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Registered nurse, health care support workers, medical staffing levels and mortality in English hospitals: a cross-sectional study

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Title Page

Title: Registered nurse, health care support workers, medical staffing levels and mortality in English hospitals: a cross-sectional study

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Abstract (292 WORDS)

Objectives: To examine associations between mortality and registered nurse (RN) staffing in English hospitals taking account of medical and health care support worker (HCSW) staffing.

Setting: Secondary care provided in acute hospital NHS Trusts in England.

Participants: Two data sets examined: Administrative data from 137 NHS acute hospital Trusts (staffing measured as beds per staff member). A cross-sectional survey of 2917 registered nurses in a subsample of 31 Trusts (measured patients per ward nurse).

Outcome measure: Risk-adjusted mortality rates for adult patients (administrative data).

Results: For medical admissions, higher mortality was associated with more occupied beds per RN (RR 1.22, 95% CI = 1.04-1.43, p=.02) and per doctor (RR 1.10, 95% CI = 1.05-1.15, p <0.01) employed by the hospital whereas, lower HCSW staffing was associated with lower mortality (RR 0.95, 95% CI = 0.91-1.00, p=.04). In multivariable models the relationship was statistically significant for doctors (RR 1.08, 95% CI = 1.02-1.15, p=.02) and HCSWs (RR 0.93, 95% CI =0.89-0.98, p<01) but not RNs (RR 1.14, 95% CI = 0.95-1.38, p=.17).

Trusts with an average of ≤6 patients per RN in medical wards had a 20% lower mortality rate compared to Trusts with >10 patients per nurse (RR 0.80, 95% CI = 0.76-0.85, p<0.01). The relationship remained significant in the multivariable model (RR 0.89, 95% CI =0.83-0.95, p<0.01).

Results for surgical wards/admissions followed a similar pattern but with fewer significant results.

Conclusions: Ward based RN staffing is significantly associated with reduced mortality for medical patients. There is little evidence for beneficial associations with HCSW staffing. Higher doctor staffing levels is associated with reduced mortality. The estimated association between RN staffing and mortality changes when medical and HCSW staffing is considered and depending on whether ward or hospital wide staffing levels are considered.

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Article summary: Strength and limitations of this study

- Most of the previous work has been concentrated in North America with few papers based on UK data.
- Like much of the research in this field, it is uses a cross-sectional observational design and reports association (and cannot demonstrate causation).
- This study makes a unique contribution by including medical and health care support worker staffing in examining the observed relationships between hospital staffing and mortality.
- The inclusion of medical staffing data however creates a limitation, in that the quality of the data available in England is restricted to posts: bed ratios

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Registered nurse, health care support workers, medical staffing levels and mortality in English hospitals: a cross-sectional study

INTRODUCTION

Ensuring the safety of hospital care is a paramount concern for health care systems world-wide. Despite increasing expenditure and focus on patient safety in many countries, there remains considerable variation in hospital mortality that cannot be explained by measurable variation in case mix or individual patient risk [1 2]. Registered nurse (RN) staffing has been identified as an important modifiable factor that is associated with mortality in many studies across the world [3-5]. A higher level of registered nurse staffing is associated with lower mortality and better quality of care. The strength of association varies across studies and settings, but a 6% increase in the odds of death associated with one additional patient per nurse is typical [5 6]. Findings such as these have informed policies mandating minimum nurse patient ratios in some US and Australian states [7]. However, despite the apparently strong evidence base, the implications of the findings remain contested by many and there remains significant resistance to mandated ratios from politicians and healthcare providers in many countries. [8]

[9] Economic pressures and the ageing profile of the nursing workforce internationally all point to a potential future with fewer registered nurses. [10] Current plans for workforce development in England and other countries point toward a significant increase in both the numbers and proportion of unregistered support workers and assistant practitioners, relative to the number of registered nurses and registered nurse recruitment remains problematic. [11 12]

However, such a shift seems to be at odds with evidence that points toward a more highly trained nursing workforce being associated with fewer adverse events.[13] Research from the US and Europe showed that having a higher proportion of degree qualified nurses in the workforce was associated with lower surgical mortality rates [5 14 15], while cross sectional studies in England have found that hospitals with more unqualified nurses per bed [16] and a higher proportion of support staff to registered nurses [17] had higher mortality rates. Both these English studies also showed a significant negative association between staffing by medical doctors and mortality rates; higher medical staffing levels were associated with lower mortality rates. [16 17] Indeed, the associations between registered nurse staffing and mortality were not significant when medical staffing was included in multivariable analyses. These studies have limitations. Both used organisation level staffing data, which may not reflect the deployment of staff on wards. The Keogh review, undertaken to explore higher than

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expected mortality rates in 14 NHS Trusts, revealed a discrepancy between the view of nurse staffing levels gained from administrative data (FTE per bed) versus observing nurse staffing 'on the ground' .[18]

None the less, these studies serve to illustrate that a failure to consider other staff groups concurrently is a significant limitation in much of the existing research on this topic. The boundaries between the work of different staff groups is fluid and there is some potential for the work of one group to substitute to some degree for that of another. For example, there is some evidence that substitution between nurses and doctors may be cost effective in a variety of settings [19] and in the UK for example, responsibilities have passed from doctors to nurses as the working hours of hospital doctors have reduced in response to EU legislative changes. [20] On the other hand, unqualified support workers can undertake both clerical work and some aspects of clinical nursing care. [20]

This study therefore aims to determine the association between hospital mortality and hospital level registered nurse staffing in English general acute NHS hospital Trusts while simultaneously considering staffing by support workers and doctors using routinely collected administrative data. Because routine data on ward level staffing is not widely available in national data sources, we also use ward level nurse data from a nationally representative sub-sample of Trusts, derived from the RN4CAST survey of nurses [21] to estimate nurse staffing actually deployed on wards .

METHODS

Data sources

We obtained details of the workforce characteristics of NHS acute hospital Trusts providing inpatient general medical and surgical care from the annual NHS staff census for 2009/10 and 2010/11. We excluded specialist Trusts (e.g. cancer, paediatrics), mental health Trusts and Trusts with low numbers of general medical / surgical admissions. We obtained details of teaching status, bed occupancy and number of beds from the annual hospital estates and facilities statistics for 2009/10 and 2010/11. From this, we calculated ratios of beds per registered nurse (RN), health care support workers (HCSW, including health care assistants and auxiliary nurses) and doctors. Patient data were obtained from the national Hospital Episode Statistics for patients admitted in the two years from 1 April 2009 to 31 March 2011. We were able to link hospital level staffing, bed occupancy and mortality data for 137 Trusts. The census data does not specifically identify nurses employed delivering inpatient care on wards. Therefore in addition to the data derived from routinely collected

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datasets, we also assessed nurse staffing on medical and surgical wards directly for a nationally representative sub sample of 31 Trusts, by means of a survey of 2917 nurses from a stratified random sample of general medical/surgical wards (up to 10) in each hospital in the Trust. The survey was undertaken from January to September 2010 as part of the RN4CAST study. Nurses reported on patient and staff numbers present on their last shift. Patients per RN and Patient per HCSW were calculated for each nurse responding to the survey. Staffing levels (patients per nurse) for the medical and surgical wards of each hospital Trust were estimated by averaging responses from all nurses in each specialty. Wards classified as mixed medical / surgical were treated as medical. Detail of this survey is reported elsewhere. [21 22]

Risk adjusted mortality

We calculated the predicted number of deaths in hospital for both medical and surgical admissions, using a method based on that used to calculate the summary mortality Indicator in England[23]. This uses indirect standardisation for age, sex, elective status, socio-economic deprivation (Index of multiple deprivation), co-morbidity (modified Charlson Index), and number of emergency admissions in the previous 12 months. We collapsed reasons for admission into the Clinical Classifications Software (CCS) groupings given by the Agency for Healthcare Research and Quality [24]. For each CCS group we built a logistic regression model to predict the probability of death. We divided admissions into medical and surgical specialties using the specialty code of the admitting consultant and calculated the predicted number of deaths in each group for each Trust by summing the predicted number of deaths across all CCS groups. Thus we were able to assess the risk of deaths in a Trust relative to the number that would be expected given the case mix.

Analysis

We modelled univariate and multivariable associations between staffing and mortality using the Generalised Estimating Equations (GEE) procedure in SPSS version 20 with the observed deaths regressed on the independent variables and the natural log of the expected number of deaths used as an offset. All multivariable models controlled for hospital Trust size (bed numbers), admission year and teaching status.

For the national (137 Trusts) analysis we calculated ratios of staff per occupied bed at the hospital Trust level and used mortality and staffing data for 2009-10 and 2010-11. For the analysis of the sub-sample (n=31) we used data from 2010-11 only (to most closely match when the survey was in the field) and used estimates of RN per patient and HCSW per patient for medical and surgical units derived from ward staffing reported in our survey to model associations with medical and surgical

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mortality respectively. Ward based RN staffing levels were modelled in four groups [in medical ≤6 (n=2), 6.01 – 8.00 (n=13), 8.01 – 10.00 (n=13) and ≥10 (n=2); in surgical ≤6 (n=6), 6.01 – 8.00 (n=16), 8.01 – 10.00 (n=8) and ≥10 (n=1)]. Because no equivalent ward based measure of medical staffing was available we retained hospital Trust level doctors per bed to control for medical staffing in this analysis.

