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The effect of nurse-to-patient ratios on nurse-sensitive patient outcomes in acute specialist units: a systematic review and meta-analysis.

Title: The effect of nurse-to-patient ratios on nurse-sensitive patient outcomes in acute specialist units: a systematic review and meta-analysis

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ABSTRACT:

Background: Nurses are pivotal in the provision of high quality care in acute hospitals. However, the optimal dosing of the number of nurses caring for patients remains elusive. In light of this, an updated review of the evidence on the effect of nurse staffing levels on patient outcomes is required.

Aim: To undertake a systematic review and meta-analysis examining the association between nurse staffing levels and nurse sensitive patient outcomes in acute specialist units.

Methods: Five electronic databases were searched for English published between 2006 and 2017. The primary outcomes were nurse sensitive patient outcomes.

Results: Of 3429 unique articles identified, 35 met the inclusion criteria. All were cross-sectional and the majority utilised large administrative databases. Higher staffing levels were associated with reduced mortality, medication errors, ulcers, restraint use, infections, pneumonia, higher aspirin use and a greater number of patients receiving PCI within 90 minutes. A meta-analysis involving 175 755 patients, from six studies, admitted to ICU and/or cardiac/cardiothoracic units showed that a higher nurse staffing level decreased the risk of in-hospital mortality by 14% (0.86, 95%CI 0.79-0.94). However, the meta-analysis also showed high heterogeneity (I^2=86%).

Conclusion: Nurse-to-patient ratios influence many patient outcomes, most markedly in-hospital mortality. More studies need to be conducted on the association of nurse-to-

patient ratios with nurse sensitive patient outcomes to offset the paucity and weaknesses of research in this area. This would provide further evidence for recommendations of optimal nurse-to-patient ratios in acute specialist units.

KEY WORDS:

Nursing, workforce, staffing, systematic review, nurse-to-patient ratio

Introduction

Over the last decade there has been a renewed focus upon what constitutes an adequate level of nurse staffing. This is in part due to some spectacular failures that have occurred in care provision for hospital in-patients leading to loss of life.[1,2] Organisations across countries have adopted different approaches to managing the nursing workforce. In Victoria, Australia and California, USA, standardised and mandatory nurse staffing levels have been in place for over a decade. In the UK and Ireland there are national nurse staffing recommendations, but these are not mandated by law.[3-5] Wales has a similar situation, they recently introduced the 'Nurse Staffing Levels Act 2016', however, there are no mandated NPRs only recommendations to guide decisions about nurse staffing levels.[6] The notion of an optimal level of nurse staffing is somewhat controversial because there is no one size fits all approach to assessing staffing levels. This lack of clarity is further aggravated by a lack of consensus about the most appropriate way of estimating the size and mix of nursing teams because all measurement approaches have limitations.[4,7]

One of the challenges faced by managers responsible for staffing is finding a way to understand the influence of the multiple factors that make up each individual care environment which are likely to differ across organisations and countries. Donabedian grouped potential factors into three broad domains; structural factors (the people,

paraphernalia and place that make up the healthcare delivery system), processes of care (how care is done through the interactions between health professionals and patients) and subsequent outcomes (the end results of the care that takes place in the context of the organisation).[8]

To determine nurse-staffing levels, managers need to understand the underlying determinants which are patient factors (patient nursing need according to acuity and dependency levels), ward factors (patient throughput) and nursing staff factors (number and skill level).[9] Findings from a systematic review and meta-analysis, now a decade old, reported a significant association between increased nursing staffing in hospitals and improved nurse sensitive patients outcomes.[10] A more recent literature review by Penoyer and colleagues found an association between nurse staffing levels and patient outcomes in ICU[11]. However, their review only included studies from 1998-2008. In light of this an updated literature review is warranted. This review will examine recently published studies investigating associations between nurse staffing levels and nurse sensitive patient outcomes in acute specialist units.

Methods

To support the quality of the systematic review, a protocol was developed based on the PRISMA statement.[12] The review protocol was not registered.

Review objective

To identify studies, conducted in acute specialist units, which examine the association between nurse staffing levels (Nurse-to-Patient Ratio (NPR)) and nurse sensitive patient outcomes (as defined below).

