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Effects of the nursing practice environment, nurse staffing, patient surveillance and escalation of care on patient mortality: A multi-source quantitative study

Tamer Al-ghraiybah [a,d,*], Luise Lago [b], Ritin Fernandez [c], Jenny Sim [a,c,e]

[a] School of Nursing, University of Wollongong, Northfields Ave, Wollongong, Australia
[b] Centre for Health Research Illawarra Shoalhaven Population, Innovation Campus, University of Wollongong, Australia
[c] School of Nursing and Midwifery, University of Newcastle, Newcastle, Australia
[d] School of Nursing & Midwifery, Faculty of Health, University of Technology Sydney, Australia
[e] School of Nursing, Midwifery & Paramedicine, Australian Catholic University, North Sydney, Australia

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ABSTRACT

Background: A favourable nursing practice environment and adequate nurse staffing have been linked to reduced patient mortality. However, the contribution of nursing care processes such as patient surveillance and escalation of care, on patient mortality is not well understood.
Objective: The aim of this study was to investigate the effect of the nursing practice environment, nurse staffing, missed care related to patient surveillance and escalation of care on 30-day inpatient mortality.
Design: A multi-source quantitative study including a cross-sectional survey of nurses, and retrospective data extracted from an audit of medical and admission records.
Setting(s): A large tertiary teaching hospital (600 beds) in metropolitan Sydney, Australia.
Methods: Data on the nursing practice environment, nurse staffing and missed care were obtained from the nursing survey. Patient deterioration data and patient outcome data were collected from the medical and admission records respectively. Logistic regression models were used to examine the association between the nursing practice environment, patient deterioration and 30-day inpatient mortality accounting for clustering of episodes within patients using generalised estimating equations.
Results: Surveys were completed by 304 nurses (84.5 % female, mean age 34.4 years, 93.4 % Registered Nurses) from 16 wards. Patient deterioration data was collected for 30,011 patient deterioration events and 63,847 admitted patient episodes of care. Each additional patient per nurse (OR = 1.22, 95 % CI = 1.04–1.43) and the presence of increased missed care for patient surveillance (OR = 1.13, 95 % CI = 1.03–1.23) were associated with higher risk of 30-day inpatient mortality. The use of a clinical emergency response system reduced the risk of mortality (OR = 0.82, 95 % CI = 0.76–0.89). A sub-group analysis excluding aged care units identified a 38 % increase in 30-day inpatient mortality for each additional patient per nurse (OR = 1.38, 95 % CI = 1.15–1.65). The nursing practice environment was also significantly associated with mortality (OR = 0.79, 95 % CI: 0.72–0.88) when aged care wards were excluded.
Conclusions: Patient mortality can be reduced by increasing nurse staffing levels and improving the nursing practice environment. Nurses play a pivotal role in patient safety and improving nursing care processes to minimise missed care related to patient surveillance and ensuring timely clinical review for deteriorating patients reduces inpatient mortality.
Tweetable abstract: Patient mortality can be reduced by improving the nursing practice environment & increasing the number of nurses so that nurses have more time to monitor patients. Investing in nurses results in lower mortality and better outcomes. #PatientSafety #NurseStaffing #WorkEnvironment #Mortality.

What is already known

- Previous studies have established an association between a favourable nursing practice environment and lower hospital mortality.
- Nursing care processes are actions that connect the structure of the nursing environment and patient outcomes, including patient mortality.

* Corresponding author at: University of Wollongong, Building 41, Main Campus, Northfields Ave, Wollongong, NSW 2522, Australia.
E-mail addresses: tag940@uowmail.edu.au (T. Al-ghraiybah), lago@uow.edu.au (L. Lago), ritin.fernandez@newcastle.edu.au (R. Fernandez), Jenny.Sim@acu.edu.au (J. Sim).
Social media: @tgharaiybah (T. Al-ghraiybah) @LagoLuise (L. Lago) @Prof_Ritin (R. Fernandez) @jennysim_1 (J. Sim).

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- A theoretical model can provide a framework to improve understanding of relationships between nursing structural factors, nursing care processes and patient mortality outcomes.

What this paper adds

- This paper expands on existing studies by modelling the effect of nursing structure variables and nursing care processes on mortality.
- Inadequate patient surveillance and early recognition of patient deterioration are nursing care process indicators that are associated with patient mortality.
- Nurse Managers should monitor the patient-to-nurse ratio and monitor missed care related to patient surveillance in their wards to reduce inpatient mortality.

1. Background

Nurses care for patients 24 hours a day in healthcare settings globally and play a pivotal role in the early detection of patient deterioration to reduce morbidity and mortality. Patient surveillance is a crucial aspect of nursing care and involves the ongoing observation, assessment, recognition, and interpretation of patient data (Cho et al., 2015). Patient surveillance is directly influenced by the characteristics of the nursing environment including the nursing practice environment, nurse staffing levels, and nurse qualifications (Kutney-Lee et al., 2009). A favourable nursing practice environment and higher education levels of nurses influence the timeliness of interventions once a problem or potential problem has been identified (Hessels et al., 2015). Appropriate nurse staffing levels are essential for nurses to spend more time with patients and provide high-quality care that results in favourable patient outcomes (Stalpers et al., 2015).