RESULTS

In the 137 hospital Trusts there were 9 669 555 medical admissions and 9 302 292 surgical admissions over two years, with overall death rates of 32.8 and 7.9 per thousand respectively. There was substantial variation between Trusts in both medical and nurse staffing with a more than four-fold variation in registered nurse staffing between the lowest and highest staffed hospital Trust. This was attenuated when considering all nursing staff (RN + HCSW) although the variation was still more than threefold. These large variations are reflected in the 31 Trusts where we had measures of nurse staffing on wards, where variation between highest and lowest staffed ranged from 2-2.5 times across staff groups and specialties (table 1).

Table 1: Staffing levels (full time equivalents)

137 Trusts 2009-2011 (hospital Trust level employed staff, full time equivalents)	Mean	Minimum	Maximum
occupied bed per RN	1.53	0.69	2.81
occupied bed per HCSW	0.67	0.31	1.14
occupied bed per Nurse (HCSW+RN)	2.20	1.09	3.45
occupied bed per Doctor	0.74	0.35	1.30
31 Trusts 2010 (ward staff)			
Medical wards			
patient per RN	7.97	4.85	11.06
patient per HCSW	8.92	5.48	13.14
patient per Nurse (HCSW+RN)	4.15	2.68	5.61
Surgical wards			
patient per RN	7.33	4.60	11.34
patient per HCSW	9.58	5.72	14.68
patient per Nurse (HCSW+RN)	4.10	2.59	5.21

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Whole trust staffing

In the univariate analysis for medical admissions, an increase in the number of occupied beds per whole time equivalent RN (RR 1.22 p=.02) and doctor (RR 1.10 p <.01) employed by a Trust was associated with an increase in mortality. For HCSW, lower staffing levels (more beds per HCSW) were associated with reduced mortality (RR 0.95 p=.04). In the multivariable model the relationship was not statistically significant for RNs (RR 1.14 p=.17), but remained statistically significant for doctors (RR 1.08 p=.02) and for HCSWs (RR 0.93 p<01) (table 2).

For surgical admissions, neither occupied beds per RN (RR 1.15 p=.09) nor HCSW (RR 0.96 p=.20) were significantly associated with mortality although the direction of the relationships were similar to that for medical admissions. Occupied beds per FTE Doctor was significantly associated with increase in mortality (RR 1.08 p=.02). In the multivariable model the association with occupied beds per FTE Doctor strengthened (RR 1.13 p<0.01), but remained non-significant for RNs (RR 0.94, p=.59) and HCSWs (RR 0.95, p=.22) (table 2).

Table 2: Association between trust level staffing and standardised mortality: 137 NHS Trusts

	Univariate				**Multivariable**			
Parameter	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.03	0.96	1.09	0.43
Year, 2009/10					0.99	0.98	1.01	0.26
Beds (thousands)					0.98	0.93	1.03	0.43
Occupied beds per FTE RN	1.22	1.04	1.43	0.02	1.14	0.95	1.38	0.17
Occupied beds per FTE HCSW	0.95	0.91	1.00	0.04	0.93	0.89	0.98	<0.01
Occupied beds per FTE Doctor	1.10	1.05	1.15	<0.01	1.08	1.02	1.15	0.02
Surgical								
Non-Teaching Trust					1.01	0.94	1.09	0.71
Year, 2009/10					0.97	0.95	1.00	0.02
Beds (thousands)					1.05	0.97	1.14	0.25
Occupied bed per FTE RN	1.15	0.98	1.36	0.09	0.94	0.73	1.20	0.59
Occupied beds per FTE HCSW	0.96	0.89	1.02	0.20	0.95	0.88	1.03	0.22
Occupied beds per FTE Doctor	1.08	1.01	1.16	0.02	1.13	1.04	1.22	<0.01

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Ward nurse staffing

In our sub-sample of 31 Trusts where we used a survey to measure nurse staffing on medical and surgical wards, mortality rates were similar to the national sample with 35.2 deaths per thousand medical admissions (total medical admissions 1 260 558) and 8.9 deaths per thousand surgical admissions (total surgical admissions 1 084 429). All staffing variables were significantly associated with mortality in the univariate analysis (p<0.01, table 3).

Mortality was higher in Trusts where RNs cared for more patients. Trusts with 6 or less patients per RN in medical wards had a 20% lower risk of death among medical patients compared to Trusts with over ten patients per nurse (RR 0.80, p<0.01). The corresponding reduction for surgical wards / patients was 17% (RR 0.83, p=0.049). The relationship remained significant in the multivariable model for medical wards (RR 0.89, p<0.01) but not for surgical wards (RR 0.89, p=.23) (table 3).

Table 3: Association between ward level staffing and standardised mortality: 31 Trusts

	Univariate				Multivariable			
	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.12	1.08	1.15	<0.01
Beds (thousands)					1.08	1.04	1.13	<0.01
Patients per RN (χ^2,df,p)	(59.831, 3df, p<0.001)				(12.524,3df,<0.001)			
≤6	0.80	0.76	0.85	<0.01	0.89	0.83	0.95	<0.01
6.01 - 8.00	0.92	0.87	0.96	<0.01	0.96	0.91	1.01	0.14
8.01 - 10.00	0.91	0.87	0.96	<0.01	0.96	0.91	1.01	0.11
≥10	1.00				1.00			
Patients per HCSW	1.01	1.00	1.02	<0.01	1.00	0.99	1.01	0.92
Occupied beds per FTE Doctor	1.24	1.19	1.28	<0.01	1.12	1.06	1.17	<0.01
Surgical								
Non-Teaching Trust					1.09	1.03	1.17	<0.01
Beds (thousands)					1.15	1.07	1.24	<0.01
Patients per RN (χ^2,df,p)	(11.604, 3df, p=0.009)				(3.290, 3df, p=0.349)			
≤6	0.83	0.69	1.00	0.05	0.89	0.73	1.08	0.23
6.01 - 8.00	0.90	0.75	1.08	0.25	0.90	0.75	1.09	0.29
8.01 - 10.00	0.90	0.75	1.08	0.26	0.87	0.73	1.05	0.16
≥10	1.00				1.00			
Patients per HCSW	1.02	1.01	1.03	<0.01	1.01	1.00	1.03	0.05
Occupied beds per FTE Doctor	1.22	1.13	1.31	<0.01	1.15	1.03	1.28	<0.01

Every additional patient per HCSW was associated with a 1% increase in mortality for medical patients (RR 1.01 p<0.01) and a 2% increase for surgical patients (RR 1.02 p <0.01). These relationships were attenuated in the multivariable model and became non-significant, although the

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association with HCSW staffing on surgical wards neared statistical significance (RR 1.01 p=0.053) (table 3).

The associations with Trust level medical staffing per bed were stronger in this sub-sample than in the 137 Trusts. These associations were significant in both the univariate (medical RR 1.24, p<0.01; surgical RR 1.22, p<0.01) and multivariable analyses model (medical RR 1.12, p<0.01; surgical RR 1.15, p<0.01) (table 3).

DISCUSSION

In this study, we assessed associations between registered nurse staffing and mortality using both national administrative staffing data and surveys of ward level staffing in a sub-sample. We simultaneously considered staffing by medical doctors and support workers (HCSW). Lower levels of RN staffing level was associated with higher risk-adjusted mortality for both medical and surgical patients, although not all associations were statistically significant. Hospitals with lower levels of medical staffing also had higher mortality. When all staff groups were included in a multivariable analysis of the 137 hospital Trusts the associations with nurse staffing were reduced and no longer statistically significant. Similar results were found using ward nurse staffing levels in our sub-sample although the association between higher nurse staffing levels and lower mortality among medical patients was also significant in the fully adjusted (multivariate) models. Using hospital Trust wide staffing levels higher HCSW staffing was associated with higher levels of risk adjusted mortality although. This association was reversed in the sub-sample analysis using ward based HCSW staffing levels, although the relationship was not significant in the multivariable models.

Although the evidence showing associations between higher RN staffing and reduced mortality is extensive, few previous studies have considered staffing by both doctors and HCSW while exploring the relationship and none has done so using ward based nurse staffing. Previous studies using hospital level data found little evidence for a relationship between RN staffing and mortality once medical staffing was considered in a multivariable model [16 17] although one US study, which did not include HCSW staffing, found a significant relationship for RN staffing in a multivariable model with medical staffing [25]. Other studies which have considered less highly qualified nursing staff in hospitals (Licensed Practical Nurses and unlicensed support workers) have shown higher numbers of less trained staff or a diluted nursing skill mix to be associated with higher mortality or lower cost effectiveness [16 17 26], although in our study the negative relationship was not replicated when considering ward based HCSW staffing, which illustrates that the source of data used to explore these associations is an important consideration. Inferences about ward staffing made from hospital level data may be incorrect.