Definitions

a) Nurse-to-Patient Ratio

NPRs are typically expressed in two ways; the number of nurses working per shift or over a 24 hour period divided by the number of beds occupied by a patient over the same time period or the number of nursing hours per patient bed days (NHPPD). There are other more complex approaches to measure nurse staffing requirements but there is no single recommended approach.[3] Many of the studies included in this review have determined NPRs. A higher level of nursing staff indicates more nurses (or higher proportion of nurses) for assigned patients. Lower nurse staffing is defined as fewer nurses (or lower proportion) for the number of assigned patients[11]. Moreover, little is known about how nurse staffing levels are managed across hospitals in Europe. NPRs are easily and cheaply measured but is a relatively blunt instrument that can function as one indicator, and can be triangulated with other measurement approaches, to establish safe nurse staffing levels.

b) Nurse sensitive patient outcome measures

The nurse sensitive patient outcomes measures included in this study were based on adverse events from previous studies that have been sensitive to changes in nurse staffing.[10, 13] The nurse sensitive patient outcome measures we included were: mortality, failure to rescue, shock (including sepsis resuscitation), cardiac arrest, unplanned extubation, hospital acquired pneumonia, respiratory failure, surgical bleeding, heart failure/fluid overload, catheter associated urinary tract infection, pressure sores, patient falls, nosocomial bloodstream infection, medication error, length of stay, hospital-acquired sepsis, deep vein thrombosis, central nervous system complications, death, wound infection, pulmonary failure, and metabolic derangement.

Search strategy

The search strategy was developed by the research team with input from expert information technologists (Appendix 1). Electronic databases and grey literature was searched (Medline (OvidSP), Medline in Process (OvidSP), CINAHL (Cumulative Index to Nursing and Allied Health Literature) (EBSCO), PsycInfo (OvidSP), Embase (OvidSP), HMIC (Health Management Information Consortium) (OvidSP), Cochrane Database of Systematic Reviews, Web of Science; Science Citation Index Expanded (ISI Web of Knowledge), Web of Science; Social Sciences Citation Index (ISI Web of Knowledge), Web of Science; Conference Proceedings Citation Index –Science (ISI

Web of Knowledge), Web of Science; Conference Proceedings Citation Index- Social Science & Humanities (ISI Web of Knowledge), Index to Theses, Proquest Dissertations and Theses). A combination of keywords was used and controlled vocabulary such as MeSH (Medical Subject Headings) when available. Search terms included 18 terms on settings i.e., coronary care, high dependency, critical care, intensive care, cardiac ward, intensive treatment unit and 17 terms relating to nursing or manpower or skill mix i.e., nurse staffing, nurse ratio, nurse mix, nurse dose, nurse workload and 78 nurse sensitive outcomes i.e., wound infection, pulmonary failure, shock, pneumonia, length of stay, outcome, patient safety. The search was limited to English language and conducted from January 2006 to February 2017. Conference abstracts and reference lists of included studies were manually searched and additional studies identified.

Inclusion criteria

Following the literature search, a team of reviewers worked in pairs to independently screen titles and abstracts according to the inclusion criteria. Any disagreement between reviewers was resolved by a third reviewer. Studies that met the following inclusion criteria were included:

- Patients admitted to acute specialist units (e.g. Intensive Therapy Units/Critical Care/Intensive Care/Coronary Care, high dependency, and cardiothoracic

surgery units, where a proportion of the nurses are required to have a postgraduate Critical Care qualification) with care provision for adults (over 18 years of age). Studies with mixed population ward were included.

- Investigating the effect of NPR using either number of nurses divided by number of patients over 24 hours or the NHPPD
- published from January 2006 to February 2017 in English.
- Quantitative methodology
- Primary outcome measures:
    - at least one nurse sensitive outcome such as mortality, failure to rescue, shock, cardiac arrest, unplanned extubation, hospital acquired pneumonia, respiratory failure, surgical bleeding, heart failure/fluid overload/imbalance, urinary tract infection, pressure sores, patient falls, nosocomial bloodstream infection, medication error, pain control, unplanned readmission.

Data extraction

A tailor-made data extraction tool was developed a priori and piloted and refined. The tool included six screening questions to ensure papers fit with the review inclusion criteria (Appendix 2). Information was also extracted from each study to record under the following headings: bibliographic details; setting/country; study design; outcomes, findings/conclusions and quality assessment.

