1.04)	0.543	1.05 (0.99,1.11)	0.140
b. Hospitalisations with whole length of stay on a high intensity unit* (n=15,652)							
		NHpPD & Low RN%		NHpPD & Mid RN%		NHpPD & High RN%	
	n	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Surgical wound infection	89	**0.92 (0.86,0.99)**	**0.025**	**0.85 (0.79,0.92)**	**<0.001**	**0.92 (0.85,0.99)**	**0.018**
Urinary tract infection	185	0.97 (0.92,1.03)	0.363	**0.85 (0.79,0.92)**	**<0.001**	**0.87 (0.82,0.93)**	**<0.001**
Pressure ulcer	31	1.07 (0.90,1.28)	0.448	0.99 (0.91,1.07)	0.732	1.05 (0.95,1.15)	0.363
Pneumonia	362	1.03 (1.00,1.06)	0.099	1.03 (1.00,1.07)	0.069	**1.05 (1.03,1.08)**	**<0.001**
Deep vein thrombosis	41	0.89 (0.74,1.06)	0.201	1.04 (0.94,1.15)	0.472	1.00 (0.92,1.08)	0.918
Shock or myocardial infarction	91	**0.91 (0.89,0.93)**	**<0.001**	**1.08 (1.03,1.13)**	**0.001**	**1.16 (1.12,1.21)**	**<0.001**
Failure to rescue	177	**1.08 (1.00,1.16)**	**0.045**	1.02 (0.94,1.09)	0.690	**1.06 (1.01,1.10)**	**0.012**
30-day mortality	896	**1.11 (1.05,1.17)**	**<0.001**	**1.16 (1.11,1.20)**	**<0.001**	**1.15 (1.13,1.17)**	**<0.001**

All models adjusted for age, sex, Charlson Comorbidity Score, socioeconomic status, length of stay, admission type, hospital transfer, hospital, percentage of hospitalisation on units with below-target NHpPD, number of unit movements per hospitalisation, total number of nursing sensitive inpatient complications per hospitalisation.

[a]High intensity units included Intensive Care Units, High Dependency Areas and Coronary Care Units.

[b]NHpPD (nursing hours per patient day).

[c]RN (Registered Nurse).

[d]number of hospitalisations during which the inpatient complication was detected.

TABLE 4: NURSE STAFFING AND INPATIENT COMPLICATIONS FOR HOSPITALISATIONS WITH LENGTH OF STAY ON BOTH HIGH AND LOW INTENSITY UNITS

