Nurse staffing levels, missed vital signs and mortality in hospitals: retrospective longitudinal observational study

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Vitalpac system, which was used to collect the vital signs observations data used in the project. Until October 2015, the wives of David Prytherch and Gary Smith held minority shareholdings in The Learning Clinic Limited. Paul Schmidt held a personal shareholding prior to the commencement of the study.
Scientific summary

Background

The potential for inadequate nursing care to harm patients has been highlighted in numerous reports on failings in hospitals worldwide. There is a large body of research showing that low nurse staffing levels are associated with a range of adverse outcomes, most notably mortality. Other research suggests that a richer skill mix in the nursing team [i.e. the ratio of registered nurses (RNs) to nurses plus assistants] is associated with better outcomes, whereas some studies suggest that adding assistants to the nursing team may, in itself, have a negative effect, even if total team size is increased.

However, the extent to which these studies demonstrate a causal relationship is disputed. Almost all are cross-sectional studies and estimate relationships at a hospital level, with no direct link made between the staffing levels or care experienced by individual patients and those patients’ outcomes. In recent years, attention has turned towards mechanisms that might explain these relationships. Omissions or delays in nursing care caused by reduced capacity in the nursing team (referred to as ‘missed care’, ‘care left undone’ or ‘implicit rationing’) have received growing scrutiny as the link between nurse staffing and adverse outcomes. Specifically, an impaired capacity to observe patients at risk and take action in the face of early signs of deterioration has been hypothesised as a mechanism by which low staffing levels increase the risk of death. Consequently, this ‘missed care’ has been identified as a potential indicator of nurse staffing adequacy.

Research has demonstrated that nurses do report missing more care when staffing levels are low and suggests that, when nurses report care as missed, outcomes are worse. However, these studies have relied on nurses self-reporting, and outcomes are associated with general reports of volumes of missed care rather than omissions of specific care relevant to the outcomes. This research is also cross-sectional.

The use of clinical and workforce data collected in real time ‘at the bedside’ means that analyses need no longer be conducted using averages of staffing at a hospital level. Electronic care records open up the opportunity to use more objective measures of missed care. The current study builds on these two emerging strands of research by considering both staffing levels experienced by individual patients and care delivered to those patients.

Aims

This study aimed to determine whether or not adverse outcomes occur after patients are exposed to low nurse staffing levels on hospital wards, and whether or not missed observations mediate this relationship and could thus provide a useful indicator of inadequate staffing levels. This study examined whether, and how, variation in nurse staffing levels on general hospital wards is associated with omissions or delays in delivering necessary nursing care. There was specific focus on monitoring and acting on vital signs and whether or not variation in staffing levels and vital signs observations is associated with variation in patient death. We also aimed to model the possible costs and consequences of changes in staffing levels.

Methods

This was a retrospective, longitudinal observational study using routinely collected data from 32 general adult wards of a large acute NHS general hospital. Admissions units, care of older people and high-dependency units were included but paediatric, intensive care and maternity units were excluded.
Data were drawn from the patient administration system, cardiac arrest database, eRoster system, record of temporary staff bookings and the Vitalpac system (System C Healthcare Ltd, Maidstone, Kent; formerly The Learning Clinic Limited), which is used for recording vital signs and other observations. The study comprised 138,133 patients admitted to the hospital and spending 1 or more days on the study wards from 1 April 2012 to 31 March 2015. Across 32 wards over 1095 days, a total 30,982 days of ward staffing data (wards x days) were available.

The main outcome measures were death in hospital, adverse event [death, cardiac arrest or unplanned intensive care unit (ICU) admission], length of stay and missed vital signs observations. A set of observations was classified as missed when not done by the time due plus two-thirds of the scheduled observation interval, determined by the Trust protocol using a schedule that varied frequency according to the National Early Warning Score (NEWS) [Royal College of Physicians. National Early Warning (NEWS). Standardising the Assessment of Acute-illness Severity in the NHS. London: Royal College of Physicians; 2012]. Other outcomes included late observations, nutritional risk screening undertaken within 24 hours (as per Trust policy) and ‘failure to respond’, which is a composite outcome based on patients remaining on a general ward with a high NEWS over an extended period without being admitted to ICU or placed on an end-of-life care pathway.

We used multilevel/hierarchical mixed-effects regression models to explore the association between staffing levels and outcomes, controlling for patient factors [route of admission, risk based on the national Summary Hospital-level Mortality Indicator (Campbell MJ, Jacques RM, Fotheringham J, Maheswaran R, Nicholl J. Developing a summary hospital mortality index: retrospective analysis in English hospitals over five years. BMJ 2012;344:e1001) and NEWS on admission], daily number of admissions to the ward and a random effect for ward.