Mortality rates are an important indicator of the quality of nursing care in hospitals (Aiken et al., 2008; Olds et al., 2017; You et al., 2011). Patient characteristics such as age, sex, and comorbidities can cause variations in mortality rates between clinical areas (Evans et al., 2021). However, variation in mortality rates may also be explained by the structure of the nursing environment and nursing care processes. Structural elements of the nursing environment include the number, experience, and qualifications of nursing staff and the nursing practice environment (Ball et al., 2018). Processes used by nurses to provide care include recognition of deterioration and escalation of care to appropriate personnel (Alam et al., 2014). The link between these factors is described in Donabedian's (1980) structure–process–outcome model, which has been used for the last four decades to evaluate the quality of healthcare (Ayanian and Markel, 2016). Most nursing studies that examine patient mortality investigate the link between patient characteristics and nursing structural variables such as the nursing practice environment and nurse staffing with patient mortality, without accounting for nursing care processes (Sim et al., 2019). For instance, large-high-quality studies have found a favourable nursing practice environment is linked to improved patient outcomes, including patient mortality (Aiken et al., 2012, 2008; Cho et al., 2015; McHugh et al., 2016; Olds et al., 2017). However, the strength of the relationship varies between studies, due in part to the way the nursing practice environment is measured, and to the different factors included in models (Al-ghraiybah et al., 2021). Research that links both the nursing structure and processes of nursing care with patient mortality is limited.

Nursing care processes serve as a bridge between the structure of the nursing environment and patient outcomes, including patient mortality. Measuring nursing care processes is challenging because observing nurses' daily care activities is impractical and prone to inaccuracy (Palese et al., 2021). In addition, observation and documentation of nursing care processes may be challenging because many nursing activities are not visible to direct observation and therefore not well documented (Palese et al., 2021). As a result, some studies have examined missed care as a proxy for nursing care processes (Ausserhofer et al., 2014; Ball et al., 2018, 2014; Burston et al., 2014; Lake et al., 2019). Missed care includes nursing activities usually considered core components of nursing work that were required but not completed on the most recent shift (Ball et al., 2014). Missed care has been linked to nurse staffing, nursing staff experience, work patterns and nurses' perceptions of an unfavourable nursing practice environment (Ball et al., 2014).

Evaluation of the relationship between missed care and patient mortality is hindered by measurement issues (Recio-Saucedo et al., 2018). Missed care is measured using essential elements of care routinely provided to patients, such as medication administration, monitoring vital signs, or patient hygiene (Palese et al., 2021), but relies on nurse recall or real-time monitoring. Although there is evidence of a link between missed care and mortality (Recio-Saucedo et al., 2018), the actual mechanisms by which missed care including missed patient surveillance influences patient mortality are not clearly understood. Early identification of patients' physiological deterioration and escalation of treatment is known to reduce the risk of patient mortality (Bhonagiri et al., 2021; Mushta et al., 2018). Missed patient surveillance, however, can lead to delayed recognition of deterioration which subsequently delays the initiation of appropriate treatment, increasing the risk of adverse outcomes, including patient mortality.

Patient deterioration begins several hours before it becomes severe and irreversible (Fasolino and Verdin, 2015; Mushta et al., 2018). Failure to recognise signs of early deterioration is linked to inadequate patient surveillance and monitoring (Ghaferi and Dimick, 2015; Johnston et al., 2014; Shever, 2011). Escalation of care processes to communicate early deterioration signs is essential for improving outcomes including preventing mortality (Mushta et al., 2018). Systems for recognising deterioration include early warning scores and the use of medical emergency teams (Smith et al., 2014). These response systems use staged levels of clinical response and are initiated based on early warning scores or a person's vital signs (Smith et al., 2014). The system for recognising and responding to deterioration in public hospitals in New South Wales (Australia) is called the Clinical Emergency Response System (New South Wales Health, 2020).

The presence of sufficient nurses, with appropriate knowledge, critical thinking and clinical skills is an important facilitator of high-quality nursing care that improves patient outcomes (Cho et al., 2015). An appropriate nursing practice environment supports nurses to do their job appropriately and thus improves care delivery (Aiken et al., 2017; Ball et al., 2018; Blake, 2012; Griffiths et al., 2014; Olds et al., 2017). Therefore, studying structural elements such as the nursing practice environment and nurse staffing will provide important information to support Nurse Managers to take action that may reduce the risk of patient mortality (Ausserhofer et al., 2014; Olds et al., 2017; Sermeus et al., 2011). The aim of this study was to investigate the effect of the nursing structural elements (nursing practice environment, nurse staffing), and nursing processes (missed care and clinical emergency response systems) on patient mortality in an Australian tertiary hospital.

This study is part of a larger doctoral project exploring the effect of the nursing practice environment and nursing care process on four patient outcomes. Data collected for the larger study included nurse demographics, nursing experience, nurse staffing levels, missed care, quality and safety of care, nurse work patterns, the nurse practice environment, nurse burnout and intention to leave. This paper presents findings related to the nursing practice environment, nurse staffing and nurses' perceptions of missed care related to adequate patient surveillance. The remaining sections of the survey have been reported elsewhere.

2. Methods

2.1. Design

This is a multi-source quantitative study including (1) a cross-sectional survey of nurses, and (2) a retrospective audit of hospital

data from an audit of medical records, and (3) admission data for patients admitted between the 1st of July 2018 and the 30th of June 2021.

2.2. Setting and participants

Data were collected from one large 600-bed public hospital in metropolitan Sydney, Australia. The hospital is a tertiary teaching hospital that provides acute and subacute general care services to approximately 50,000 patients every year (Healthdirect, 2022). A total of 16 wards, including medical, surgical and sub-acute wards were included in the study. All nurses working in these wards were eligible to participate in the study. Paediatric wards were excluded due to the age of study participants, other wards were excluded due to fundamentally different processes of nursing care and scope of services (emergency department, operating suite and maternity), or where care was short-term in nature (post anaesthetic care, day surgery).

All patients who were admitted to the 16 wards from 1st of July 2018 to 30th of June 2021 and aged 18 years and over were eligible to participate in the study. Patient episodes of care relating to maternity, neonate, haemodialysis and chemotherapy were excluded using diagnosis-related groups. Other exclusions were newborn care, mental health care, and organ procurement–posthumous care types, age (under 18 years), and patients who only attended excluded wards (see Supplementary file 1 for information about the data sources and flow of participants through the study).