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There is currently significant debate about establishing mandatory minimum nurse staffing levels in England and elsewhere. However, the evidence base to draw on in order to identify specific safe staffing ratios is slim, despite the large volume of research. Recommended or mandated staffing levels for RNs in general medical and surgical units range from no more than 4 patients per RN (day shift in level 1 hospitals in the State of Victoria, Australia) to 10 patients per RN at night (level 2/3 hospitals in Victoria). Ratios between 4-1 and 6-1 on day shifts are typical [27]. In this study the risk of mortality was 11% lower in Trusts where registered nurses on medical wards reported caring for an average of 6 or fewer patients compared to Trusts where nurses reported caring for an average of 10 or more.

Although the patterns of results for medical and surgical mortality were similar, we did not find significant associations between registered nurse staffing and surgical mortality in our adjusted multivariable models, either for hospital wide or ward RN staffing. In previous research the relationship between RN staffing and surgical patient outcomes has been clearer than for medical patients[28]. We used all surgical admissions in our study, where overall mortality rates are low, whereas previous research has typically focussed on high risk sub groups of patients which may provide a more sensitive indicator.

Although policy in England has raised the possibility of using HCSW to substitute for RNs, the evidence here suggests that this may not be consistent with patient safety. We found that trusts with more HCSW per bed had higher rates of mortality among medical patients. Although this finding was not replicated when we looked at ward based staffing levels our multivariable models showed no evidence for benefit from higher HCSW staffing levels. This is consistent with other findings from the RN4CAST study which found no association between the level of HCSW staffing and the occurrence of missed nursing care reported by RNs [22]. While HCSW may deliver essential care, there is no evidence from large observational studies that their presence in the workforce can substitute for registered nurses in ensuring patient safety.

In common with most research in this area our study was cross sectional and cannot demonstrate causation, although the association between nurse staffing and mortality has recently been demonstrated in a prospective study [29]. Our study has a number of limitations. Our ward based staffing data arises from only 31 Trusts and was estimated from nurse report. This does not, in itself, provide a robust basis to identify safe staffing thresholds. Although we had ward level staffing data, it was only possible to model outcomes at the level of medical / surgical specialties rather than at the level of the ward, and therefore any variation at the ward level remains hidden. Further research is required to provide more robust estimates of associations in larger samples of hospitals. Our

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results do not provide support for using HCSW to substitute for registered nurses but we were unable to consider whether they may act as complements, enhancing the effectiveness of RNs, because we were unable to explore the interaction between different staff groups due to co-linearity. However, our previous work on nursing care left undone suggests that HCSW neither substitute for nor complement the ability of RNs to deliver core professional nursing work. [22]

CONCLUSIONS

Based on these findings we conclude that while a causal association between RN staffing and patient outcomes remains plausible, the current evidence base is not sufficient to identify safe staffing thresholds across different types of wards. However, given the overall strength of evidence for an association, it does seem feasible to identify staffing levels where risk to patients is likely to be increased, as recently suggested in a review of safety in the NHS [30]. When determining the safety of nurse staffing on hospital wards, the level of RN staffing is crucial and there is no evidence to suggest that higher levels of HCSW staffing have a role in reducing mortality rates. Current policies geared toward substituting HCSW for registered nurses should be reviewed in the light of this evidence. Future research exploring associations between nurse staffing and patient outcomes needs to include measures of both medically qualified staff and unregistered practitioners.

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The ethical approval to undertake the survey in England was given by the National Research Ethics service (NHS REC ref 09/H0808/69).

The authors have no competing interests to declare.

No additional data are available.

CONTRIBUTORSHIP STATEMENT

All authors meet the ICJME criteria for authorship:

- Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
- Drafting the work or revising it critically for important intellectual content; AND
- Final approval of the version to be published;

	Conception and design	Acquisition of data	Analysis	Interpretation	drafting	Revising (planned)	Final approval (will be sought)
JB	√	√		√	√	√	√
PG	√	√	√	√	√	√	√
SJ	√	√	√	√		√	√
TM		√	√		√	√	√
AMR	√			√	√	√	√

Furthermore, we agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and issues resolved.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	√
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	√
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	√
Objectives	3	State specific objectives, including any prespecified hypotheses	√
Methods			
Study design	4	Present key elements of study design early in the paper	√
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	√
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	√
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	√
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	√
Bias	9	Describe any efforts to address potential sources of bias	√
Study size	10	Explain how the study size was arrived at	√
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	√
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	√
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	√
		(*e*) Describe any sensitivity analyses	n/a

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Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	√
		(b) Give reasons for non-participation at each stage	√
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	√
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	√
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	√
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	√
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	√
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	√
Generalisability	21	Discuss the generalisability (external validity) of the study results	√
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	√

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

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Title Page

Title: Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

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Abstract (293 WORDS)

Objectives: To examine associations between mortality and registered nurse (RN) staffing in English hospital Trusts taking account of medical and health care support worker (HCSW) staffing.

Setting: Secondary care provided in acute hospital NHS Trusts in England.

Participants: Two datasets are examined: Administrative data from 137 NHS acute hospital Trusts (staffing measured as beds per staff member). A cross-sectional survey of 2917 registered nurses in a subsample of 31 Trusts (measured patients per ward nurse).

Outcome measure: Risk-adjusted mortality rates for adult patients (administrative data).

Results: For medical admissions, higher mortality was associated with more occupied beds per RN (RR 1.22, 95% CI = 1.04-1.43, p=.02) and per doctor (RR 1.10, 95% CI = 1.05-1.15, p <0.01) employed by the Trust whereas, lower HCSW staffing was associated with lower mortality (RR 0.95, 95% CI = 0.91-1.00, p=.04). In multivariable models the relationship was statistically significant for doctors (RR 1.08, 95% CI = 1.02-1.15, p=.02) and HCSWs (RR 0.93, 95% CI =0.89-0.98, p<01) but not RNs (RR 1.14, 95% CI = 0.95-1.38, p=.17).

Trusts with an average of ≤6 patients per RN in medical wards had a 20% lower mortality rate compared to Trusts with >10 patients per nurse (RR 0.80, 95% CI = 0.76-0.85, p<0.01). The relationship remained significant in the multivariable model (RR 0.89, 95% CI =0.83-0.95, p<0.01).

Results for surgical wards/admissions followed a similar pattern but with fewer significant results.

Conclusions: Ward based RN staffing is significantly associated with reduced mortality for medical patients. There is little evidence for beneficial associations with HCSW staffing. Higher doctor staffing levels is associated with reduced mortality. The estimated association between RN staffing and mortality changes when medical and HCSW staffing is considered and depending on whether ward or Trust wide staffing levels are considered.

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Article summary: Strength and limitations of this study

- Most of the previous work has been concentrated in North America with few papers based on UK data.
- Like much of the research in this field, it is uses a cross-sectional observational design and reports association (and cannot demonstrate causation).
- This study makes a unique contribution by including medical and health care support worker staffing in examining the observed relationships between Trust staffing and mortality.
- The inclusion of medical staffing data however creates a limitation, in that the quality of the data available in England is restricted to posts: bed ratios.

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Registered nurse, health care support workers, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

INTRODUCTION

Ensuring the safety of hospital care is a paramount concern for health care systems world-wide. Despite increasing expenditure and focus on patient safety in many countries, there remains considerable variation in hospital Trust mortality that cannot be explained by measurable variation in case mix or individual patient risk [1 2]. Registered nurse (RN) staffing has been identified as an important modifiable factor that is associated with mortality in many studies across the world [3-5]. A higher level of registered nurse staffing is associated with lower mortality and better quality of care. The strength of association varies across studies and settings, but a 6% increase in the odds of death associated with one additional patient per nurse is typical [5 6]. Findings such as these have informed policies mandating minimum nurse patient ratios in some US and Australian states [7]. However, despite the apparently strong evidence base, the implications of the findings remain contested by many and there remains significant resistance to mandated ratios from politicians and healthcare providers in many countries. [8]

[9] Economic pressures and the ageing profile of the nursing workforce internationally all point to a potential future with fewer registered nurses. [10] Current plans for workforce development in England and other countries point toward a significant increase in both the numbers and proportion of unregistered support workers and assistant practitioners, relative to the number of registered nurses and registered nurse recruitment remains problematic. [11 12]

However, such a shift seems to be at odds with evidence that points toward a more highly trained nursing workforce being associated with fewer adverse events.[13] Research from the US and Europe showed that having a higher proportion of degree qualified nurses in the workforce was associated with lower surgical mortality rates [5 14 15], while cross sectional studies in England have found that hospitals with more unqualified nurses per bed [16] and a higher proportion of support staff to registered nurses [17] had higher mortality rates. Both these English studies also showed a significant negative association between staffing by medical doctors and mortality rates; higher medical staffing levels were associated with lower mortality rates. [16 17] Indeed, the associations between registered nurse staffing and mortality were not significant when medical staffing was included in multivariable analyses. These studies have limitations. Both used organisation level staffing data, which may not reflect the deployment of staff on wards. The Keogh review, undertaken to explore higher than

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expected mortality rates in 14 NHS Trusts, revealed a discrepancy between the view of nurse staffing levels gained from administrative data (FTE per bed) versus observing nurse staffing 'on the ground' .[18]

None the less, these studies serve to illustrate that a failure to consider other staff groups concurrently is a significant limitation in much of the existing research on this topic. The boundaries between the work of different staff groups is fluid and there is some potential for the work of one group to substitute to some degree for that of another. For example, there is some evidence that substitution between nurses and doctors may be cost effective in a variety of settings [19] and in the UK for example, responsibilities have passed from doctors to nurses as the working hours of hospital doctors have reduced in response to EU legislative changes. [20] On the other hand, unqualified support workers can undertake both clerical work and some aspects of clinical nursing care. [20]

This study therefore aims to determine the association between mortality and Trust level registered nurse staffing in English general acute NHS hospital Trusts while simultaneously considering staffing by support workers and doctors using routinely collected administrative data. Because routine data on ward level staffing is not widely available in national data sources, we also use ward level nurse data from a nationally representative sub-sample of Trusts, derived from the RN4CAST survey of nurses [21] to estimate nurse staffing actually deployed on wards .