For patient outcomes, we used survival models to study the effect of exposure to variation in staffing levels relative to ward norms [RN and health-care assistant (HCA) hours per patient day (HPPD)]. We considered staffing levels as both a binary variable [exposure to days when staffing fell below (1) planned staffing levels for the ward, (2) mean staffing levels for the ward and (3) 80% of the mean], and a continuous variable (HPPD relative to the mean or HPPD below the mean for the ward). In general, we focused on patients’ exposure to staffing over the first 5 days of the hospital stay, with the staffing variables modelled as a cumulative sum. Secondary analyses considered exposure to days with high levels of temporary staffing, and the effect of weekend admission/stay, to control for variation in medical staffing levels. For missed observations, we used Poisson or negative binomial models to explore the relationship between nursing hours and the rate of missed and late observations. We also investigated the presence of non-linear effects by adding quadratic and cubic terms of staffing variables and for interaction between RN and HCA staff by adding interaction terms.

The results of regression models were used to estimate the costs and consequences of changes to current staffing levels and skill mix in terms of changes in staffing, changes in length of stay and changes in mortality.

**Results**

The average length of stay was 6.8 days. A total of 4.1% of patients died. Overall, 16% of observations were missed, with 44% of observations for patients in high-acuity categories (NEWS of ≥ 6) missed. The average staffing level across all wards was 4.75 RN HPPD and 2.99 HCA HPPD, with an average skill mix of 60% RN. Staffing levels varied considerably both between and within wards. Mean RN HPPD varied from 2.91 (medical respiratory ward) to 9.61 (renal high care). Skill mix varied from 86% to 46%. Mean RN HPPD was highly correlated with the RN HPPD estimated from the planned ward establishment (Pearson’s $r = 0.97$), with average RN HPPD of 95% of the establishment level. Similarly, mean HCA staffing was closely correlated with the planned ward establishment (Pearson’s $r = 0.81$), with a mean HCA staffing of 115% of establishment. Over the first 5 days, patients were exposed to a mean of 1.93 days when RN HPPD fell below the mean for
the ward and 1.94 days when HCA staffing fell below the mean for the ward. The cumulative sum of RN HPPD below the mean was 0.39 and the cumulative sum of HCA HPPD below the mean was 0.25.

For each day of RN HPPD below the mean, the hazard of death increased by 3% [hazard ratio (HR) 1.03, 95% confidence interval (CI) 1.01 to 1.04] and each additional RN HPPD was associated with a 3% reduction in the hazard of death. The overall relationship appeared to be linear. Exposure to days with staffing below establishment was associated with a larger increase in the hazard of death (HR 1.09), although exposure to days with staffing below 80% of the mean was not associated with a significantly increased hazard of death; this was possibly a consequence of the relatively rarity of the event and ‘covert’ replacement of RNs when staffing was low. Exposure to days with HCA HPPD below the mean was also associated with an increased hazard of death (HR 1.04, 95% CI 1.02 to 1.07) but the relationship was non-linear. Both reductions and increases in HCA HPPD were associated with increased hazard of death.

Days with a high number of admissions per RN (>125% of the ward mean) were associated with increased hazard of death (HR 1.05, 95% CI 1.01 to 1.09), as were days with >1.5 HPPD of temporary RN and HCA staffing (HR 1.12 and 1.05, respectively). Adverse events were reduced with more RN HPPD, and length of stay was reduced by a mean of 0.23 days for each additional RN HPPD that a patient experienced. When we added effects indicating weekend admission or stay, nurse staffing effects were unaltered, suggesting that these results do not arise from a correlation between low levels of medical cover and lower nurse staffing at weekends.

Missed observations in high-acuity patients were significantly associated with RN HPPD [incidence rate ratio (IRR) 0.98, 95% CI 0.97 to 0.99] but not with HCA HPPD (IRR 1.00, 95% CI 0.99 to 1.01), whereas the overall rate of missed observations was related to overall care hours per patient day (RN plus HCA) but not to skill mix. There were diminishing returns from increased staffing at higher levels. RN HPPD were significantly associated with the rate of ‘failure to respond’ for patients with NEWS of ≥7, and HCA HPPD was associated with the rate of nutritional risk assessments not done within 24 hours of admission.

The relationship between exposure to RN staffing below the mean and mortality was mediated by missed high-acuity vital signs observations (NEWS of ≥6) with significant indirect effects but no direct effect. For HCA staffing below the mean, mediation was partial with significant direct and indirect effects. Other relationships between staffing and mortality were not mediated by missed vital signs observations.