2.3. Variables and measurements

2.3.1. Nursing survey data

2.3.1.1. Sociodemographic data. Demographic data included age, gender, nursing position, employment status, years of nursing experience, years working in the ward and highest nursing qualification.

2.3.1.2. Nursing practice environment. The Australian version of the Practice Environment Scale was used to assess nurses' perceptions of the nursing practice environment (Walker et al., 2010). The PES-AUS has good internal consistency (composite score Cronbach's $\alpha = 0.89$; domain range 0.86 to 0.90) (Stone et al., 2019). The Australian version of the Practice Environment Scale includes 30 items that measure five domains. The items are scored on a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). Overall scores and subscales scores were used to measure the nursing practice environment; a higher score indicates a more positive nursing practice environment (Walker et al., 2010).

2.3.1.3. Nurse staffing. Data on nurse staffing were collected using nurse-reported estimates of the total number of nurses of all designations and the number of Registered Nurses (RNs) who provided direct patient care for patients in their ward on their most recent morning, afternoon, and night shifts. The survey also included nurse-reported estimates of the total number of patients who were present in their ward on these three shifts. The predictive validity of this method of measuring hospital nurses' workloads has been established by previous research (Aiken et al., 2014; Sermeus et al., 2011). The patient-to-nurse ratio was calculated by dividing the total number of patients by the total number of nurses on each ward on each shift.

$$\text{Patient} - \text{to} - \text{nurse ratio} = \text{Total number of patients}/\text{Total number of nurses}.$$

The term “nurse” encompasses both registered and enrolled nurses within the Australian context (McHugh et al., 2020). Patient-to-nurse ratios in the study hospital are mandated by industrial agreements but do not account for skill mix or nurse qualifications. Though individual nurses may oversee varying numbers of patients, the ward's average ratio during a shift must adhere to prescribed industrial agreements (McHugh et al., 2020). The average patient-to-nurse ratio was therefore measured across all shifts. By collating this data across all shifts and wards in the hospital, we derived the patient-to-nurse ratio average at the ward-level and across each individual shift and across all three shifts. Our final models use a three-shift average for the patient-to-nurse ratio and this method has been used in previous studies (Aiken et al., 2014; McHugh et al., 2021, 2020; Sermeus et al., 2011). The same approach was used to calculate the patient-to-Registered Nurse ratio.

2.3.1.4. Missed care related to patient surveillance. Data on missed care was gathered by asking nurses to select from a list of 13 activities that were necessary but left undone because the nurse lacked the time to complete them on their most recent shift. These 13 nursing activities are recognised as core components of nursing work (Ball et al., 2014; Schubert et al., 2008). The included activities are listed in Table 1. For the purpose of this study, we analysed only missed care related to adequate patient surveillance.

2.3.2. Patient deterioration data

Patient deterioration was used as a proxy to measure the processes of nursing care related to patient surveillance. Patient deterioration was measured using medical record audit data from the NSW Health Clinical Emergency Response system (New South Wales Health, 2020). The two tiers within this system are the clinical review process and the rapid response process (Pain et al., 2017). The clinical review process is initiated by clinical staff, usually nurses, and requires evaluation and treatment of a patient within 30 minutes of initiating a clinical review call by the treating or on-call medical team (New South Wales Health, 2020). The rapid response process is initiated when significant physiological deterioration is recognised, and the rapid response team must assess the patient immediately (New South Wales Health, 2020). A dedicated team of medical and nursing specialists from Intensive Care, the Emergency Department and across the hospital is required to respond to a rapid response call. Both the clinical review process and the rapid response process are initiated based on the physiological parameters of the patient, or the use of clinical judgement (New South Wales Health, 2020). Cardiopulmonary resuscitation is initiated when advanced life support is required and is the highest tier of emergency response (New South Wales Health, 2020). In this study, we calculated the rate of calls that escalated from clinical review to rapid response, and the rate of calls that escalated from rapid response to cardiopulmonary resuscitation in each ward over the three-year period.

Table 1
Missed care activities.

Missed care activities
• Adequate patient surveillance
• Adequate documentation of nursing care
• Administering medication on time
• Comfort/talk with patients
• Develop or update nursing care plans/care pathways
• Educating patients and/or family
• Frequent changing in the patient's position
• Oral hygiene
• Pain management
• Planning care
• Preparing patients and families for discharge
• Skincare
• Undertaking treatments/procedures

2.3.3. Patient outcome data

2.3.3.1. Patient characteristics. Patient demographics (age at admission, sex), emergency status (emergency vs planned) and whether the patient was transferred from another hospital (Aiken et al., 2017; Ball et al., 2018; Olds et al., 2017) were collected to inform risk-adjusted models that control for differences in patient characteristics across wards. The Charlson Comorbidity Index (Sundararajan et al., 2004) was derived from diagnoses and used to group episodes into low, medium and high mortality risk (Aiken et al., 2011; Ball et al., 2018; Estabrooks et al., 2011).

2.3.3.2. Patient mortality. Mortality was measured by including any patient who died in the hospital within 30 days of admission. This measurement was chosen because it is more relevant to hospital performance than other mortality definitions, for example including deaths that occurred outside of the hospital after discharge (Borzecki et al., 2010).

2.4. Data collection

2.4.1. Nurses

Nursing surveys were developed using PaperSurvey.iO to enable automated data extraction using Optical Mark Recognition. The nursing surveys were distributed in the 16 participating wards between 18th January 2021 and 15th March 2021. To encourage participation, a recruitment poster was displayed in each ward and the Nurse Managers described the study in nursing meetings. The Participant Information Sheet was on the front page of each survey and the Clinical Nurse Educator in each ward helped to promote the study by distributing surveys to potential participants. Completed surveys were returned to a secured box located in each ward or posted to the research team. The surveys were collected from the locked box every week by a member of the research team and then scanned and uploaded to PaperSurvey.iO. Quality control measures were applied to verify participant responses in three stages: (1) Surveys were manually inspected to ensure they had been correctly scanned; (2) individual responses were verified to correct messy writing, or where data had been entered outside text fields; and (3) each field was manually assessed for accuracy in character recognition. Additional details about this process are reported elsewhere (Al-Ghraiybah et al., 2023).