METHODS

Data sources

We obtained details of the workforce characteristics of NHS acute hospital Trusts providing inpatient general medical and surgical care from the annual NHS staff census for 2009/10 and 2010/11. We excluded specialist Trusts (e.g. cancer, paediatrics), mental health Trusts and Trusts with low numbers of general medical / surgical admissions. We obtained details of teaching status, bed occupancy and number of beds from the annual estates and facilities statistics for 2009/10 and 2010/11. From this, we calculated ratios of beds per registered nurse (RN), health care support workers (HCSW, including health care assistants and auxiliary nurses) and doctors. Patient data were obtained from the national Hospital Episode Statistics for patients admitted in the two years from 1 April 2009 to 31 March 2011. We were able to link Trust level staffing, bed occupancy and mortality data for 137 Trusts. The census data does not specifically identify nurses employed delivering inpatient care on wards. Therefore in addition to the data derived from routinely collected datasets,

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we also assessed nurse staffing on medical and surgical wards directly for a nationally representative sub sample of 31 Trusts, by means of a survey of nurses from a stratified random sample of general medical/surgical wards (up to 10) in each hospital in the Trust. The survey was undertaken from January to September 2010 as part of the RN4CAST study. About two-fifths (39%, 2917) of nurses responded to the survey. Nurses reported on patient and staff numbers present on their last shift. Patients per RN and Patient per HCSW were calculated for each nurse responding to the survey. Staffing levels (patients per nurse) for the medical and surgical wards of each hospital Trust were estimated by averaging responses from all nurses in each specialty. Wards classified as mixed medical / surgical were treated as medical. Design and methods of this survey are reported in more detail elsewhere.[21 22]

Risk adjusted mortality

We calculated the predicted number of deaths in hospital Trusts for both medical and surgical admissions, using a method based on that used to calculate the summary mortality Indicator in England[23]. This uses indirect standardisation for age, sex, elective status, socio-economic deprivation (Index of multiple deprivation), co-morbidity (modified Charlson Index), and number of emergency admissions in the previous 12 months. We collapsed reasons for admission into the Clinical Classifications Software (CCS) groupings given by the Agency for Healthcare Research and Quality [24]. For each CCS group we built a logistic regression model to predict the probability of death. We divided admissions into medical and surgical specialties using the specialty code of the admitting consultant and calculated the predicted number of deaths in each group for each Trust by summing the predicted number of deaths across all CCS groups. Thus we were able to assess the risk of deaths in a Trust relative to the number that would be expected given the case mix.

Analysis dataset

Data consisted of observed and expected deaths aggregated by medical and surgical specialty for 2009-10 and 2010-11 separately. These data were linked to Trust level staffing data, hospital Trust size and teaching status for each year.

Analysis

We used the Generalised Estimating Equations (GEE) modelling procedure in SPSS version 22 to produce crude and adjusted effects of staffing on mortality. Observed deaths were regressed on the independent variables and the natural log of the expected number of deaths used as an offset. All adjusted staffing effects controlled for hospital Trust size (bed numbers), admission year and teaching status.

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For the national (137 Trusts) analysis we calculated ratios of staff per occupied bed at the hospital Trust level and used mortality and staffing data for 2009-10 and 2010-11. For the analysis of the sub-sample (n=31) we used data from 2010-11 only (to most closely match when the survey was in the field) and used estimates of RN per patient and HCSW per patient for medical and surgical units derived from ward staffing reported in our survey to model associations with medical and surgical mortality respectively. Ward based RN staffing levels were modelled in four groups [in medical ≤6 (n=2), 6.01 – 8.00 (n=13), 8.01 – 10.00 (n=13) and ≥10 (n=2); in surgical ≤6 (n=6), 6.01 – 8.00 (n=16), 8.01 – 10.00 (n=8) and ≥10 (n=1)]. Because no equivalent ward based measure of medical staffing was available we retained hospital Trust level doctors per bed to control for medical staffing in this analysis.

An assessment of collinearity was performed prior to fitting the GEE models. If the condition index was 30 or greater the independent variables would be further scrutinised using the variance inflation factor and variance proportions[25,26]. Consideration was then given to removing variables causing the collinearity from the model. The condition index was below 30 for all models without interactions. However when interactions (e.g. occupied beds per FTE RN x occupied beds per FTE HCSW) were added the condition indices exceeded 100 and so interactions were excluded from the models.

RESULTS

In the 137 hospital Trusts there were 9 669 555 medical admissions and 9 302 292 surgical admissions over two years, with overall death rates of 32.8 and 7.9 per thousand respectively. There was substantial variation between Trusts in both medical and nurse staffing with a more than four-fold variation in registered nurse staffing between the lowest and highest staffed hospital Trust. This was attenuated when considering all nursing staff (RN + HCSW) although the variation was still more than threefold. These large variations are reflected in the 31 Trusts where we had measures of nurse staffing on wards, where variation between highest and lowest staffed ranged from 2-2.5 times across staff groups and specialties (table 1).

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Table 1: Staffing levels (full time equivalents)

137 Trusts 2009-2011 (hospital Trust level employed staff, full time equivalents)	Mean	Minimum	Maximum
occupied bed per RN	1.53	0.69	2.81
occupied bed per HCSW	0.67	0.31	1.14
occupied bed per Nurse (HCSW+RN)	2.20	1.09	3.45
occupied bed per Doctor	0.74	0.35	1.30
31 Trusts 2010 (ward staff)			
Medical wards			
patient per RN	7.97	4.85	11.06
patient per HCSW	8.92	5.48	13.14
patient per Nurse (HCSW+RN)	4.15	2.68	5.61
Surgical wards			
patient per RN	7.33	4.60	11.34
patient per HCSW	9.58	5.72	14.68
patient per Nurse (HCSW+RN)	4.10	2.59	5.21

The correlations between staffing variables were typically weak to moderate although there was a strong correlation between occupied beds per FTE RN and occupied beds per FTE Doctor (r=0.72)(Table 2).

Table2: correlations between staffing variables

137 Trusts	Occupied beds per FTE HCSW	Occupied beds per FTE Doctor
Occupied beds per FTE RN	0.13, p=0.031	0.72, p<.001
Occupied beds per FTE HCSW		-0.14, p=.021

31 RN4CAST Trusts	Patients per HCSW	Occupied beds per FTE Doctor
Patients per RN	0.38, p=.002	-0.40, p=.001
Patients per HCSW		-0.24, p=.056

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Whole Trust staffing

In the unadjusted analysis for medical admissions, an increase in the number of occupied beds per whole time equivalent RN (RR 1.22 p=0.016) and doctor (RR 1.10 p <0.001) were associated with an increase in mortality. For HCSW this association was reversed (RR 0.95 p=0.041). In the adjusted analysis the association for RNs was attenuated and no longer statistically significant (RR 1.14 p=0.17), but remained statistically significant for doctors (RR 1.08 p=0.016) and for HCSWs (RR 0.93 p=0.003) (table 2).

For surgical admissions, neither occupied beds per RN (RR 1.15 p=0.088) nor HCSW (RR 0.96 p=0.20) were significantly associated with mortality although the direction of the associations were similar to that for medical admissions. An increase in the number of occupied beds per FTE Doctor was significantly associated with increase in mortality (RR 1.08 p=0.020). In the adjusted model the association with occupied beds per FTE Doctor strengthened (RR 1.13 p=0.002), but remained non-significant for RNs (RR 0.94, p=0.59) and HCSWs (RR 0.95, p=0.22) (table 3).

