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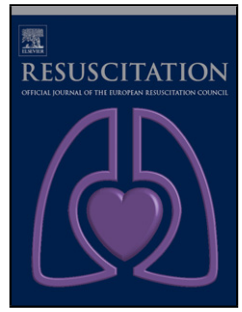

The association between nurse staffing levels and a failure to respond to patients with deranged physiology: A retrospective observational study in the UK

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The association between nurse staffing levels and a failure to respond to patients with deranged physiology: a retrospective observational study in the UK

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ABSTRACT

Background:

Responding to abnormalities in patients' vital signs is a fundamental aspect of nursing. However, failure to respond to patient deterioration is common and often leads to adverse patient outcomes. This study aimed to determine the association between Registered Nurse (RN) and Nursing Assistant (NA) staffing levels and the failure to respond promptly to patients' abnormal physiology.

Methods:

This retrospective, observational study used routinely collected patients' vital signs and administrative data, including nursing staffing, from 32 general wards of an acute hospital in England between April 2012 and March 2015. Mixed-effects binomial regression was used to model the relationship between nurse staffing, measured as 'Hours per Patient Day' (HPPD), and a composite primary outcome representing failure to respond for patients with National Early Warning Score (NEWS) values $\geq$ 6 and $\geq$ 7.

Results:

There were 189,123 NEWS values $\geq$ 6 and 114,504 NEWS values $\geq$ 7, affecting 28,098 patients. For patients with NEWS values $\geq$ 7, failure to respond was significantly associated with levels of RN HPPD ((IRR 0.98, 95% CI 0.96-0.99, p = 0.0001) but not NA HPPD (((IRR 0.99, 95%CI 0.96-1.01, p = 0.238). For patients with NEWS values $\geq$ 6, no such relationship existed.

Conclusions:

RN, but not NA, staffing levels influence the rates of failure to respond for patients with the most abnormal vital signs (NEWS values $\geq$ 7). These findings offer a possible explanation for the increasingly reported association between low RN staffing and an increased risk of patient death during a hospital admission.

Keywords: Nursing; Vital signs; Patient deterioration; Policy; Rapid response systems.

INTRODUCTION

Responding to abnormalities in patients' vital signs using ward-based therapies or by escalating to other members of the healthcare team (e.g., outreach team, ward doctor, nurse practitioner) is a fundamental aspect of nursing and an important contributor to patient safety. Guidance from national bodies in the United Kingdom recommends a graded response strategy, requiring only an increase in the frequency of surveillance in many cases, with escalation of care when severe physiological abnormalities occur.[1,2] However, failure to respond to patient deterioration, even when clear protocols exist, is common and may lead to adverse patient outcomes.[3-5] Several explanations for these failures have been proposed including the impact of staff inexperience, hierarchies in medicine and nursing, communication barriers, poor non-technical skills and staff concerns about negative reactions from colleagues when requesting help.[4-7]

Research suggests that the quality of patient care on hospital wards deteriorates when there is understaffing,[8] yet the causal relationship between low staffing and poor patient outcomes is currently unproven.[9] Nursing work that is delayed or left incomplete (often termed 'missed care'[10] because nurses do not have the capacity to deliver all of the required care) provides a plausible explanation for poorer patient outcomes.[8,11] Specifically, nurses report that an overwhelming workload, constant interruptions, time pressures and competing clinical activities are barriers to the detection of and response to patient deterioration.[12-14]

The relationship between general ward nurse staffing levels and a failure to escalate care when patient's physiology is markedly abnormal has not yet been investigated. Therefore, we undertook a retrospective observational study using routinely collected records of vital signs and other clinical and administrative data, including nursing staff rostering, to investigate whether and how variation in nurse staffing levels are associated with omissions or delays in responding to patient deterioration.

METHODS

This study formed part of a larger retrospective, longitudinal, observational study of 32 medical and surgical wards in a single large (~800 beds) acute National Health Service (NHS) hospital in the South of England (NIHR HS&DR 13/114/17), for the period 1 April 2012 to 31 March 2015. (NIHR HS&DR 13/114/17).[15] The study was approved by the National Research Ethics Service, East Midlands – Northampton Committee Ref: 15/EM/0099. Patient consent was not required.