2.4.2. Patients

Process of care data on recognition of deterioration were collected retrospectively from a secondary data source that contained medical record audit data from patients who had experienced a clinical emergency response system call between the 1st of July 2018 and the 30th of June 2021. De-identified data on patient deterioration were provided by the clinical governance department at South Eastern Sydney Local Health District (SESLHD).

The patient outcome data at the episode level were extracted from hospital discharge databases [Admitted Patient Data Collection (APDC) and Admitted Patient Death Review (APDR) data collections] from 1st of July 2018 to 30th of June 2021. The patient outcome data was provided by the SESLHD via the Australian Health Services Research Institute at the University of Wollongong. Admitted patient datasets were provided at five levels: episode, stay, ward, diagnosis and procedure. The five datasets were merged to produce a single episode of care level dataset, linking episodes with corresponding ward movements, diagnoses and procedures, and stay-level information. An episode of care represents a specific segment of a patient's stay and is characterised by a particular episode of care type (e.g., acute, subacute).

2.5. Data management

Data from the nursing survey, data on patient deterioration and the patient outcome data were cleaned and assessed for invalid or missing values. The nursing survey and patient deterioration data were collected at the individual nurse and patient levels respectively, whilst patient outcome data were collected at the episode of care level. To link these datasets, the nursing survey and patient deterioration data were aggregated at the ward level. Using the ward-level nursing survey and patient deterioration data, variables were then derived for each episode of care based on ward movements. To do this, we applied weights based on the amount of time each patient spent in each ward. For example, if a patient moved between two wards, and spent 10 % of time in one ward and 90 % in another ward, the structure and process measures were weighted 10 % for the first ward and 90 % for the second ward to represent the relative contribution of these measures to the outcome. The analysis dataset, therefore, contained information collected at the individual nurse level (nurse survey), ward level (aggregated nurse survey data; and patient deterioration data) and episode of care level (patient outcomes) and was analysed at the episode of care level. The analysis dataset was encrypted and stored on a restricted access, password-protected server in a building with restricted access. Only the researchers had access to the master database, as per Research Data Management Guidelines.

The nurse survey had low rates of missing data. All variables had less than 2.5 % missing data except for age (8.0 %), nurse experience (4.1 %) and nurse staffing (25.5 %). Missing or erroneous data related to nursing staffing were managed by imputing the mean for each shift at the ward level and the procedures used to do this are reported elsewhere (Al-Ghraiybah et al., 2023).

2.6. Data analysis

Counts and percentages along with means and standard deviation have been presented as appropriate. Descriptive statistics were used to summarise patient mortality, ward characteristics, and the nursing practice environment at ward and hospital levels. Correlation between the nursing structure variables (NPE and nurse staffing) and processes of nursing care (missed care related to patient surveillance, escalation to rapid response and escalation to cardiopulmonary resuscitation) was assessed at the ward level. Correlations between missed care related to patient surveillance and escalation of care variables were also assessed at the ward level. Multicollinearity was assessed at the episode of care level using Pearson's Correlation Coefficient.

Logistic models with generalised estimating equations were fit to assess the association between the study variables relating to structure (nursing practice environment and nursing staffing) and process (patient deterioration) and mortality, accounting for clustering of episodes within patients. Adjustments were made for nurse experience and percentage of Registered Nurses in each ward, and for patient and episode characteristics (age, sex, the Charlson Comorbidity Index, diagnosis-related group type, emergency status and whether patient transferred from another hospital). The ward-level Nursing Practice Environment scores were standardised prior to fitting statistical models (mean = 0, SD = 1) and process measure percentages (missed care, escalation to rapid response, and escalation to cardiopulmonary resuscitation) were multiplied by 10 for interpretation of model coefficients in units of 10 percentage points. A sub-group analysis was also carried out by fitting models with and without the two aged care wards due to the differences in patient characteristics and care processes between patients in aged care and the remaining hospital. A sensitivity analysis was conducted to assess the impact of different measures of nurse staffing on the model parameters. A comparison between the patient-to-nurse ratio and patient-to-RN ratio across all shifts was conducted, as well as models using morning, afternoon or night shift. Model coefficients were calculated for both unadjusted and adjusted mortality models. Odds ratios and 95 % confidence intervals were reported, and an alpha level of <0.05 was used to detect statistical significance. All data analysis was conducted using SAS v9.4 (SAS Institute Inc., 2017) and data visualisation used R version 4.2.3.

2.7. Ethical consideration

Ethical approval was obtained from the Joint University of Wollongong and Illawarra Shoalhaven Local Health District Health and Medical Research Ethics Committee (2020/ETH03012). All participants in the nursing survey were provided with the participant information sheet and participants could freely choose whether to complete the anonymous survey. Data collected from the file audits were not identifiable. Site specific ethical approval was granted for the collection and analysis of hospital discharge databases [Admitted Patient Data Collection (APDC) and Admitted Patient Death Review (APDR)].

3. Results

3.1. Descriptive results

3.1.1. Nursing survey

A total of 304 nurses from 16 wards completed the nurse survey (45.0 % response rate). Participating wards included nine surgical wards, six medical wards (including two aged care wards) and one sub-acute rehabilitation ward. Nurse participants were predominately female (84.5 %), and the majority were Registered Nurses with an average nursing experience of 9.2 years (SD = 3.0) (Table 2). The mean score for the PES-AUS composite scale was 3.0 (SD = 0.4). The average number of patients per nurse on the most recent morning shift was 3.4 (SD = 0.5), compared to 3.8 (SD = 0.7) on the afternoon shift, and 5.7 (SD = 1.0) on the night shift. The average number of patients per nurse across all shifts was 4.3 (SD = 0.6). The average number of missed care tasks on the last shift was 2.8 (SD = 2.0). Adequate patient surveillance was missed by 19.1 % of participants on their most recent shift.