Quality Assessment

All included studies were assessed by the Newcastle-Ottawa Scale (NOS) to determine the quality of non-randomised studies.[14] This tool was designed to facilitate the incorporation of quality assessment into the systematic review. This tool has been used in previous Cochrane reviews for assessment of risk of bias in non-randomised studies. The content validity and inter-rater reliability of this scale was previously established. The NOS comprises of eight items: representativeness of cohort, selection of cohort, ascertainment of exposure, outcome of interest was not present at baseline, comparability of cohorts, assessment of outcome, length of follow-up and adequacy of follow-up.[14] Each item was awarded a '*' for meeting the criterion. A study was also awarded an additional '*' if the analysis was adjusted for potential confounding variables. The quality of each study was graded as low, medium or high according to the number of stars (*). The quality assessment was conducted independently by two reviewers. Disagreements were resolved by a third reviewer.

Statistical Analysis

As this systematic review involved cross-sectional studies we used adjusted measures, as reported by authors, as the primary effect measures to control for confounding when

it was available. Odds ratios were used as an appropriate effect measure if available. Other effect measures were: hazard ratios or risk ratios.

A meta-analysis was conducted on homogenous studies using a random-effect model with in-hospital mortality as the primary outcome. In studies where patient-to-nurse ratios were used, these were converted to NPRs by calculating the inverse ratio. The overall effect sizes will be presented in a forest plot. In studies where a pooled meta-analysis was unable to be performed, a narrative analysis will be undertaken.

Clinical homogeneity was assessed in terms of study cohort, hospital units, diagnosis and risk of bias. The I^2 was also used to determine statistical heterogeneity. If I^2>40% a random effects model will be used. A sensitivity analysis will also be conducted using a fixed-effects model was used to determine if the conclusions were different.
Data analysis was conducted using review manager version 5.3.[15]

Results

We identified a total of 4472 studies from the literature search. After duplicates were removed 3429 records were screened using title and abstract. Of these, we identified 196 full-text articles for retrieval. We included 35 articles in the final analysis (see

Figure 1). Reasons for exclusion included research relating to neonates, non-acute settings, no NPRs and no nurse sensitive patient outcomes were reported.

Insert Figure 1 - Study Flow Diagram

Description of studies

All of the 35 papers were cross-sectional studies except for one point prevalence study. All of the studies had a large sample size derived from administrative datasets (Table 1). Fourteen studies were conducted in the USA/Canada/Mexico, 17 studies in Europe, three studies in China and one in Thailand. In terms of study setting, 11 studies included patients throughout the hospital including critical care, 19 studies restricted their cohort to intensive care units only (included cardiovascular patients), and five studies in specialist cardiac units.

Insert Table 1 – Characteristics of Included Studies

Quality appraisal

The NOS comprises of three principle domains: case selection, representativeness of cohorts, and measurement of outcome.[14] All 35 cohort studies met the criterion for representativeness of cohort selection, five studies received one star and 24 studies

received two stars for comparability of cohorts, 24 studies discussed outcome assessment and 35 studies defined their length of follow-up (Table 2).

Insert Table 2- Cross-sectional Quality Appraisal

There were 24 studies that rated highly on the NOS for assessing the quality of non-randomised trials (Table 2). All of these studies controlled for several confounding factors in either their methodology or data analysis. The majority of these studies adjusted for age, co-morbidities and hospital characteristics as potential confounders. Seven studies were rated as low quality mainly due to the lack of comparability of cohorts.

Nurse-to-Patient Ratios

Various approaches were used to measure NPRs. Schwab et al calculated the NPR per shift (number of nurses per day/3 (per shift)/number of patients per day) using monthly census data.[38] Other studies used similar approaches.[19,25,26,31,33,37] Several authors provided less detail about how the NPR was calculated.[18,28,30,32] Valentin et al. calculated both the NPR by shift and the occupancy rate (maximum number of occupied beds divided by allocated beds), NPR for each shift in each unit and the relative turn over (number of admitted and discharged patients divided by the number of unit beds).[43]

Cho et al. calculated the NPR based on the bed occupancy rate and then categorised it into grades.[21] Grade 1 indicated the number of beds per nurse was <0.5 up to Grade 9 when the ratio was >2.0. In Cho et al.[20], the ratio of bed occupancy rate to the number of FTE nurses was used for calculation. This bed occupancy rate was extracted from the ICU survey data over a three-month period. Tourangeau et al. calculated the 'nursing staff dose' rather than a NPR.[42] This was calculated as the total nursing worked hours divided by the sum of weighted patient cases discharged from each hospital.