Information relating to patients (e.g. demographics, admission and discharge data, ward transfers, patient outcomes) were obtained from the Patient Administration System (PAS), allowing the calculation of bed occupancy and the number of admissions per ward. Data relating to vital signs measurements (measured values, National Early Warning Score (NEWS)[2] values, time of observation, and time to next observation) were retrieved from the VitalPAC system[16] in use in the hospital. NEWS (Figure 1) provides a composite measure of patients' physiological abnormalities by allocating 0–3 points to measurements of each of six vital signs – heart rate, respiratory rate, systolic BP, temperature, conscious level evaluated using the AVPU scale and SpO2 based on their derangement from "normal". [2] Two points are added when supplemental oxygen is in use when the vital signs are measured.[2]

Nurse staffing levels were derived from two electronic data sources. For standard contractual shifts, the following data were extracted from the hospital's electronic rostering system: date; location; number of hours and grade of each nurse for every shift. For bank (extra contractual work by staff employed by the hospital) and agency (staff employed through an external agency) shifts, similar data were a second separate source database. Data on shifts undertaken by student nurses were not available, but these staff were considered supernumerary for the purposes for staff allocation.

All readily identifiable information for patients and staff was removed at source. Internal identifiers were anonymised prior to transfer to the research database. Consequently, it was not possible for the research team to identify participants in the study.

For each day of the study, nursing shifts were linked to vital signs observations and admission data using ward location identifiers and time stamps. For each ward, daily patient occupancy and staffing levels were calculated. A theoretical maximum of 35,040 ward days (365 days x 3 years x 32 wards) was available during the study period. Data from ward days where the patient census fell below 25% of the ward median (usually where one or more of the wards was closed or where patient records and staffing could not be matched) were excluded from further analyses. It was not possible to link the staffing roster to the specific staff member measuring and recording the vital signs as no standard identifier was available. Therefore, attempts were made to identify the grade of staff taking the observations using a descriptive field in the VitalPAC system.

The primary outcome of the study was a 'failure to respond' - a composite outcome based on patients remaining on a general ward with high NEWS values ($\geq$ 6) over an extended period without being admitted to ICU or placed on an end-of-life (EoL) care pathway. Patients with a NEWS value $\geq$ 6 are henceforth termed 'high-acuity'. Each time a patient had a set of vital signs measured, the VitalPAC system calculated a single integer, the NEWS[2] value, which was used to determine when the patient should next be observed (higher score ranges generally prompt more frequent vital signs measurement) and whether additional clinical actions are required.

We calculated two 'failure to respond' measures. According to the study hospital's escalation protocol (Table 1), a patient with a NEWS value $\geq$ 7 should be observed at least hourly and be seen by a doctor within at least 30 minutes. Based on this, and as doctors' visits were not recorded within the available electronic records (i.e., VitalPAC), we considered that there had been a 'failure to respond' if a patient with a NEWS value $\geq$ 7 had not met one of the following conditions within an *a priori* period of 4 hours:

- a documented NEWS value < 7 (indicating physiological improvement)
- admission to the intensive care unit (ICU)
- evidence that the patient had been placed on the EoL care pathway (based on an EoL 'flag' having been placed within the VitalPAC system)

Similarly, the hospital's protocol directs that a patient with a NEWS value $\geq$ 6 should be observed at least 4 hourly and be seen by a doctor within 2 hours. Based on this, we considered that there had been a 'failure to respond' if a patient with a NEWS value $\geq$ 6 had not met one of the following conditions within an *a priori* period of 16 hours:

- a documented NEWS value < 6
- admission to the ICU
- evidence that the patient had been placed on the EoL care pathway

For each study day on each ward, the average staffing levels in Hours per Patient Day (HPPD) for both Registered Nurses (RN) and Health Care Assistants (HCA) were calculated. RNs are qualified nurses on the Nursing and Midwifery Council Register with university diploma or degree level qualification or equivalent. NAs are nursing assistant personnel with no formal training requirements or registration, typically employed in roles described as health care assistants in NHS pay bands 2-3. HPPD was calculated by dividing the total number of nursing hours worked by the daily bed occupancy for the ward. Daily bed occupancy was calculated from the PAS database where a value of one indicates a single bed being occupied continuously for one day. A HPPD of 24 indicates one-to-one nursing.

