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

Peter Griffiths,[1,2]* Jane Ball,[1,2] Karen Bloor,[3] Dankmar Böhning,[4] Jim Briggs,[5] Chiara Dall'Ora,[1,2] Anya De Iongh,[6] Jeremy Jones,[1] Caroline Kovacs,[5] Antonello Maruotti,[1] Paul Meredith,[2,7] David Prytherch,[2,5,7] Alejandra Recio Saucedo,[1,2] Oliver Redfern,[5] Paul Schmidt,[2,7] Nicola Sinden[7] and Gary Smith[8]

[1]Health Sciences, University of Southampton, Southampton, UK
[2]National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care Wessex, Southampton, UK
[3]Health Sciences, University of York, York, UK
[4]Mathematical Sciences, University of Southampton, Southampton, UK
[5]Centre for Healthcare Modelling and Informatics, University of Portsmouth, Portsmouth UK
[6]Independent lay researcher c/o National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care, Southampton, UK
[7]Clinical Outcomes Research Group, Portsmouth Hospitals NHS Trust, Queen Alexandra Hospital, Portsmouth, UK
[8]Health and Social Sciences, Bournemouth University, Bournemouth, UK

*Corresponding author Peter.griffiths@soton.ac.uk

**Declared competing interests of authors:** All authors received grant support from the National Institute for Health Research (NIHR) for the conduct of this study, remuneration for employment from their employing institution and may be in receipt of other funding for non-commercial independent research outside the current work. Peter Griffiths is a member of the advisory group for NHS Improvement's ongoing work on safe staffing in adult inpatient wards (unpaid). Chiara Dall'Ora received grants from the NIHR Collaboration for Leadership in Applied Health Research and Care (CLAHRC) Wessex to support her PhD. Anya De Iongh received personal fees for freelance work and employment outside the submitted work from Help & Care (Bournemouth, UK), Dorset HealthCare University NHS Foundation Trust, Health Education England/Skills for Health, University of Southampton, University of Cambridge, King's College London, Queen Mary University London and the NIHR. Gary Smith receives non-financial support from non-commercial organisations: Resuscitation Council UK, Royal College of Physicians of London, International Society of Rapid Response Systems and the NIHR outside the submitted work. For some of the period of the research, Portsmouth Hospitals NHS Trust (PHT), which employed Paul Meredith, David Prytherch, Gary Smith, Nicola Sinden and Paul Schmidt, had a royalty agreement with The Learning Clinic Limited (now part of System C Healthcare Ltd, Maidstone, Kent) to pay for the use of PHT intellectual property within The Learning Clinic Limited's

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.

Published November 2018
DOI: 10.3310/hsdr06380

# Scientific summary

## Nurse staffing levels, missed vital signs and mortality in hospitals

Health Services and Delivery Research 2018; Vol. 6: No. 38
DOI: 10.3310/hsdr06380

NIHR Journals Library www.journalslibrary.nihr.ac.uk

# 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 × 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 $\geq 6$) 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 $\geq 7$, 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 $\geq 6$) 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.

## Funding

Funding for this study was provided by the Health Services and Delivery Research programme of the National Institute for Health Research.

# Health Services and Delivery Research

ISSN 2050-4349 (Print)

ISSN 2050-4357 (Online)

This journal is a member of and subscribes to the principles of the Committee on Publication Ethics (COPE) (www.publicationethics.org/).

Editorial contact: journals.library@nihr.ac.uk

The full HS&DR archive is freely available to view online at www.journalslibrary.nihr.ac.uk/hsdr. Print-on-demand copies can be purchased from the report pages of the NIHR Journals Library website: www.journalslibrary.nihr.ac.uk

**Criteria for inclusion in the *Health Services and Delivery Research* journal**
Reports are published in *Health Services and Delivery Research* (HS&DR) if (1) they have resulted from work for the HS&DR programme or programmes which preceded the HS&DR programme, and (2) they are of a sufficiently high scientific quality as assessed by the reviewers and editors.

## HS&DR programme

The Health Services and Delivery Research (HS&DR) programme, part of the National Institute for Health Research (NIHR), was established to fund a broad range of research. It combines the strengths and contributions of two previous NIHR research programmes: the Health Services Research (HSR) programme and the Service Delivery and Organisation (SDO) programme, which were merged in January 2012.

The HS&DR programme aims to produce rigorous and relevant evidence on the quality, access and organisation of health services including costs and outcomes, as well as research on implementation. The programme will enhance the strategic focus on research that matters to the NHS and is keen to support ambitious evaluative research to improve health services.

For more information about the HS&DR programme please visit the website: http://www.nets.nihr.ac.uk/programmes/hsdr

## This report

The research reported in this issue of the journal was funded by the HS&DR programme or one of its preceding programmes as project number 13/114/17. The contractual start date was in June 2015. The final report began editorial review in September 2017 and was accepted for publication in February 2018. The authors have been wholly responsible for all data collection, analysis and interpretation, and for writing up their work. The HS&DR editors and production house have tried to ensure the accuracy of the authors' report and would like to thank the reviewers for their constructive comments on the final report document. However, they do not accept liability for damages or losses arising from material published in this report.

This report presents independent research funded by the National Institute for Health Research (NIHR). The views and opinions expressed by authors in this publication are those of the authors and do not necessarily reflect those of the NHS, the NIHR, NETSCC, the HS&DR programme or the Department of Health and Social Care. If there are verbatim quotations included in this publication the views and opinions expressed by the interviewees are those of the interviewees and do not necessarily reflect those of the authors, those of the NHS, the NIHR, NETSCC, the HS&DR programme or the Department of Health and Social Care.



Published by the NIHR Journals Library (www.journalslibrary.nihr.ac.uk), produced by Prepress Projects Ltd, Perth, Scotland (www.prepress-projects.co.uk).