Table 3: Association between Trust level staffing and standardised mortality: 137 NHS Trusts

	Unadjusted				Adjusted			
Parameter	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.03	0.96	1.09	0.43
Year, 2009/10					0.99	0.98	1.01	0.26
Beds (thousands)					0.98	0.93	1.03	0.43
Occupied beds per FTE RN	1.22	1.04	1.43	0.016	1.14	0.95	1.38	0.17
Occupied beds per FTE HCSW	0.95	0.91	1.00	0.041	0.93	0.89	0.98	0.003
Occupied beds per FTE Doctor	1.10	1.05	1.15	<0.001	1.08	1.02	1.15	0.016
Surgical								
Non-Teaching Trust					1.01	0.94	1.09	0.71
Year, 2009/10					0.97	0.95	1.00	0.02
Beds (thousands)					1.05	0.97	1.14	0.25
Occupied bed per FTE RN	1.15	0.98	1.36	0.088	0.94	0.73	1.20	0.59
Occupied beds per FTE HCSW	0.96	0.89	1.02	0.20	0.95	0.88	1.03	0.22
Occupied beds per FTE Doctor	1.08	1.01	1.16	0.020	1.13	1.04	1.22	0.002

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Nurse based ward staffing

In our sub-sample of 31 Trusts where we used a survey to measure nurse staffing on medical and surgical wards, mortality rates were similar to the national sample with 35.2 deaths per thousand medical admissions (total medical admissions 1 260 558) and 8.9 deaths per thousand surgical admissions (total surgical admissions 1 084 429). All staffing variables were significantly associated with mortality in the unadjusted analysis (p<0.01, table 4).

Mortality was higher in Trusts where RNs cared for more patients. Trusts with 6 or less patients per RN in medical wards had a 20% lower risk of death among medical patients compared to Trusts with over ten patients per nurse (RR 0.80, p<0.001). The corresponding reduction for surgical wards / patients was 17% (RR 0.83, p=0.049). This difference was attenuated but remained significant in the adjusted model for medical wards (RR 0.89, p<0.001) but not for surgical wards (RR 0.89, p=0.23) (table 4).

Table 4: Association between ward level staffing and standardised mortality: 31 Trusts

	unadjusted				adjusted			
	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.12	1.08	1.15	<0.01
Beds (thousands)					1.08	1.04	1.13	<0.01
Patients per RN (χ^2,df,p)	(59.831, 3df, p<0.001)				(12.524,3df,<0.001)			
≤6	0.80	0.76	0.85	<0.001	0.89	0.83	0.95	0.001
6.01 - 8.00	0.92	0.87	0.96	<0.001	0.96	0.91	1.01	0.14
8.01 - 10.00	0.91	0.87	0.96	<0.001	0.96	0.91	1.01	0.11
≥10	1.00				1.00			
Patients per HCSW	1.01	1.00	1.02	0.001	1.00	0.99	1.01	0.92
Occupied beds per FTE Doctor	1.24	1.19	1.28	<0.001	1.12	1.06	1.17	<0.001
Surgical								
Non-Teaching Trust					1.09	1.03	1.17	<0.01
Beds (thousands)					1.15	1.07	1.24	<0.01
Patients per RN (χ^2,df,p)	(11.604, 3df, p=0.009)				(3.290, 3df, p=0.349)			
≤6	0.83	0.69	1.00	0.049	0.89	0.73	1.08	0.23
6.01 - 8.00	0.90	0.75	1.08	0.26	0.90	0.75	1.09	0.30
8.01 - 10.00	0.90	0.75	1.08	0.26	0.87	0.73	1.05	0.16
≥10	1.00				1.00			
Patients per HCSW	1.02	1.01	1.03	0.002	1.01	1.00	1.03	0.053
Occupied beds per FTE Doctor	1.22	1.13	1.31	<0.001	1.15	1.03	1.28	0.010

Every additional patient per HCSW was associated with a 1% increase in mortality for medical patients (RR 1.01 p=0.001) and a 2% increase for surgical patients (RR 1.02 p =0.002). These adjusted

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associations were attenuated and non-significant, although on surgical wards this association neared statistical significance (RR 1.01 p=0.053) (table 4).

The unadjusted associations with occupied beds per FTE doctor were stronger in this sub-sample than in the 137 Trusts. These associations were significant in both the unadjusted (medical RR 1.24, p<0.001; surgical RR 1.22, p<0.001) and adjusted analyses (medical RR 1.12, p<0.001; surgical RR 1.15, p=0.010) (table 4).

DISCUSSION

In this study, we assessed associations between registered nurse staffing and mortality using both national administrative staffing data and surveys of ward level staffing in a sub-sample. We simultaneously considered staffing by medical doctors and support workers (HCSW). When all staff groups were included 137 hospital Trusts analysis the adjusted associations with mortality were not statistically significant for nurse staffing but were for doctor staffing. In our sub-sample higher nurse staffing levels was significantly associated with lower mortality among both medical and surgical patients in the adjusted model. Higher HCSW staffing was associated with higher levels of risk adjusted mortality in the analysis of 137 Trusts. In the sub-sample, which used nurse survey based estimates of HCSW staffing levels, the adjusted association was not significant.

Although the evidence showing associations between higher RN staffing and reduced mortality is extensive, few previous studies have considered staffing by both doctors and HCSW while exploring the relationship and none has done so using nurse based ward estimates. Previous studies using hospital Trust level data found little evidence for a relationship between RN staffing and mortality adjusting for medical staffing [16 17] although one US study, which did not include HCSW staffing, found a significant relationship for RN staffing adjusting for medical staffing [27]A study of ICUs in England found a relationship between consultant numbers, RN numbers and mortality, but no evidence of a relationship with support worker levels[28]. Other studies which have considered less highly qualified nursing staff in hospitals (Licensed Practical Nurses and unlicensed support workers) have shown higher numbers of less trained staff or a diluted nursing skill mix to be associated with higher mortality or lower cost effectiveness [16 17 28], although in our study the negative relationship was not replicated when considering nurse based estimates of HCSW staffing. However a challenge in interpreting study findings, is the extent to which the role of the Health Care Support Worker or 'nursing aide' role varies[30].

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This illustrates that the source of data used to explore these associations is an important consideration. Inferences about ward staffing made from hospital or Trust level data may be incorrect.

There is currently significant debate about establishing mandatory minimum nurse staffing levels in England and elsewhere. However, the evidence base to draw on in order to identify specific safe staffing ratios is slim, despite the large volume of research. Recommended or mandated staffing levels for RNs in general medical and surgical units range from no more than 4 patients per RN (day shift in level 1 hospitals in the State of Victoria, Australia) to 10 patients per RN at night (level 2/3 hospitals in Victoria). Ratios between 4-1 and 6-1 on day shifts are typical [31]. In this study, irrespective of specialty, the risk of mortality was 11% lower in Trusts where registered nurses reported caring for an average of 6 or fewer patients compared to Trusts where nurses reported caring for an average of 10 or more.

Although the patterns of results for medical and surgical mortality were similar, we did not find significant adjusted associations between registered nurse staffing and surgical mortality, either for Trustwide or nurse estimated ward staffing. In previous research the relationship between RN staffing and surgical patient outcomes has been clearer than for medical patients[32]. We used all surgical admissions in our study, where overall mortality rates are low, whereas previous research has typically focussed on high risk sub groups of patients which may provide a more sensitive indicator.

Although policy in England has raised the possibility of using HCSW to substitute for RNs, the evidence here suggests that this may not be consistent with patient safety. We found that Trusts with more HCSW per bed had higher rates of mortality among medical patients. Although this finding was not replicated when we looked at nurse estimated ward staffing levels our adjusted models showed no evidence for benefit from higher HCSW staffing levels. This is consistent with other findings from the RN4CAST study which found no association between the level of HCSW staffing and the occurrence of missed nursing care reported by RNs [22]. While HCSW may deliver essential care, there is no evidence from large observational studies that their presence in the workforce can substitute for registered nurses in ensuring patient safety.

In common with most research in this area our study was cross sectional and cannot demonstrate causation, although the association between nurse staffing and mortality has recently been demonstrated in a prospective study [33]. Our study has a number of limitations. Our nurse based staffing data arises from only 31 Trusts and was estimated from nurse report. This does not, in itself, provide a robust basis to identify safe staffing thresholds. Although we had ward level staffing data, it was only possible to model outcomes at the level of medical / surgical specialties rather than at the level of the ward, and therefore any variation at the ward level remains hidden. Further research is required to provide more robust estimates of associations in larger samples of hospital Trusts. Our results do not provide support for using HCSW to substitute for registered nurses but we were unable to consider whether they may act as complements, enhancing the effectiveness of RNs, because we were unable to explore the interaction between different staff groups due to co-linearity. However, our previous work on nursing care left undone suggests that HCSW neither substitute for nor complement the ability of RNs to deliver core professional nursing work. [22]

CONCLUSIONS

Based on these findings we conclude that while a causal association between RN staffing and patient outcomes remains plausible, the current evidence base is not sufficient to identify safe staffing thresholds across different types of wards. However, given the overall strength of evidence for an association, it does seem feasible to identify staffing levels where risk to patients is likely to be increased, as recently suggested in a review of safety in the NHS [34]. When determining the safety of nurse staffing on hospital wards, the level of RN staffing is crucial and there is no evidence to suggest that higher levels of HCSW staffing have a role in reducing mortality rates. Current policies geared toward substituting HCSW for registered nurses should be reviewed in the light of this evidence. Future research exploring associations between nurse staffing and patient outcomes needs to include measures of both medically qualified staff and unregistered practitioners.