We used mixed-effects binomial regression to examine the relationship between nurse staffing and a 'failure to respond' to high-acuity patients. All models were controlled using random effects for ward, proportion of patients on the ward who were 'unwell' (NEWS of ≥ 3) and admissions per RN.

All summary measures are reported using median and interquartile range, unless otherwise stated. The co-variate 'admissions per HCA' was dropped from our modelling when preliminary testing as part of the larger study[15] confirmed that it was not a significant predictor in missed care models, just as it was not in survival models.

Analyses were undertaken using the R statistical environment v3.5[17] and mixed-effects models were fit using the gamlss package.[18] The extent to which the labour inputs from one group might substitute for the other was considered by modelling the effect of each staff group separately. Our interest in a possible interaction between the two main staffing variables (RN and HCA HHPD) in which NAs might act as labour complements to enhance the effectiveness of RNs was tested by adding a linear interaction term between RN and NA staffing levels to the model. The extent to which these terms improved model fit was investigated by examined examining the Akaike information criterion (AIC) and Bayesian information criterion (BIC).

RESULTS

During the study period, 138,133 patients (emergency, 108,865 (78.8%); elective, 29 268 (21.2%)) were admitted to the hospital and spent one or more days on one of the 32 study wards. Patients had a median age of 66.6 years, median Charlson Comorbidity Index of 3, median length of hospital stay of 2.7 days and a 4.1% mortality rate. A total of 64,596 patients (47%) were male.

From the 138,133 patients admitted, a total of 2,864,975 complete sets of vital signs were available for analysis. Vital sign sets in high-acuity patients accounted for 6% (184,628) of the total. There were 189,123 NEWS values $\geq$ 6 and 114,504 NEWS values $\geq$ 7, affecting a total of 28,098 patients. For NEWS values $\geq$ 6 (response expected within 16 hours), the average response rate was 84%, but for values ≥ 7 (response expected within 4 hours), it was lower (50%). The death rate amongst affected patients was 18% for those with NEWS values ≥ 6 and 23% for those with values ≥ 7.

We identified a total of 538,238 shifts worked over the study period by either RNs or NAs. From the theoretical maximum of 35,040 ward days available during the study period, there were 1,822 (5.2%) ward days where one or more of the study wards was closed and 2,236 (6.4%) wards where patient records and staffing could not be matched properly. Mean staffing levels for RNs were 4.75 HPPD, with high variation both within and between wards (Figure 2). On average, the within-ward SD of staffing levels was 18% of the mean.

Attempts to identify the staff groups measuring the vital sign sets were hampered by the lack of standard coding and a large proportion of observations attributed to 'unknown' staff. Consequently, we judged these data as unreliable and did not consider them further in the analysis.

Table 2 shows the relationship between staffing levels and a 'failure to respond'. For patients with NEWS values ≥ 7, a failure to respond was significantly associated with levels of RN HPPD (IRR 0.98, 95% CI 0.96-0.99, p = 0.0001) but not NA HPPD (IRR 0.99, 95%CI 0.96-1.01, p = 0.238). For patients with NEWS values ≥ 6, there was no such relationship. Additionally, there was no evidence of an interaction when we introduced a linear interaction term between RN and NA staffing levels to the model (NEWS values ≥ 6, IRR 1.00, 95% CI 0.99-1.01, p =0.802; NEWS values ≥ 7, IRR 1.00, 95% CI 1.00-1.01, p=0.563).