We estimated that, if average skill mix and staffing levels matched those planned by the Trust, involving an increase of 0.32 RN HPPD and a similar decrease in HCA HPPD, this would be associated with an estimated reduction in the mortality rate of 2%, avoiding 50 deaths per year and releasing 4464 bed-days as a result of reduced hospital stays. Staff costs would increase by £28 per patient and £26,351 per life saved; however, taking into account the value of avoided hospital stays, there are net savings.

**Discussion**

Higher RN staffing levels were associated with lower mortality and reduced length of stay, and this study provides further evidence that this relationship is causal. Although a causal mechanism involving missed vital signs observations and mortality was confirmed, there are other causal pathways and the absolute rate of missed vital signs observations cannot be directly used to guide staffing decisions. This evidence points towards increases in skill mix as a cost-effective approach to improving patient safety, which can also decrease bed utilisation.

Increased mortality rates were observed when the number of patient admissions per RN was higher than normal for the ward. Admissions are a significant source of nursing workload, but they are not considered in census approaches to determining the required staff. Flexible approaches to staffing have been advocated as a means of meeting the varying demand for patient care, but our findings suggest that heavy reliance on
temporary staff is associated with adverse outcomes. However, our findings are consistent with previous research that suggests that there is no harm, and potentially some benefit, from modest use of temporary RNs, because required staffing levels can be maintained. Our findings about HCA staffing levels are complex. Previous research has tended to be pervasively negative about the impact of unregistered assistant staff within the nursing team. Our study showed that low HCA staffing levels, relative to the assessed requirement for each ward, were associated with increased mortality. However, any substantial variation from this level appeared to be associated with decreased mortality. It may be that, whereas low HCA staffing adversely affects mortality because the overall capacity to deliver work is lower, higher levels of HCA staffing generate demands for additional delegation and supervision from RNs, which may lead to adverse outcomes, even in the face of otherwise adequate staffing levels.

Staffing levels were associated with missed care: the more members of staff there were, the less care was missed. When focusing on less routine care, observations in high-acuity patients or ‘failure to respond’, it seems that RN staffing levels influence rates, whereas HCA staffing levels do not. However, despite evidence of missed observation mediating relationships with mortality, it is clear that 100% compliance with vital signs observations could not be achieved through increases in staffing levels because the level of missed observations was high and the effect sizes were small. Nor is it clear whether or not such a level of compliance would be desirable, even if it could be achieved. While our stakeholder consultations strongly supported a goal of 100% compliance, the current evidence base around the required observation frequency makes it possible that some of the current ‘non-compliance’ results from the exercise of clinical judgement, which may (or may not) be sound. Thus, although changes in compliance may indicate staffing issues, the absolute rate is not a good indicator.

Although we established that variation in staffing preceded the outcomes we observed, this remains an observational study, and there were limitations in the accuracy in our staffing data because internal redeployments were not recorded. Regarding the extent to which variation in staffing was influenced by variation in the assessed need for staff, the observed association would tend to underestimate the true relationships. However, this study provides a much stronger basis for causal inference because of the longitudinal design and the support it provides for a widely hypothesised causal mechanism.

Our economic modelling suggests that if the Trust were able to change its skill mix to that which it planned (i.e. involving a small increase in RN staffing and a small decrease in HCA staffing), outcomes could be improved at a low cost per patient with a net reduction in cost once reductions in length of stay were also considered. Although our findings, in common with other research, point towards increased RN staffing and/or a richer RN skill mix, current RN shortages make this challenging. However, these findings highlight the benefits in terms of patient outcome and costs that could arise from addressing the current shortage of supply of RNs. For individual hospitals, the findings show the significant advantages that may be derived from attracting and retaining RNs to their workforce.

This was an observational study and, although the longitudinal design and exploration of mechanisms improve substantially on previous research, direct causal inference does not follow. Nonetheless, a causal interpretation is plausible. However, there were limitations in the accuracy of our staffing data, including the inability to track internal redeployments. Variation in staffing could be influenced by variation in the assessed need for staff, which would tend to attenuate our estimated associations. Economic decision-making is limited by these factors, as well as the absence of longer term follow-up and estimates of quality-adjusted life-years (QALYs) for patients. There is also the challenge of generalising from a single-site study.

A number of priorities for future research emerge from this study:

- replicating the current study across multiple sites and extension of the economic analysis to consider cost per QALY and other measures of patient value
- validating existing and novel methods to determine ward level staffing requirements, including an assessment of whether or not the use of such tools is associated with improved outcomes/experience
• exploring other measures of missed nursing care that can derive from routine data in order to provide a fuller picture of care delivery
• investigating into the mechanisms for the safe and effective use of assistant personnel within the nursing team
• further exploring the association between temporary staff and outcomes and effective approaches to flexible staffing.

**Trial registration**

This study is registered as ISRCTN17930973.

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