3.1.2. Patient deterioration

A total of 30,011 instances of patient deterioration were audited over the three-year study period. Approximately 75.1 % (n = 22,523) of deterioration events were clinical reviews and 22.1 % (n = 6635) were rapid responses.

Table 2
Summary of nursing survey and process of nursing care variables.

Nursing survey (n = 304)		
Characteristics of nurses	N (%)	Range
Female	250 (84.5)	
Age	34.4 (11.2)	20–73
Registered Nurse (RN)	283 (93.4)	
	M (SD)	Range
Nursing experience (years)	9.2 (3.0)	0.02–50.0
Nursing practice environment	M (SD)	Range
Nurse participation in hospital affairs	2.9 (0.5)	1.2–4
Nurse foundations for quality	3.1 (0.4)	1.1–4
Nurse Manager ability, leadership & support nurses	3.2 (0.4)	1.2–4
Staffing resources adequacy	2.8 (0.5)	1.0–4
Collegial nurse–physician relations	3.1 (0.5)	1.3–4
Composite scale	3.0 (0.4)	1.2–4
Nurse staffing	M (SD)	Range
Patients per nurse on morning shift	3.4 (0.5)	2.4–6.0
Patients per nurse on afternoon shift	3.8 (0.7)	2.2–5.5
Patients per nurse on night shift	5.7 (1.0)	2.9–9.3
Patients per nurse across all shifts	4.3 (0.6)	2.7–6.2
Patients per RN on morning shift	4.0 (0.8)	2.7–9.0
Patients per RN on afternoon shift	4.2 (0.7)	2.5–7.0
Patients per RN on night shift	6.6 (1.6)	2.9–11.0
Patients per RN across all shifts	4.9 (0.8)	3.1–7.9
Care left undone	M (SD)	Range
	N (%)	
Missed care activities (13 types) (average per nurse)	2.8 (2.0)	1–12
Missed care related to patient surveillance (percentage)	57 (19.1)	
Patient deterioration calling system (n = 30,011)	N (%)	
Clinical review calls (number)	22,523 (75.1)	
Rapid response calls (number)	6635 (22.1)	
Cardiopulmonary resuscitation events (number)	853 (2.8)	

Table 3
Characteristics of episodes of care from 2018/19 to 2020/21.

	All episodes of care (n = 63,847)	Episodes of care with death (n = 1617)
	n (%) or M (SD)	n (%) or M (SD)
Financial years		
2018/19	20,493 (32.1)	526 (32.5)
2019/20	21,433 (33.6)	535 (33.1)
2020/21	21,921 (34.3)	556 (34.4)
Gender		
Male	32,730 (51.3)	900 (55.7)
Female	31,117 (48.7)	717 (44.3)
Age		
18–74	36,523 (57.2)	378 (23.4)
75–84	14,845 (23.3)	499 (30.9)
≥85	12,479 (19.6)	740 (45.8)
All ages	66.9 (19.4)	81.1 (11.9)
Major diagnosis category		
Diseases and disorders of the digestive system	8915 (14.0)	145 (9.0)
Diseases and disorders of the circulatory system	8777 (13.8)	180 (11.1)
Diseases and disorders of the nervous system	7890 (12.4)	319 (19.7)
Diseases and disorders of the musculoskeletal system	7488 (11.7)	77 (4.8)
Diseases and disorders of the respiratory system	6782 (10.6)	416 (25.7)
Diseases and disorders of the kidney and urinary tract	4303 (6.7)	87 (5.4)
Diseases and disorders of the hepatobiliary system and pancreas	2471 (3.9)	88 (5.4)
Other	17,221 (27.0)	305 (18.9)
Emergency status		
Emergency	52,685 (82.5)	1528 (94.5)
Non-emergency	11,162 (17.5)	89 (5.5)
Diagnosis related groups		
Medical	46,797 (73.3)	1532 (94.7)
Surgical	13,415 (21.0)	44 (2.7)
Other	3635 (5.7)	41 (2.5)
Charlson Comorbidity Index		
Low risk	42,029 (65.8)	540 (33.4)
Medium risk	9173 (14.4)	216 (13.4)
High risk	12,645 (19.8)	861 (53.3)
Transfer from another hospital		
Yes	1624 (2.5)	44 (2.7)
No	62,223 (97.5)	1573 (97.3)
Length of patient stay (days)	8.1 (14.8)	12.8 (18.4)

3.1.3. Patient outcomes

A total of 63,847 patient episodes of care occurred during the study period for 36,788 patients (Table 3). Approximately 51.3 % of episodes (n = 32,730) were for males, and the mean patient age was 66.9 years. Patients admitted as emergency cases accounted for 52,685 (82.5 %) of the sample, and 1624 (2.5 %) patients were transferred from other hospitals. The most common Major Diagnostic Categories (MDC) were for the digestive system with 8915 episodes (14.0 %), circulatory system with 8777 episodes (13.8 %) and the nervous system with 7890 episodes (12.4 %). A total of 1617 (2.5 %) patient episodes of care ended with death in hospital within 30 days of admission. Of the patients who died, 45.8 % were aged 85 years or above (n = 740), and 25.7 % (n = 416) were grouped to the respiratory system MDC.

Statistically significant correlations were found between nursing practice environment and escalation of care to cardiopulmonary resuscitation (r = −0.58). There was no evidence of an association between the nursing practice environment and either escalation to rapid response (r = −0.44) or missed care related to patient surveillance (r = 0.21). There was no evidence of an association between the patient-to-nurse ratio and escalation of care to rapid response (r =

Table 4
Nursing structure, processes of nursing care variable and outcomes at ward level.