DISCUSSION

To our knowledge this is the first study to investigate the relationship between levels of nursing staffing and 'failure to respond' to patients with markedly disordered physiology. The results provide evidence that higher RN staffing was associated with lower levels of 'a failure to respond' for patients with NEWS values $\geq$ 7. However, no such relationship could be demonstrated for NA staffing, nor for either RN or NA staffing for patients with NEWS values $\geq$ 6. In addition, there was no evidence of an interaction between registered nurse and health care assistant staffing levels, providing evidence that NA staffing did not act as a substitute for RNs or as a labour complement by increasing the capacity of RN staff to respond.

Major strengths of the study were that it drew upon a large, three-year dataset of routinely collected vital signs observation sets and nurse staffing records, recorded in standard electronic formats that were easily interrogated. In addition, we used a repeatable, composite objective outcome of a 'failure to respond', the components of which were easily retrievable from the hospital's electronic records.

The main limitations of the study are that it is observational, relies on data from a single acute hospital and excluded certain hospital wards (e.g., paediatric, intensive care, maternity). Additionally, the criteria chosen to reflect a 'failure to respond' were pragmatic and not comprehensive. For instance, ward staff may have initiated other activities (e.g., physiotherapy or drugs administration) that represent a timely and appropriate response, but which were not recorded electronically. Further, the *a priori* timescales within which we expected a response (four times the response time identified in the protocol for NEWS values of $\geq$ 7 and $\geq$ 6) are generous and may not reflect the optimal response timescale for all clinical conditions.[19,20] Additionally, the generous timescales may have contributed to the high response rate of 84% seen in patients with NEWS values $\geq$ 6, and our inability to show an impact of nurse staffing on 'failure to respond' in this patient group.

There were also limitations in the accuracy in our nurse staffing data because the study hospital did not record internal redeployments. Also, we were unable to measure actual staffing levels against staffing requirements on a shift-by-shift basis, although the ward random effects account for differences in average demand by ward since staffing is planned to reflect patient acuity and dependency. Our multi-level models take into account differences in response rates between and within wards. However, they do not readily permit exploration of the nature and causes of differences between wards. Finally, attempts to identify the staff groups measuring vital signs were hampered by the lack of standard coding and a large proportion of observations attributed to 'unknown' staff.

Low RN staffing is associated with reports of missed nursing care in hospitals[8,9,21] and an increased risk of patient death during a hospital admission,[22] yet it is far from proven that low RN staffing leads to an increased risk of death *because* nursing work is delayed or left incomplete. Recently, our group has focused on a single distinct, but extremely common, aspect of nurse clinical activity – the monitoring of patients' vital signs and the response to demonstrable vital sign abnormalities. Earlier research has shown that the adherence to a hospital's vital signs monitoring protocol appears to be sensitive to levels of RN and NA staffing, although the effects are small.[23] The results of the current study demonstrate that, at least for patients with the greatest physiological disturbance, there is also a significant relationship between a failure to respond and levels of RN staffing, although not for that of NAs. Whilst these findings do not prove a causal relationship, failure to respond due to inadequate nurse staffing does offer a possible credible explanation for the increasingly reported association between low RN staffing and an increased risk of patient death during a hospital admission.

The finding in patients with NEWS values $\geq$ 7 of a significant relationship between levels of RN staffing and a failure to respond that was not present for levels of NA staffing is intuitive. In the face of RN staffing shortages NAs are increasingly employed to support RNs to undertake some tasks that would otherwise be undertaken by RNs, including taking vital signs.[24] However, NAs are unlikely to possess the necessary interpretation and decision-making skills to initiate or make the necessary clinical response to patient deterioration without reference to RNs, [25] and this is supported by the fact that NA staffing did not appear to substitute for RN staffing when considering responses to patient deterioration. This underlines the importance of ensuring the presence of an appropriate number of RN on general wards. We were unable to show a relationship between a failure to respond and levels of either RN or NA for patients with NEWS values $\geq$ 6.