(2,956 WORDS)

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The ethical approval to undertake the survey in England was given by the National Research Ethics service (NHS REC ref 09/H0808/69).

The authors have no competing interests to declare.

No additional data are available.

CONTRIBUTORSHIP STATEMENT

All authors meet the ICJME criteria for authorship:

- Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
- Drafting the work or revising it critically for important intellectual content; AND
- Final approval of the version to be published;

	Conception and design	Acquisition of data	Analysis	Interpretation	drafting	Revising (planned)	Final approval (will be sought)
JB	√	√		√	√	√	√
PG	√	√	√	√	√	√	√
SJ	√	√	√	√		√	√
TM		√	√		√	√	√
AMR	√			√	√	√	√

Furthermore, we agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and issues resolved.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	√
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	√
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	√
Objectives	3	State specific objectives, including any prespecified hypotheses	√
Methods			
Study design	4	Present key elements of study design early in the paper	√
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	√
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	√
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	√
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	√
Bias	9	Describe any efforts to address potential sources of bias	√
Study size	10	Explain how the study size was arrived at	√
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	√
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	√
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	√
		(*e*) Describe any sensitivity analyses	n/a

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Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	√
		(b) Give reasons for non-participation at each stage	√
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	√
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	√
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	√
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	√
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	√
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	√
Generalisability	21	Discuss the generalisability (external validity) of the study results	√
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	√

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

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Title Page

Title: Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

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Abstract (293 WORDS)

Objectives: To examine associations between mortality and registered nurse (RN) staffing in English hospital Trusts taking account of medical and health care support worker (HCSW) staffing.

Setting: Secondary care provided in acute hospital NHS Trusts in England.

Participants: Two datasets are examined: Administrative data from 137 NHS acute hospital Trusts (staffing measured as beds per staff member). A cross-sectional survey of 2917 registered nurses in a subsample of 31 Trusts (measured patients per ward nurse).

Outcome measure: Risk-adjusted mortality rates for adult patients (administrative data).

Results: For medical admissions, higher mortality was associated with more occupied beds per RN (RR 1.22, 95% CI = 1.04-1.43, p=.02) and per doctor (RR 1.10, 95% CI = 1.05-1.15, p <0.01) employed by the Trust whereas, lower HCSW staffing was associated with lower mortality (RR 0.95, 95% CI = 0.91-1.00, p=.04). In multivariable models the relationship was statistically significant for doctors (RR 1.08, 95% CI = 1.02-1.15, p=.02) and HCSWs (RR 0.93, 95% CI =0.89-0.98, p<01) but not RNs (RR 1.14, 95% CI = 0.95-1.38, p=.17).

Trusts with an average of ≤6 patients per RN in medical wards had a 20% lower mortality rate compared to Trusts with >10 patients per nurse (RR 0.80, 95% CI = 0.76-0.85, p<0.01). The relationship remained significant in the multivariable model (RR 0.89, 95% CI =0.83-0.95, p<0.01).

Results for surgical wards/admissions followed a similar pattern but with fewer significant results.

Conclusions: Ward based RN staffing is significantly associated with reduced mortality for medical patients. There is little evidence for beneficial associations with HCSW staffing. Higher doctor staffing levels is associated with reduced mortality. The estimated association between RN staffing and mortality changes when medical and HCSW staffing is considered and depending on whether ward or Trust wide staffing levels are considered.

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Article summary: Strength and limitations of this study

- Most previous work has been concentrated in North America with few papers based on UK data.
- Like much of the research in this field, it uses a cross-sectional observational design and reports association (so cannot demonstrate causation).
- This study makes a unique contribution by including medical and health care support worker staffing in examining the observed relationships between Trust staffing and mortality.
- The inclusion of medical staffing data however creates a limitation, in that the quality of the data available in England is restricted to posts: bed ratios.

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Registered nurse, health care support workers, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study

INTRODUCTION

Ensuring the safety of hospital care is a paramount concern for health care systems world-wide. Despite increasing expenditure and focus on patient safety in many countries, there remains considerable variation in hospital Trust mortality that cannot be explained by measurable variation in case mix or individual patient risk.[1 2] Registered nurse (RN) staffing has been identified as an important modifiable factor that is associated with mortality in many studies across the world [3-5]. A higher level of registered nurse staffing is associated with lower mortality and better quality of care. The strength of association varies across studies and settings, but a 6% increase in the odds of death associated with one additional patient per nurse is typical.[5 6] Findings such as these have informed policies mandating minimum nurse patient ratios in some US and Australian states.[7] However, despite the apparently strong evidence base, the implications of the findings remain contested by many and there remains significant resistance to mandated ratios from politicians and healthcare providers in many countries.[8 9] Economic pressures and the ageing profile of the nursing workforce internationally all point to a potential future with fewer registered nurses.[10] Current plans for workforce development in England and other countries point toward a significant increase in both the numbers and proportion of unregistered support workers and assistant practitioners, relative to the number of registered nurses and registered nurse recruitment remains problematic. [11 12]

However, such a shift seems to be at odds with evidence that points toward a more highly trained nursing workforce being associated with fewer adverse events.[13] Research from the US and Europe showed that having a higher proportion of degree qualified nurses in the workforce was associated with lower surgical mortality rates [5 14 15], while cross sectional studies in England have found that hospitals with more unqualified nurses per bed [16] and a higher proportion of support staff to registered nurses [17] had higher mortality rates. Both these English studies also showed a significant negative association between staffing by medical doctors and mortality rates; higher medical staffing levels were associated with lower mortality rates.[16 17] Indeed, the associations between registered nurse staffing and mortality were not significant when medical staffing was included in multivariable analyses. These studies have limitations. Both used organisation level staffing data, which may not reflect the deployment of staff on wards. The Keogh review, undertaken to explore higher than expected mortality rates in 14 NHS Trusts, revealed a discrepancy between the view of nurse staffing

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levels gained from administrative data (FTE per bed) versus observing nurse staffing 'on the ground'.[18]

None the less, these studies serve to illustrate that a failure to consider other staff groups concurrently is a significant limitation in much of the existing research on this topic. The boundaries between the work of different staff groups is fluid and there is some potential for the work of one group to substitute to some degree for that of another. For example, there is some evidence that substitution between nurses and doctors may be cost effective in a variety of settings [19] and in the UK for example, responsibilities have passed from doctors to nurses as the working hours of hospital doctors have reduced in response to EU legislative changes. [20] On the other hand, unqualified support workers can undertake both clerical work and some aspects of clinical nursing care. [20]

This study therefore aims to determine the association between mortality and Trust level registered nurse staffing in English general acute NHS hospital Trusts while simultaneously considering staffing by support workers and doctors using routinely collected administrative data. Because routine data on ward level staffing is not widely available in national data sources, we also use ward level nurse data from a nationally representative sub-sample of Trusts, derived from the RN4CAST survey of nurses [21] to estimate nurse staffing actually deployed on wards .

METHODS

Data sources

We obtained details of the workforce characteristics of NHS acute hospital Trusts providing inpatient general medical and surgical care from the annual NHS staff census for 2009/10 and 2010/11. We excluded specialist Trusts (e.g. cancer, paediatrics), mental health Trusts and Trusts with low numbers of general medical / surgical admissions. We obtained details of teaching status, bed occupancy and number of beds from the annual estates and facilities statistics for 2009/10 and 2010/11. From this, we calculated ratios of beds per registered nurse (RN), doctors and health care support workers (HCSWs including health care assistants and auxiliary nurses) . HCSWs in England are unregistered care staff (without nursing qualifications) who undertake many aspects of fundamental care for patients in NHS hospital wards (such as helping patients to wash, use the toilet, and monitoring vital signs). Patient data were obtained from the national Hospital Episode Statistics for patients admitted in the two years from 1 April 2009 to 31 March 2011. We were able to link Trust level staffing, bed occupancy and mortality data for 137 Trusts. The census data does

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not specifically identify nurses employed delivering inpatient care on wards. Therefore in addition to the data derived from routinely collected datasets, we also assessed nurse staffing on medical and surgical wards directly for a nationally representative sub sample of 31 Trusts, by means of a survey of nurses from a stratified random sample of general medical/surgical wards (up to 10) in each hospital in the Trust. The survey was undertaken from January to September 2010 as part of the RN4CAST study. RNs in the 31 Trusts (covering 46 hospitals and 401 wards) were surveyed; 2990 of 7609 (39%) responded. The nurse response rate varied between the 31 Trusts from 19% to 69%.