Stone et al. calculated the number of nursing hours per patient day (NHPPD) from payroll and ICU census data.[41] Diya et al.[22] calculated the NHPPD but did not stipulate how this was calculated. Van den Heede et al.[44,45] calculated the NHPPD daily for each ward. It was based on daily ward census data. A similar approach was adopted by Shuldham et al.[40] and Hart et al.[23] both of whom made the distinction between the numbers of hours worked by permanent staff versus temporary staff. Adjustment for staff sick leave and annual leave was not always accounted for suggesting that staffing ratios may have been overestimated.[16] Sometimes day-to-day staffing levels were unobtainable in which case a proxy of highest NPR in a 24-hour period was used.[17]

4.4 Nurse Sensitive Outcomes

Mortality

There were 19 studies that examined mortality. Thirteen studies had a primary outcome of in-hospital mortality, one study examined 28-day mortality and five studies with 30-day mortality. Of the 19 studies, 10 were conducted in ICU, two studies in an acute cardiac unit, two in the Emergency Department and seven studies recruited patients throughout the hospital regardless of unit including ICU/CCUs. Six studies reported odds ratios on all-cause in-hospital mortality of 175 755 patients admitted to ICU and/or cardiac/cardiothoracic units.[20,21,29,31,37,46] A meta-analysis was conducted on the six studies using a random effects model. The pooled analysis showed that a higher level of nurse staffing decreased the risk of in-hospital mortality by 14%, (95%CI 0.79-0.94). However, the meta-analysis also showed high heterogeneity (I^2=86%) with one study showing a wide confidence interval. The pooled analysis was influenced by four of the six studies each ranging from 21-24%.[20,29,31,46]

Insert Figure 2 - MA

As the I^2 was>40% a sensitivity analysis was performed using a fixed effects model. The pooled analysis of the fixed effects model (OR 0.90, 95%CI 0.88-0.92) was similar to the random effects model (OR 0.86, 95%CI 0.79-0.94) despite the high heterogeneity.

Other Nurse Sensitive Outcomes

Fifteen studies examined the effect of NPRs on nurse sensitive outcomes other than mortality. Three studies examined mortality as a primary endpoint and nurse sensitive outcomes as their secondary endpoint.[39,41,44] However, none of the studies combined all of the nurse sensitive patient outcomes, rather they typically selected three or four outcome measures. Three studies conducted in critical care units, reported an association between higher number of NHPPD[35,41] or a higher level of nurse staffing[33] resulted in a reduction in events for nurse sensitive patient outcomes. Another study reported on medication errors and found that as the number of nurses decreased, the odds ratio for parenteral medication errors increased, some of which caused harm and death.[43] A higher level of nurse staffing in critical care units were associated with a lower incidence of pressure ulcer development,[23,41] use of physical restraints[16] and incidence of nosocomial infection[25,38,41] including late onset ventilator assisted pneumonia.[26] In the Emergency Department, a higher level of nurse staffing increased the prescribing of aspirin on arrival to the Emergency Department and a percutaneous coronary intervention within 90 minutes of arrival.[27]

Evidence was less clear in studies where results were combined across setting such as high dependency and critical care units. One such study examined the association between NPRs and a range of nurse sensitive patient outcomes; there were few

significant results.[40] However as the number of permanent staff compared to temporary staff increased, the rates of sepsis decreased.[40] Hart and Davis found that the use of agency staff was associated with a higher incidence of hospital acquired pressure ulcers but only in medical surgical units rather than critical care units and Coronary Care settings.[23] A statistically significant association was also reported between a higher level of nurse staffing on the ward and critical care unit settings and lower rates of failure to rescue.[35] Three studies reported no association between NPRs and nurse sensitive patient outcomes, after adjusting for confounding variables.[17,30,44] Merchant et al. reported no association between NPRs and in hospital cardiac arrests rates.[30] Similarly Blot et al. reported no association between NPRs and ventilator associated pneumonia, after adjusting for confounding variables.[17] Due to the heterogeneity in outcome measures no meta-analysis was performed.