Future research should aim to replicate this study, mitigate its limitations and validate its findings. Ideally this should be undertaken as part of a multicentre study, although this is likely to pose difficulties due to different practices of recording vital signs and nurse staffing in different centres. Consideration should also be given to shortening the response timescales studied to better reflect clinical urgency. In addition, additional components should be added to the composite outcome of 'failure to respond', e.g., in-hospital cardiac arrest, treatment limitation, administered drug therapy. More evidence is also required to validate approaches to setting staffing levels, the safe and effective use of NAs within the nursing team, and the economic benefits (e.g., cost per QALY) of increasing staffing on improving ward responses to patient deterioration.

CONCLUSIONS

This is the first study to demonstrate an association between nurse staffing levels and an objective measure of complete and timely care in relation to monitoring patients' vital signs, a key mechanism hypothesised to explain the link between low nurse staffing and adverse clinical outcomes. Registered nurse staffing levels appear to influence the rates of 'failure to respond' for the patients with the most abnormal vital signs, whereas HCA staffing levels do not.

DECLARATION OF CONFLICTS OF INTEREST

The following potential conflicts of interest are declared by the authors and the other members of the Missed Care Study team. Paul Meredit, Nicky Sinden and Paul Schmidt are employees of Portsmouth Hospitals NHS Trust (PHT), which had a royalty agreement with The Learning Clinic (TLC) to pay for the use of PHT intellectual property within the Vitalpac product, which expired during the course of this study. David Prytherch and Gary Smith are former employees of PHT. Paul Schmidt, and the wives of David Prytherch and Gary Smith, held shares in TLC until 2015. Jim Brigg's research has previously received funding from TLC through a Knowledge Transfer Partnership. Peter Griffiths was an unpaid member of the advisory group for NHS Improvement's work developing improvement resources for safe staffing in adult inpatient wards.

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DISCLAIMER

The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

DATA SHARING STATEMENT

The data sharing agreement we have with the host Trust means that we are unable to share data with third parties.

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All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. The following members of the Missed Care Study team contributed to acquiring funding and the preparation of the report of the project on which this paper is based: Jane Ball (Professorial Research Fellow): contributed to the design of the study, acquisition of funding and interpretation of data; commented on drafts and made significant revisions to the report. Karen Bloor (Professor of Health Economics and Policy): contributed to the design of the economic aspects of the study and interpretation of all data; commented on drafts and made significant revisions to the final report. Dankmar Böhning (Professor, Medical Statistics): contributed to the design of the study, statistical analysis plan and interpretation of data; supervised statistical analysis, commented on the drafts leading to significant revisions to the final report. Anya De Iongh (Independent PPI Representative): contributed to the design of the study and interpretation of data; contributed to the design of stakeholder engagement to inform the economic modelling; commented on the drafts and drafted the lay summary. Chiara Dall'Ora (Research Associate, Nursing): contributed to the acquisition of workforce data and ward profiles; contributed to the analysis and interpretation of data; commented on drafts and made significant revisions to the report. Jeremy Jones (Principal Research Fellow): contributed to the design of the economic aspects of the study and interpretation of the economic analysis; commented on the drafts leading to revisions of the final report. Caroline Kovacs (Research Associate, Health Informatics): contributed to the acquisition of data and drafting sections of the report relating to the use of routine data; commented on the drafts leading to revisions of the final report. Paul Meredith (Data Manager, Healthcare Research): contributed to the design of the study and led on the extraction of data from Trust systems; contributed

to the interpretation of data; commented on the drafts leading to revisions of the final report. David Prytherch (Professor, Health Informatics): contributed to the design of the study and analysis/interpretation of data; commented on the drafts leading to revisions of the final report. Paul Schmidt (Consultant in Acute Medicine): contributed to the design of the study, acquisition of funding and interpretation of data; commented on drafts and made significant revisions to the report. Nicky Sinden (Lead Nurse for Workforce): contributed to the design of the study and acquisition of workforce data; commented on the drafts and made significant revisions to the final report.