a. Hospitalisations with first part of length of stay on a high intensity unit[a] (n=9,277)							
		NHpPD[c] & Low RN[d]%		NHpPD & Mid RN%		NHpPD & High RN%	
	n[e]	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Surgical wound infection	161	**0.91 (0.83,0.99)**	**0.029**	**0.90 (0.85,0.95)**	**<0.001**	0.95 (0.91,1.01)	0.077
Urinary tract infection	385	**0.87 (0.79,0.95)**	**0.003**	**0.91 (0.87,0.94)**	**<0.001**	**0.93 (0.90,0.96)**	**<0.001**
Pressure ulcer	80	0.96 (0.87,1.06)	0.387	1.03 (0.97,1.10)	0.340	**1.09 (1.04,1.14)**	**<0.001**
Pneumonia	836	0.98 (0.93,1.03)	0.423	1.01 (0.98,1.03)	0.679	**1.03 (1.00,1.05)**	**0.022**
Deep vein thrombosis	<25			Numbers too small to compute			
Shock or myocardial infarction	86	**1.08 (1.02,1.16)**	**0.014**	**1.06 (1.01,1.12)**	**0.017**	**1.17 (1.12,1.21)**	**<0.001**
Failure to rescue	75	1.07 (0.91,1.26)	0.406	1.01 (0.93,1.09)	0.913	1.09 (1.00,1.18)	0.058
30-day mortality	286	1.06 (0.98,1.16)	0.151	**1.07 (1.02,1.13)**	**0.006**	**1.06 (1.02,1.10)**	**0.004**
b. Hospitalisations with admission to a high intensity unit following a theatre procedure (n=6,333)							
		NHpPD & Low RN%		NHpPD & Mid RN%		NHpPD & High RN%	
	n	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Surgical wound infection	264	**0.63 (0.50,0.80)**	**<0.001**	**0.78 (0.72,0.85)**	**<0.001**	**0.89 (0.84,0.93)**	**<0.001**
Urinary tract infection	202	1.04 (0.93,1.17)	0.473	1.00 (0.93,1.07)	0.888	**0.91 (0.87,0.96)**	**<0.001**
Pressure ulcer	37	1.11 (1.00,1.23)	0.054	1.03 (0.91,1.17)	0.640	1.01 (0.94,1.09)	0.738
Pneumonia	522	0.93 (0.83,1.04)	0.213	1.00 (0.95,1.04)	0.836	**1.04 (1.01,1.07)**	**0.016**
Deep vein thrombosis	45	0.91 (0.74,1.11)	0.331	0.86 (0.69,1.07)	0.167	0.98 (0.89,1.07)	0.577
Shock or myocardial infarction	52	0.95 (0.68,1.34)	0.777	1.10 (0.99,1.22)	0.066	**1.09 (1.03,1.15)**	**0.006**
Failure to rescue	64	**0.17 (0.06,0.49)**	**0.001**	1.11 (0.98,1.24)	0.092	0.99 (0.91,1.08)	0.882
30-day mortality	185	0.94 (0.84,1.06)	0.340	**1.16 (1.08,1.23)**	**<0.001**	**1.11 (1.05,1.17)**	**<0.001**
c. Hospitalisations with admission to a high intensity unit following a low intensity unit[b] inpatient unit (n=5,511)							
		NHpPD & Low RN%		NHpPD & Mid RN%		NHpPD & High RN%	
	n	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Surgical wound infection	205	0.88 (0.77,1.01)	0.060	**0.91 (0.86,0.96)**	**0.002**	0.97 (0.93,1.01)	0.169
Urinary tract infection	261	0.92 (0.81,1.06)	0.246	**0.93 (0.89,0.96)**	**<0.001**	**0.92 (0.88,0.97)**	**0.001**
Pressure ulcer	41	1.12 (0.96,1.31)	0.159	0.99 (0.92,1.07)	0.793	0.97 (0.91,1.04)	0.373
Pneumonia	485	0.97 (0.90,1.04)	0.380	0.97 (0.94,1.01)	0.098	1.00 (0.97,1.03)	0.953
Deep vein thrombosis	82	0.90 (0.76,1.06)	0.198	**0.93 (0.87,0.99)**	**0.020**	1.00 (0.94,1.05)	0.903
Shock or myocardial infarction	78	**1.13 (1.02,1.25)**	**0.016**	1.02 (0.96,1.08)	0.501	**1.11 (1.06,1.17)**	**<0.001**
Failure to rescue	144	0.91 (0.81,1.02)	0.109	0.97 (0.92,1.03)	0.338	**1.06 (1.01,1.12)**	**0.031**
30-day mortality	484	1.08 (0.94,1.24)	0.302	**1.08 (1.04,1.13)**	**<0.001**	**1.06 (1.02,1.10)**	**0.004**

All models adjusted for age, sex, Charlson Comorbidity Score, socioeconomic status, length of stay, admission type, hospital transfer, hospital, percentage of hospitalisation on units with below-target NHpPD, number of unit movements per hospitalisation, total number of nursing sensitive inpatient complications per hospitalisation.
[a]High intensity units included Intensive Care Units, High Dependency Areas and Coronary Care Units.
[b]Low intensity units included general and specialty medical and surgical units.
[c]NHpPD (nursing hours per patient day).
[d]RN (Registered Nurse).
[e]number of hospitalisations during which the inpatient complication was detected.