Discussion

This analysis found that a higher level of nurse staffing was associated with a decrease in risk of in-hospital mortality (OR 0.86, 95%CI 0.79-0.94) and nurse-sensitive outcomes. Due to the heterogeneity between studies particularly in NPRs, no recommendation can be made regarding the optimal ratio required to improve patient outcomes. However, studies do report the higher the level of nurse staffing, the greater the reduction in in-hospital mortality. Unfortunately, all of these studies were cross-

sectional so no causal relationship can be determined. This systematic review builds on work conducted previously by Kane et al.[10] who found a higher level of nurse staffing was associated with a lower mortality in ICU (OR 0.91, 95%CI 0.86 – 0.96), surgical wards (OR 0.84, 95%CI 0.8 – 0.89) and medical wards (OR 0.94, 95%CI 0.94 – 0.95) per additional 1.0 FTE nurse per patient day.[10] Our meta-analysis found a decrease in risk of 14% in in-hospital mortality for every additional one decrease in patient load over 24 hours. All of the studies included in the meta-analysis rated high in the NOS quality assessment tool.

We also examined the effect of NPRs on nurse sensitive patient outcomes. There was a large degree of heterogeneity in the type of nurse sensitive patient outcomes that were measured as an end-point so no meta-analysis was conducted. Park et al. examined the effect of nurse staffing and failure-to-rescue (FTR) rates.[35] FTR rates were defined as mortality post an adverse event associated with post-surgical complications. Park et al. analysed data from an administrative dataset 159 non-ICUs and 158 ICUs from 42 hospitals.[35] In ICUs, they found a higher number of NHPPD was associated with a lower FTR rate (OR -0.022, 95%CI -0.39 - -0.005 (adjusted)).[35] Stone et al. also examined the effect of NPRs on nurse sensitive outcomes.[41] These outcomes included: central line bloodstream infections, ventilator assisted pneumonia, catheter associated urinary tract infection, 30-day mortality, and presence of decubitus pressure ulcers.

Their sample comprised of 15,846 patients from 51 ICUs in 31 hospitals. Stone et al. found that patients cared for with a higher number of NHPPD were 68% less likely to experience bloodstream infections (95%CI 0.15-0.17), 79% less likely to experience pneumonia (95%CI 0.08 – 0.53) and there was a 31% reduction in risk for a decubitus pressure ulcer (95%CI 0.49 – 0.98).[41] Cardiac outcomes were also improved with a higher level of nurse stafing. Every 10% increase in the number of nurses was associated with a 7.1% increase in prescribing of aspirin on arrival and 6.3% decrease in time for a percutaneous coronary intervention within 90 minutes of arriving in hospital.[27]

O'Brien-Pallas et al. investigated the association of NPRs with nurse sensitive patient outcomes.[33] Their outcomes included: deep vein thrombosis, pressure ulcers, falls with injury, medical errors with consequences, pneumonia, catheter associated urinary tract infection and wound infections. O'Brien-Pallas et al. analysed an administrative dataset of 1,230 patients from 24 cardiac and cardiovascular units from six hospitals.[33] They calculated the NPR as the average number of patients cared for daily by a nurse on day shift during the data collection period. They found that for every additional patient per nurse, patients were 22% less likely to experience 'excellent or good quality care' and 35% more likely to experience a longer than expected length of stay.[33]

Limitations/Weakness of the Evidence Base

The results of this systematic review and meta-analysis should be interpreted with caution. There were several limitations associated with the review. Several studies combined patients from non-specialist units with special units which may have skewed the results. Stone et al. conducted a separate analysis for ICU and non-ICU units.[41] They found that in non-ICUs, NPRs were not statistically associated with rate of nurse sensitive patient outcomes. However, there was a reduction in rate of nurse sensitive patient outcomes in patients in an ICU with a higher level of nurse staffing.

There was also a large degree of heterogeneity in how the NPRs were calculated. For example, Perez et al. did not stipulate how they calculated the NPR,[36] Van Den Heede et al. calculated the number of NHPPD[44,45] and Cho et al. calculated the number of patients/bed to total FTE.[20,21]

Conclusion

This systematic review found that there may be an association between a higher level of nurse staffing and improved patient outcomes. For every increase of one nurse, patients were 14% less likely to experience in-hospital mortality.

More studies need to be conducted on the association of NPRs with nurse sensitive patient outcomes. However, there needs to be greater homogeneity in the nurse sensitive endpoints measured and the calculation of the NPR. Such metrics should not be used in isolation but can contribute to a 'triangulated' approach to the decision making process about safe and sustainable nurse staffing levels.

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