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LEGENDS to FIGURES

Figure 1: National Early Warning Score (NEWS). Reproduced from: Royal College of Physicians. National Early Warning Score (NEWS): Standardising the assessment of acute illness severity in the NHS. Report of a working party. London: RCP, 2012.

National Early Warning Score (NEWS)*

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

*The NEWS initiative flowed from the Royal College of Physicians' NEWS Development and Implementation Group (NEWSDIG) report, and was jointly developed and funded in collaboration with the Royal College of Physicians, Royal College of Nursing, National Outreach Forum and NHS Training for Innovation

Figure 2: Mean Registered Nurse staffing per ward

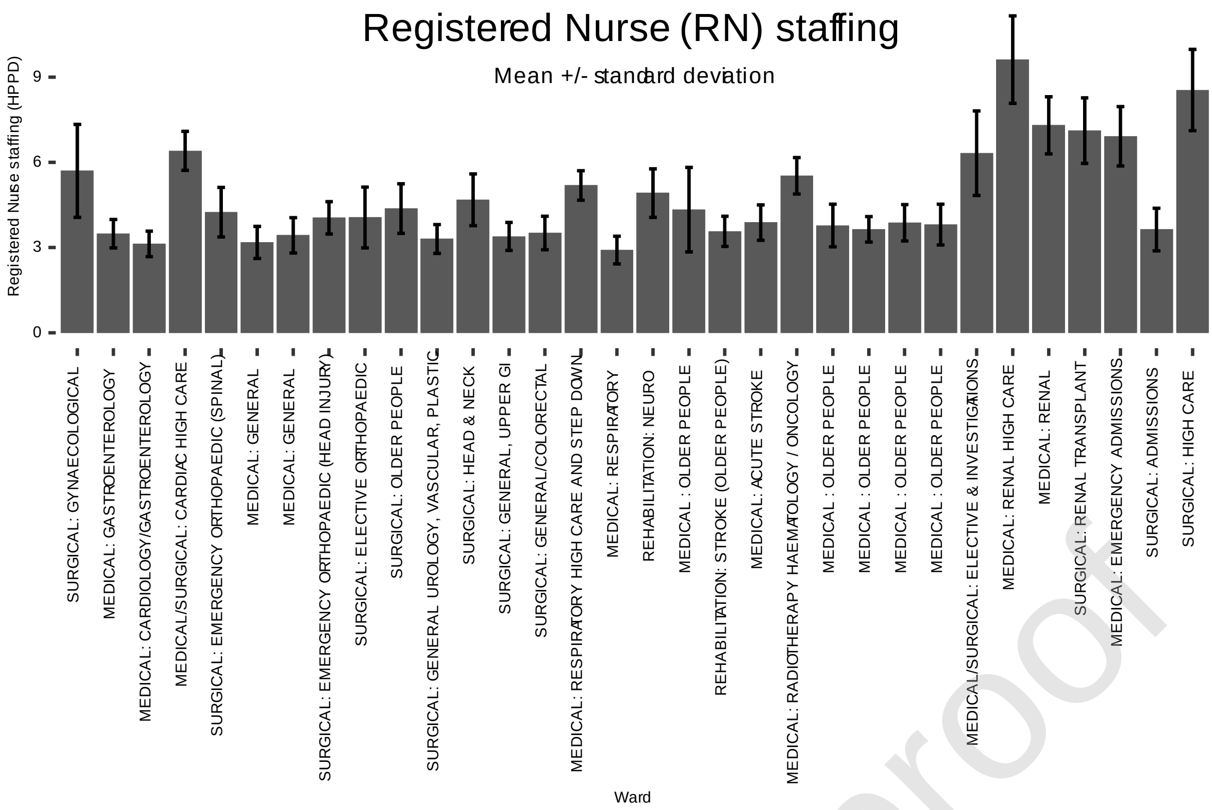
Registered Nurse (RN) staffing
Mean +/- standard deviation
Registered Nurse staffing (HPPD)
0
3
6
9
SURGICAL: GYNAECOLOGICAL
MEDICAL: GASTROENTEROLOGY
MEDICAL: CARDIOLOGY/GASTROENTEROLOGY
MEDICAL/SURGICAL: CARDIAC HIGH CARE
SURGICAL: EMERGENCY ORTHOPAEDIC (SPINAL)
MEDICAL: GENERAL
MEDICAL: GENERAL
SURGICAL: EMERGENCY ORTHOPAEDIC (HEAD INJURY)
SURGICAL: ELECTIVE ORTHOPAEDIC
SURGICAL: OLDER PEOPLE
SURGICAL: GENERAL UROLOGY, VASCULAR, PLASTIC
SURGICAL: HEAD & NECK
SURGICAL: GENERAL, UPPER GI
SURGICAL: GENERAL/COLORECTAL
MEDICAL: RESPIRATORY HIGH CARE AND STEP DOWN
MEDICAL: RESPIRATORY
REHABILITATION: NEURO
MEDICAL : OLDER PEOPLE
REHABILITATION: STROKE (OLDER PEOPLE)
MEDICAL: ACUTE STROKE
MEDICAL: RADIOTHERAPY HAEMATOLOGY / ONCOLOGY
MEDICAL : OLDER PEOPLE
MEDICAL : OLDER PEOPLE
MEDICAL : OLDER PEOPLE
MEDICAL : OLDER PEOPLE
MEDICAL/SURGICAL: ELECTIVE & INVESTIGATIONS
MEDICAL: RENAL HIGH CARE
MEDICAL: RENAL
SURGICAL: RENAL TRANSPLANT
MEDICAL: EMERGENCY ADMISSIONS
SURGICAL: ADMISSIONS
SURGICAL: HIGH CARE
Ward