	All wards (16 wards)			All wards except aged care (14 wards)			Aged care wards (2 wards)		
	Mean (SD) N (%)	Median	IQR	Mean (SD) N (%)	Median	IQR	Mean (SD) N (%)	Median	IQR
Nursing practice environment	3.02 (0.14)	2.99	0.18	3.01 (0.14)	2.97	0.15	3.15 (0.06)	3.15	0.09
Nurse staffing									
Patient-to-nurse ratio (all shifts)	4.3 (0.4)	4.3	0.4	4.4 (0.5)	4.3	0.4	4.2 (0.3)	4.2	0.4
Patient-to-RN ratio (all shifts)	5.0 (0.7)	4.9	0.6	5.0 (0.7)	4.9	0.7	5.1 (0.2)	5.1	0.3
Rapid response rate[a]	26.7 (11.1)	27.4	16.5	27.9 (11.3)	28.9	16.7	18.3 (3.8)	18.7	6.3
2018/19	16.2 (4.6)	15.6	5.2	16.4 (4.8)	16.2	5.5	14.4 (0.8)	14.4	1.2
2019/20	30.7 (8.3)	32.2	9.3	32.0 (8.1)	32.6	4.1	22.0 (1.1)	22.0	1.5
2020/21	33.2 (10.6)	31.8	10.0	35.3 (9.6)	33.1	11.2	18.7 (3.4)	18.7	4.8
Cardiopulmonary resuscitation rate[b]	12.1 (7.3)	12.5	11.6	12.2 (7.4)	13.3	11.4	11.5 (7.1)	11.6	8.5
2018/19	6.7 (6.8)	4.2	6.5	6.4 (7.1)	4.2	3.8	8.1 (6.2)	8.1	8.8
2019/20	16.6 (6.1)	18.3	9.7	16.6 (6.1)	18.3	8.4	17.1 (9.0)	17.1	12.7
2020/21	12.7 (5.6)	13.8	7.0	13.2 (5.5)	14.3	7.0	9.2 (6.0)	9.2	8.5

[a] Rapid response events per clinical review event (%).
[b] Cardiopulmonary resuscitation event per rapid response event (%).

−0.44), escalation of care to cardiopulmonary resuscitation (r = −0.29), or missed care related to patient surveillance (r = 0.26). Similarly, there was no evidence of an association between patient-to-RN ratio and escalation of care to rapid response (r = −0.44), escalation of care to cardiopulmonary resuscitation (r = −0.41) or missed care related to patient surveillance (r = 0.12). There was also no evidence of an association between missed care related to patient surveillance and either escalation to rapid response (r = −0.16) or escalation of care to cardiopulmonary resuscitation (r = −0.23).

Table 4 presents the descriptive statistics (e.g., mean, median and IQR) at the ward level. Mortality rates were highest in episodes of care which included time in aged care units (6.9 %), compared to episodes of care with patients who did not visit aged care wards (1.8 %). The proportion of clinical review calls that escalated to rapid response reviews was 26.7 % (SD = 11.1). This proportion was lower in aged care wards (18.3 %, SD = 3.8). The proportion of rapid response reviews that escalated to cardiopulmonary resuscitation was 12.1 % (SD = 7.3), with a slightly lower rate in aged care of 11.5 % (SD = 7.1).

3.2. Effect of study variables on 30-day inpatient mortality

Results of generalised estimating equation models to explore the effect of the nursing practice environment, nurse staffing, missed care related to patient surveillance and escalation of the level of care on patient mortality are presented in Table 5. Multicollinearity between variables was assessed, and there was a high correlation between the escalation to rapid response and escalation to cardiopulmonary resuscitation (r = 0.77). Therefore, separate models were fit for the two patient deterioration variables (escalation to rapid response, and escalation to cardiopulmonary resuscitation).

Model 1 shows results for 30-day inpatient mortality with covariates nursing practice environment, patient-to-nurse ratio, missed care related to patient surveillance and escalation from clinical review call to rapid response call. The model is risk adjusted for nursing and ward characteristics (nurse experience and percentage of RNs) and for patient characteristics [age at admission, sex, diagnosis related groups (medical, surgical and others), Charlson Comorbidity Index group, emergency status (emergency vs planned), transfer from other hospitals] for all 16 wards. The patient-to-nurse ratio was statistically significantly associated with patient mortality (OR = 1.22, 95 % CI: 1.04–1.43), with each additional patient per nurse increasing the odds of patient mortality by 22 %. Missed care related to patient surveillance was also statistically significantly associated with 30-day inpatient mortality (OR = 1.13, 95 % CI: 1.03–1.23). Each 10 % increase in missed care related to patient surveillance was associated with a 13 % increase in the odds of 30-day inpatient mortality. There was no evidence of an association between escalation from clinical review to rapid response and 30-day inpatient mortality (OR = 1.00, 95 % CI: 0.95–1.07).

Model 2 included all items from Model 1 but replaced escalation to rapid response rate with the escalation to cardiopulmonary resuscitation rate for all 16 wards. The odds of 30-day inpatient mortality increased by 16 % when the percentage of nurses reporting missed care related to patient surveillance increased by 10 % (OR = 1.16, 95 % CI: 1.07–1.25). An increased rate of escalation to cardiopulmonary

Table 5
Adjusted odds ratios from generalised estimating equation models for 30-day inpatient mortality.