Nurses reported on patient and staff numbers present on their last shift. Patients per RN and patients per HCSW were calculated for each nurse responding to the survey. Staffing levels (patients per nurse) for the medical and surgical wards of each hospital Trust were estimated by averaging responses from all nurses in each specialty. Wards classified as mixed medical / surgical were treated as medical. Detail of the design and methods of this survey reported elsewhere.[21 22]

Risk adjusted mortality

We calculated the predicted number of deaths in hospital Trusts for both medical and surgical admissions, using a method based on that used to calculate the summary mortality Indicator in England.[23] This uses indirect standardisation for age, sex, elective status, socio-economic deprivation (Index of multiple deprivation), co-morbidity (modified Charlson Index), and number of emergency admissions in the previous 12 months. We collapsed reasons for admission into the Clinical Classifications Software (CCS) groupings given by the Agency for Healthcare Research and Quality. [24] For each CCS group we built a logistic regression model to predict the probability of death. We divided admissions into medical and surgical specialties using the specialty code of the admitting consultant and calculated the predicted number of deaths in each group for each Trust by summing the predicted number of deaths across all CCS groups. Thus we were able to assess the risk of deaths in a Trust relative to the number that would be expected given the case mix.

Analysis dataset

Data consisted of observed and expected deaths aggregated by medical and surgical specialty for 2009-10 and 2010-11 separately. These data were linked to Trust level staffing data, hospital Trust size and teaching status for each year.

Analysis

We used the Generalised Estimating Equations (GEE) modelling procedure in SPSS version 22 to produce crude and adjusted effects of staffing on mortality. GEE was used in preference to a

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multilevel model because it is more suited to estimating population average effects. There were only two time-points, which would have limited the usefulness of a multilevel model. Observed deaths were regressed on the independent variables and the natural log of the expected number of deaths was used as an offset. All adjusted staffing effects controlled for hospital Trust size (bed numbers), admission year and teaching status.

For the national (137 Trusts) analysis we calculated ratios of staff per occupied bed at the hospital Trust level and used mortality and staffing data for 2009-10 and 2010-11. For the analysis of the sub-sample (n=31) we used data from 2010-11 only (to most closely match when the survey was in the field) and used estimates of RN per patient and HCSW per patient for medical and surgical units derived from ward staffing reported in our survey to model associations with medical and surgical mortality respectively. Ward based RN staffing levels were modelled in four groups [in medical ≤6 (n=2), 6.01 – 8.00 (n=13), 8.01 – 10.00 (n=13) and ≥10 (n=2); in surgical ≤6 (n=6), 6.01 – 8.00 (n=16), 8.01 – 10.00 (n=8) and ≥10 (n=1)]. Because no equivalent ward based measure of medical staffing was available we retained hospital Trust level doctors per bed to control for medical staffing in this analysis.

An assessment of collinearity was performed prior to fitting the GEE models. If the condition index was 30 or greater the independent variables would be further scrutinised using the variance inflation factor and variance proportions.[25,26] Consideration was then given to removing variables causing the collinearity from the model. The condition index was below 30 for all models without interactions. However when interactions (e.g. occupied beds per FTE RN x occupied beds per FTE HCSW) were added the condition indices exceeded 100 and so interactions were excluded from the models.

RESULTS

In the 137 hospital Trusts there were 9 669 555 medical admissions and 9 302 292 surgical admissions over two years, with overall death rates of 32.8 and 7.9 per thousand respectively. There was substantial variation between Trusts in both medical and nurse staffing with a more than four-fold variation in registered nurse staffing between the lowest and highest staffed hospital Trust. This was attenuated when considering all nursing staff (RN + HCSW), although the variation was still more than threefold. These large variations are reflected in the 31 Trusts where we had measures of nurse staffing on wards, where variation between highest and lowest staffed ranged from 2-2.5 times across staff groups and specialties (table 1).

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Table 1: Staffing levels (full time equivalents)

137 Trusts 2009-2011 (hospital Trust level employed staff, full time equivalents)	Mean	Minimum	Maximum
occupied bed per RN	1.53	0.69	2.81
occupied bed per HCSW	0.67	0.31	1.14
occupied bed per Nurse (HCSW+RN)	2.20	1.09	3.45
occupied bed per Doctor	0.74	0.35	1.30
31 Trusts 2010 (ward staff)			
Medical wards			
patient per RN	7.97	4.85	11.06
patient per HCSW	8.92	5.48	13.14
patient per Nurse (HCSW+RN)	4.15	2.68	5.61
Surgical wards			
patient per RN	7.33	4.60	11.34
patient per HCSW	9.58	5.72	14.68
patient per Nurse (HCSW+RN)	4.10	2.59	5.21

The correlations between staffing variables were typically weak to moderate although there was a strong correlation between occupied beds per FTE RN and occupied beds per FTE Doctor (r=0.72) (Table 2).

Table2: correlations between staffing variables

137 Trusts	Occupied beds per FTE HCSW	Occupied beds per FTE Doctor
Occupied beds per FTE RN	0.13, p=0.031	0.72, p<.001
Occupied beds per FTE HCSW		-0.14, p=.021

31 RN4CAST Trusts	Patients per HCSW	Occupied beds per FTE Doctor
Patients per RN	0.38, p=.002	-0.40, p=.001
Patients per HCSW		-0.24, p=.056

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Whole Trust staffing

In the unadjusted analysis for medical admissions, an increase in the number of occupied beds per whole time equivalent RN (RR 1.22 p=0.016) and doctor (RR 1.10 p<0.001) were associated with an increase in mortality. For HCSW this association was reversed (RR 0.95 p=0.041). In the adjusted analysis the association for RNs was attenuated and no longer statistically significant (RR 1.14 p=0.17), but remained statistically significant for doctors (RR 1.08 p=0.016) and for HCSWs (RR 0.93 p=0.003) (table 2).

For surgical admissions, neither occupied beds per RN (RR 1.15 p=0.088) nor HCSW (RR 0.96 p=0.20) were significantly associated with mortality although the direction of the associations were similar to that for medical admissions. An increase in the number of occupied beds per FTE Doctor was significantly associated with an increase in mortality (RR 1.08 p=0.020). In the adjusted model the association with occupied beds per FTE Doctor strengthened (RR 1.13 p=0.002), but remained non-significant for RNs (RR 0.94, p=0.59) and HCSWs (RR 0.95, p=0.22) (table 3).

Table 3: Association between Trust level staffing and standardised mortality: 137 NHS Trusts

	Unadjusted				**Adjusted**			
Parameter	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.03	0.96	1.09	0.43
Year, 2009/10					0.99	0.98	1.01	0.26
Beds (thousands)					0.98	0.93	1.03	0.43
Occupied beds per FTE RN	1.22	1.04	1.43	0.016	1.14	0.95	1.38	0.17
Occupied beds per FTE HCSW	0.95	0.91	1.00	0.041	0.93	0.89	0.98	0.003
Occupied beds per FTE Doctor	1.10	1.05	1.15	<0.001	1.08	1.02	1.15	0.016
Surgical								
Non-Teaching Trust					1.01	0.94	1.09	0.71
Year, 2009/10					0.97	0.95	1.00	0.02
Beds (thousands)					1.05	0.97	1.14	0.25
Occupied bed per FTE RN	1.15	0.98	1.36	0.088	0.94	0.73	1.20	0.59
Occupied beds per FTE HCSW	0.96	0.89	1.02	0.20	0.95	0.88	1.03	0.22
Occupied beds per FTE Doctor	1.08	1.01	1.16	0.020	1.13	1.04	1.22	0.002

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Nurse based ward staffing

In our sub-sample of 31 Trusts where we used a survey to measure nurse staffing on medical and surgical wards, mortality rates were similar to the national sample with 35.2 deaths per thousand medical admissions (total medical admissions 1 260 558) and 8.9 deaths per thousand surgical admissions (total surgical admissions 1 084 429). All staffing variables were significantly associated with mortality in the unadjusted analysis (p<0.01, table 4).

Mortality was higher in Trusts where RNs cared for more patients. Trusts with 6 or less patients per RN in medical wards had a 20% lower risk of death among medical patients compared to Trusts with over ten patients per nurse (RR 0.80, p<0.001). The corresponding reduction for surgical wards / patients was 17% (RR 0.83, p=0.049). This difference was attenuated but remained significant in the adjusted model for medical wards (RR 0.89, p<0.001) but not for surgical wards (RR 0.89, p=0.23) (table 4).