Table 1: Trust escalation and observation schedule policy (summary).

NEWS value	Risk category	Max interval between observations	Nurse Actions	Doctor Actions
0-1	Low	6 h / 12 h if stable for 6 h	None specified – observations as per schedule	
2	Low	6 h	None specified – observations as per schedule	
3-5	Medium	4 h	Inform nurse in charge	
<6, but with one or more individual triggers	High	4 h	Registered nurse to inform doctor (FY2 / SHO)	See patient within 2 hours
6	High	4 h	Registered nurse to inform doctor (FY2 / SHO)	See patient within 2 hours
7-8	High	1 h	Registered nurse to inform doctor (FY2 / SHO) Consider continuous monitoring	See patient within 30 minutes Call SpR / outreach (after 8.30 SpR / ICU)
9+	Critical	30 min	Registered nurse to inform doctor (SpR) Consider continuous monitoring	See patient within 15 minutes Call SpR / outreach (after 8.30 SpR / ICU)

NEWS = National Early Warning Score
SpR = Specialist Registrar
ICU = Intensive Care Unit
SHO or FY2 = Foundation Year 2 doctor

Extreme values on any one parameter may trigger a higher level of escalation than otherwise indicated

Table 2: Mixed-effects binomial regression: association between staffing and failure to respond for NEWS values of ≥6 or **≥ 7**

Trigger event	NEWS ≥ 6				NEWS ≥ 7			
	p	IRR	95% CI		p	IRR	95% CI	
RN HPPD	0.614	0.99	0.96	1.02	0.001	0.98	0.96	0.99
NA HPPD	0.686	0.99	0.93	1.05	0.238	0.99	0.96	1.01
Admissions per RN	0.190	0.99	0.97	1.01	0.145	1.00	0.99	1.00
Proportion unwell	<0.001	4.29	3.67	5.02	<0.001	1.26	1.20	1.33
RN*NA	0.802	1.00	0.99	1.01	0.563	1.00	1.00	1.01
	AIC: 57946 BIC: 58249				AIC: 62886 BIC: 63185			

NEWS = National Early Warning Score
RN*NA - inclusion of a linear interaction term between RN and NA staffing levels

All models were controlled for ward (random effects), proportion of patients on the ward who were ‘unwell’ (NEWS of ≥ 3) and admissions per RN.