All wards	Model 1 (all wards) (n = 63,847)			Model 2 (all wards) (n = 63,847)		
	Odds ratio	95 % CI	p-Value	Odds ratio	95 % CI	p-Value
Nursing practice environment	1.02	0.95–1.11	0.547	1.00	0.93–1.08	0.915
Patient-to-nurse ratio	1.22	1.04–1.43	0.013	1.14	0.97–1.35	0.115
Missed care — patient surveillance	1.13	1.03–1.23	0.007	1.16	1.07–1.25	<0.001
Escalation to rapid response	1.00	0.95–1.07	0.887	–	–	–
Escalation cardiopulmonary resuscitation	–	–	–	0.82	0.76–0.89	<0.0001
Excluding aged care wards	**Model 3 (all non-aged care wards) (n = 60,542)**			**Model 4 (all non-aged care wards) (n = 60,542)**		
	Odds ratio	95 % CI	p-Value	Odds ratio	95 % CI	p-Value
Nursing practice environment	0.79	0.72–0.88	<0.001	0.78	0.70–0.87	<0.001
Patient-to-nurse ratio	1.38	1.15–1.65	<0.001	1.17	0.97–1.43	0.105
Missed care — patient surveillance	1.58	1.39–1.80	<0.001	1.56	1.37–1.77	<0.001
Escalation to rapid response	1.02	0.95–1.08	0.638	–	–	–
Escalation cardiopulmonary resuscitation	–	–	–	0.74	0.67–0.82	<0.001

All models are adjusted for nursing characteristics (nurse experience and percentage of RNs) and for patient characteristics [age at admission, sex, diagnosis related groups (medical, surgical and others) Charlson Comorbidity Index group, emergency status (emergency vs planned), transfer from other hospitals]. Model coefficients for process measures (missed care, escalation to rapid response, and escalation to cardiopulmonary response) are scaled — odds ratios should be interpreted as the effect of a 10 % change.

resuscitation was statistically significantly associated with 30-day inpatient mortality (OR = 0.82, 95 % CI: 0.76–0.89). Every 10 % increase in rapid response calls being escalated to cardiopulmonary resuscitation events was associated with decreased odds of 30-day inpatient mortality by 18 %.

Models 3 and 4 were developed as a part of a sub-group analysis that repeated Models 1 and 2 but excluded the two aged care units. In Model 3, there was evidence of an association between the nursing practice environment and patient mortality (OR = 0.79, 95 % CI: 0.72–0.88), with a one standard deviation increase on the nursing practice environment scale the odds of 30-day inpatient mortality decreased by 21 %. There was evidence of an association between the patient-to-nurse ratio and patient mortality (OR = 1.38, 95 % CI: 1.15–1.65). Adding one additional patient to the nurse workload was associated with an increase of 38 % in the odds of 30-day inpatient mortality. The odds of 30-day inpatient mortality increased by 58 % when the percentage of nurses reporting missed care related to patient surveillance increased by 10 % (OR = 1.58, 95 % CI: 1.39–1.80).

In Model 4, there was evidence of an association between the nursing practice environment and patient mortality (OR = 0.78, 95 % CI: 0.70–0.87), with a one standard deviation increase on the nursing practice environment scale the odds of 30-day inpatient mortality decreased by 22 %. The odds of 30-day inpatient mortality increased by 56 % when the percentage of nurses reporting missed care related to patient surveillance increased by 10 % (OR = 1.56, 95 % CI: 1.37–1.77). Escalation from rapid response to cardiopulmonary resuscitation was also statistically significantly associated with patient mortality (OR = 0.74, 95 % CI: 0.67–0.82), with an increase of 10 % in the escalation from rapid response to cardiopulmonary resuscitation associated with a decrease in the odds of 30-day inpatient mortality by 26 %.

The results of the sensitivity analysis comparing models using the patient-to-nurse ratio and the patient-to-RN ratio are shown in Supplementary file 2. Analysis was completed for morning, afternoon, night, morning and afternoon combined and all shifts combined. Supplementary file 2 presents model estimates for the patient-to-nurse ratio and patient-to-RN ratio when all three shifts were combined. The results were generally consistent for the analysis of all wards. When aged care wards were excluded, the odds ratios associated with the patient-to-nurse ratio and missed care were higher than when the patient-to-RN ratio was modelled, however the confidence intervals overlapped.

4. Discussion

This is one of the first studies to examine the relationship between the nursing practice environment, nurse staffing, and missed care related to patient surveillance and patient mortality. Our findings show that nurse staffing has a significant effect on patient mortality, consistent with findings from previous studies in other countries (Aiken et al., 2021; Ball et al., 2018; Cho et al., 2015; McHugh et al., 2016). The mechanism of the influence of nurse staffing on patient mortality has been attributed to the omission of essential nursing care, particularly missed care related to patient surveillance (Griffiths et al., 2018). Patient surveillance involves performing frequent patient assessments, attending to subjective and objective cues and recognising complications, and then taking the necessary nursing actions (Silber, 2014). When nurses are assigned a large number of patients, they may not have adequate time to perform patient surveillance. When nurses are unable to complete patient surveillance as part of routine care, they can fail to recognise early patient deterioration which prevents the implementation of appropriate interventions. Previous research has not examined the link between nurse staffing with the processes of nursing care (missed care related to patient surveillance) and patient mortality (Al-ghraiybah et al., 2021). The results from this study support and expand upon earlier research by including a process measure and examining a cohort of medical and surgical patients (Aiken et al., 2021; Ball et al., 2018; Cho et al., 2015; McHugh et al., 2016).

The nursing practice environment was not directly associated with 30-day inpatient mortality in this study when all 16 wards were included in the analysis. Our findings are inconsistent with previous studies (Aiken et al., 2008; Cho et al., 2015; Olds et al., 2017), which may relate to the sample size in our study. The COVID-19 pandemic impacted our ability to conduct this research in multiple hospitals, which contrasts with the previous research including between 14 and 600 hospitals (Aiken et al., 2008; Cho et al., 2015; Olds et al., 2017). In addition, most research that has examined the relationship between the nursing practice environment and patient mortality has used surgical patients. Although there was no evidence to support the association between the nursing practice environment and patient mortality across a mixture of medical and surgical wards in this study, a significant association was identified when aged care wards were excluded from the analysis.