Table 4: Association between ward level staffing and standardised mortality: 31 Trusts

	unadjusted				adjusted			
	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p	Risk Ratio	$L_{95\%CL}$	$U_{95\%CL}$	p
Medical								
Non-Teaching Trust					1.12	1.08	1.15	<0.01
Beds (thousands)					1.08	1.04	1.13	<0.01
Patients per RN (χ^2,df,p)	(59.831, 3df, p<0.001)				(12.524,3df,<0.001)			
≤6	0.80	0.76	0.85	<0.001	0.89	0.83	0.95	0.001
6.01 - 8.00	0.92	0.87	0.96	<0.001	0.96	0.91	1.01	0.14
8.01 - 10.00	0.91	0.87	0.96	<0.001	0.96	0.91	1.01	0.11
≥10	1.00				1.00			
Patients per HCSW	1.01	1.00	1.02	0.001	1.00	0.99	1.01	0.92
Occupied beds per FTE Doctor	1.24	1.19	1.28	<0.001	1.12	1.06	1.17	<0.001
Surgical								
Non-Teaching Trust					1.09	1.03	1.17	<0.01
Beds (thousands)					1.15	1.07	1.24	<0.01
Patients per RN (χ^2,df,p)	(11.604, 3df, p=0.009)				(3.290, 3df, p=0.349)			
≤6	0.83	0.69	1.00	0.049	0.89	0.73	1.08	0.23
6.01 - 8.00	0.90	0.75	1.08	0.26	0.90	0.75	1.09	0.30
8.01 - 10.00	0.90	0.75	1.08	0.26	0.87	0.73	1.05	0.16
≥10	1.00				1.00			
Patients per HCSW	1.02	1.01	1.03	0.002	1.01	1.00	1.03	0.053
Occupied beds per FTE Doctor	1.22	1.13	1.31	<0.001	1.15	1.03	1.28	0.010

Every additional patient per HCSW was associated with a 1% increase in mortality for medical patients (RR 1.01 p=0.001) and a 2% increase for surgical patients (RR 1.02 p =0.002). These adjusted

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associations were attenuated and non-significant, although on surgical wards this association neared statistical significance (RR 1.01 p=0.053) (table 4).

The unadjusted associations with occupied beds per FTE doctor were stronger in this sub-sample than in the 137 Trusts. These associations were significant in both the unadjusted (medical RR 1.24, p<0.001; surgical RR 1.22, p<0.001) and adjusted analyses (medical RR 1.12, p<0.001; surgical RR 1.15, p=0.010) (table 4).

DISCUSSION

In this study, we assessed associations between registered nurse staffing and mortality using both national administrative staffing data and surveys of ward level staffing in a sub-sample. We simultaneously considered staffing by medical doctors and support workers (HCSW). When all staff groups were included (in the analysis of 137 hospital Trusts) the adjusted associations with mortality were not statistically significant for nurse staffing but were for doctor staffing. In our sub-sample higher nurse staffing levels was significantly associated with lower mortality among both medical and surgical patients in the adjusted model. Higher HCSW staffing was associated with higher levels of risk adjusted mortality in the analysis of 137 Trusts. In the sub-sample, which used nurse survey based estimates of HCSW staffing levels, the adjusted association was not significant.

Although the evidence showing associations between higher RN staffing and reduced mortality is extensive, few previous studies have considered staffing by both doctors and HCSW while exploring the relationship and none has done so using nurse based ward estimates. Previous studies using hospital Trust level data found little evidence for a relationship between RN staffing and mortality adjusting for medical staffing [16 17] although one US study, which did not include HCSW staffing, found a significant relationship for RN staffing adjusting for medical staffing [27]. A study of ICUs in England found a relationship between consultant numbers, RN numbers and mortality, but no evidence of a relationship with support worker levels[28]. Other studies which have considered less highly qualified nursing staff in hospitals (Licensed Practical Nurses and unlicensed support workers) have shown higher numbers of less trained staff or a diluted nursing skill mix to be associated with higher mortality or lower cost effectiveness. [16 17 29] In our study the negative relationship was not replicated when considering nurse based estimates of HCSW staffing. However a challenge in interpreting study findings, is the extent to which the role of the Health Care Support Worker or 'nursing aide' role varies[30].

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This illustrates that the source of data used to explore these associations is an important consideration. Inferences about ward staffing made from hospital or Trust level data may be incorrect.

There is currently significant debate about establishing mandatory minimum nurse staffing levels in England and elsewhere. However, the evidence base to draw on in order to identify specific safe staffing ratios is slim, despite the large volume of research. Recommended or mandated staffing levels for RNs in general medical and surgical units range from no more than 4 patients per RN (day shift in level 1 hospitals in the State of Victoria, Australia) to 10 patients per RN at night (level 2/3 hospitals in Victoria). Ratios between 4-1 and 6-1 on day shifts are typical.[31] In this study, irrespective of specialty, the risk of mortality was 11% lower in Trusts where registered nurses reported caring for an average of 6 or fewer patients compared to Trusts where nurses reported caring for an average of 10 or more.

Although the pattern of results for medical and surgical mortality were similar, we did not find significant adjusted associations between registered nurse staffing and surgical mortality, using either the Trust-wide or nurse estimated ward staffing. In previous research the relationship between RN staffing and surgical patient outcomes has been clearer than for medical patients[32]. We used all surgical admissions in our study, where overall mortality rates are low, whereas previous research has typically focussed on high-risk sub groups of patients, which may provide a more sensitive indicator.

Although policy in England has raised the possibility of using HCSW to substitute for RNs, the evidence here suggests that this may not be consistent with patient safety. We found that Trusts with more HCSWs per bed had higher rates of mortality among medical patients. Although this finding was not replicated when we looked at nurse estimated ward staffing levels, our adjusted models showed no evidence for benefit from higher HCSW staffing levels. This is consistent with other findings from the RN4CAST study which found no association between the level of HCSW staffing and the occurrence of missed nursing care reported by RNs. [22] While HCSW may deliver essential care, there is no evidence from large observational studies that their presence in the workforce can substitute for registered nurses in ensuring patient safety.

In common with most research in this area our study was cross sectional and cannot demonstrate causation, although the association between nurse staffing and mortality has recently been demonstrated in a prospective study. [33] Our study has several limitations; the nurse based staffing data arises from only 31 Trusts and was estimated from nurse report. This does not, in itself, provide a robust basis to identify safe staffing thresholds. Although we had ward level staffing data, it was only possible to model outcomes at the level of medical / surgical specialties rather than at the level of the ward, and therefore any variation at the ward level remains hidden. Further research is required to provide more robust estimates of associations in larger samples of hospital Trusts. Our results do not provide support for using HCSW to substitute for registered nurses but we were unable to consider whether they may act as complements, enhancing the effectiveness of RNs, because we were unable to explore the interaction between different staff groups due to co-linearity. However, our previous work on nursing care left undone suggests that HCSWs neither substitute for nor complement the ability of RNs to deliver core professional nursing work. [22]

CONCLUSIONS

Based on these findings we conclude that while a causal association between RN staffing and patient outcomes remains plausible, the current evidence base is not sufficient to identify safe staffing thresholds across different types of wards. However, given the overall strength of evidence for an association, it does seem feasible to identify staffing levels where risk to patients is likely to be increased, as recently suggested in a review of safety in the NHS [34]. When determining the safety of nurse staffing on hospital wards, the level of RN staffing is crucial and there is no evidence to suggest that higher levels of HCSW staffing have a role in reducing mortality rates. Current policies geared toward substituting HCSW for registered nurses should be reviewed in the light of this evidence. Future research exploring associations between nurse staffing and patient outcomes needs to include measures of both medically qualified staff and unregistered practitioners.

(3,197 WORDS)

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COMPETING INTERESTS

The authors have no competing interests to declare.

DATA SHARING

No additional data are available.

CONTRIBUTORSHIP STATEMENT

All authors meet the ICJME criteria for authorship.

Jane Ball has made substantial contributions to the conception and design of the work, assisted in the acquisition of data and interpretation of findings, and has contributed to drafting the paper and revising it for important intellectual content.

Peter Griffiths has made substantial contributions to the conception and design of the work, assisted in the acquisition of data, the analysis and interpretation of findings, and has drafted the paper and assisted with revisions for important intellectual content.

Trevor Murrells has made a significant contribution to the analysis and interpretation of data for the work, and has contributed to drafting the paper and critically revising the work for important intellectual content.

Simon Jones has made substantial contributions to the conception and design of the work, assisted in the acquisition of data, the analysis and interpretation of findings, and has revised the work critically for important intellectual content.

Anne Marie Rafferty has made substantial contributions to the conception and design of the work, assisted in the interpretation of findings, and has assisted with drafting and revised the work critically for important intellectual content.

All authors give final approval of the version to be published.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	√
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	√
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	√
Objectives	3	State specific objectives, including any prespecified hypotheses	√
Methods			
Study design	4	Present key elements of study design early in the paper	√
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	√
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	√
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	√
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	√
Bias	9	Describe any efforts to address potential sources of bias	√
Study size	10	Explain how the study size was arrived at	√
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	√
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	√
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	n/a
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	√
		(*e*) Describe any sensitivity analyses	n/a

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Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	√
		(b) Give reasons for non-participation at each stage	√
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	√
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	√
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	√
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	√
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	√
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	√
Generalisability	21	Discuss the generalisability (external validity) of the study results	√
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	√

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Correction

Griffiths P, Ball J, Murrells T, *et al*. Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study. *BMJ Open* 2016;5:e008751.

The correlations in the bottom half of table 2 of this paper are incorrect – the current version relates to the correlation RN per patient and HCSW per patient rather than Patients per RN and Patients per HCSW. There are no resulting changes to the text but the revised figures for 31 Trusts are:

RN-HCSW r=0.24, p=0.063
RN-Doctor r=0.55, p<0.001
HCSW-Doctor r=0.16, p=0.21

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