Various factors have been associated with high mortality in aged care wards including 'do not resuscitate' orders, age, and presence of comorbidities (Jiang et al., 2022). Do not resuscitate orders mean that when deterioration occurs, care is not escalated to the clinical review team or the rapid response teams. Thus, the aged care unit may be expected to have a lower rate of clinical review assessments and rapid response activations (Payne and Thornlow, 2008). The descriptive data from our study supports this assumption. The total number of rapid response events that escalated from clinical reviews, in wards excluding aged care was 28.8 % (SD = 11.9) (see Table 4). In contrast, aged care wards had a notably lower average of 19.2 % (SD = 4.78). This data suggests that aged care wards have a 33 % lower rate of rapid response escalations than non-aged care wards. Several studies have suggested including do not resuscitate status in mortality risk adjustment variables (Bradford et al., 2014; Patel et al., 2018), however, do not resuscitate data was not available in our dataset.

An association between missed care related to patient surveillance and patient mortality was identified in this study. Previous studies on the relationship between missed nursing care and mortality have reported inconsistent findings (Ambrosi et al., 2017; Lucero et al., 2010; Schubert et al., 2013). This study was more specific by examining adequate patient surveillance as an individual item of missed care. Studies exploring missed care have found that nursing activities related to patient surveillance are among the top five activities most frequently left undone (Jones et al., 2015). Inadequate patient surveillance results in delayed identification of physiological measures, failure to detect early deterioration, and failure to escalate care to the appropriate team (Fasolino and Verdin, 2015). The findings from our study indicate that escalation of care using formal clinical review mechanisms for deteriorating patients reduces mortality (Bhonagiri et al., 2021; Green et al., 2018). In our study, we assumed that with an increase in the number of escalations, better processes of nursing care are provided in the ward as nurses apply adequate patient surveillance and detect deterioration early and follow the hospital policy for escalation. However, these results should be interpreted with caution as the data relies on an administrative dataset and the threshold for reaching the point of deterioration could indicate inadequate nursing care prior to the escalation. To obtain a full picture of the nursing care process and its relationship with nursing structure and patient outcomes, future studies could employ observational design methods to provide more accurate measurement of nursing care processes related to clinical deterioration.

Avoidable errors in hospitals are considered a major cause of inpatient mortality (Makary and Daniel, 2016). Errors may result from inadequate nurse staffing and resources, failure to execute nursing care, or system failures (Holden et al., 2013). Avoidable errors can be prevented by ensuring adequate nursing resources are available and implementing patient safety strategies to reduce the probability of errors being made (Alanazi et al., 2022). The findings from our study suggest that inadequate patient surveillance or follow-up is part of errors of omission which may result from system failure. These findings resonate with analysis by Johnston et al. (2014) of failure to escalate care. Johnston et al. (2014) proposed that organisational factors, team factors and

environmental factors present in an organisation may be contributing factors, and unclear escalation policy, high workload, and fear of criticism might lead to failure to escalate the care and patient deaths. These findings have implications for the healthcare system: reducing deaths resulting from errors of omission require hospitals to ensure nurses have adequate time for patient surveillance. This can be achieved by implementing evidence-based guidelines on minimum nurse staffing, having fewer patients per nurse, and improving the nursing practice environment. Future research using observational methods to collect data about vital signs to measure the processes of nursing care is required.

The study has several strengths including the use of validated instruments, the observance of rigorous procedures for cleaning and validating the patient outcome data, the collection of empirical data on the processes of nursing care, using a robust risk-adjustment model, and the exploration of a unique measure for the processes of nursing care. In addition, the study included medical, surgical and sub-acute wards which broadens the approach used in previous studies.

4.1. Limitations

The following limitations should be considered when interpreting this study. First, the design used in this study limits causal inference. Second, as patients in the study may have attended multiple wards, information on structure, staffing and processes from each visited ward was aggregated to the episode level to model mortality risk. Although we accounted for patient risk factors and clustering of episodes within patients, the analysis of crossed-classified random effects according to the combinations of wards within patient episodes within patients was beyond the scope of this paper. Therefore, variation in structure, process and outcomes was not accounted for at the ward level within episodes. Another important limitation of our study is the presence of missing data in the staffing variables. This may be attributed to nurses' difficulty in accurately recalling staffing information during the survey or the design of the survey instrument. Finally, this research was undertaken during the COVID-19 pandemic. The current study originally sought to include multiple hospitals in the study, however, the COVID-19 pandemic meant that access to a broader range of hospitals was not possible. The findings should be interpreted with caution when comparing them with similar research in the literature as only one hospital was included in this study.

5. Conclusions

The findings of the current study suggest that higher numbers of patients per nurse and missed patient care related to patient surveillance can contribute to patient mortality. These results highlight the importance of ensuring that appropriate nurse staffing levels are maintained, and that patient surveillance is not compromised due to staffing shortages or other factors. Nurse Managers must consider implementing strategies to monitor nurse staffing, including the number of patients per nurse, and missed care related to patient surveillance. This can include regular auditing and feedback mechanisms, as well as investing in staffing resources and training programmes for nurses to optimise patient care and ultimately reduce preventable hospital deaths. By taking these steps, healthcare organisations can provide the highest quality of care to patients whilst also maximising the effectiveness of nursing resources and promoting a culture of safety in the hospital setting.

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CRediT authorship contribution statement

Tamer Al-ghraiybah: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Luise Lago:** Data curation, Formal analysis, Methodology, Project administration, Supervision, Writing – review & editing. **Ritin Fernandez:** Investigation, Methodology, Supervision, Validation, Writing – review & editing. **Jenny Sim:** Conceptualization, Project Administration, Methodology, Investigation, Formal analysis, Validation, Supervision, Writing – review & editing.

Data availability

Due to ethical considerations, the research data is not publicly available.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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