Rates of Significant Preventable Adverse Events in Hospitalized Patients With Respiratory Disease

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Objective: Patients admitted to the hospital with an acute illness secondary to respiratory disease are at increased risk of adverse events, many of which may be preventable. This study examined the incidence and nature of preventable adverse events (PAEs) leading to significant morbidity or mortality in a cohort of patients admitted with a primary respiratory presentation at an acute care hospital.

Methods: A review was conducted of patients admitted to a pulmonary ward at our center who were either transferred to the ICU or died on the ward between January 1, 2020 and April 19, 2021. Electronic medical records were reviewed for any indication of an event that led to clinical decompensation or death. Logistic regression was conducted to assess the association between select patient clinical factors and the occurrence of a PAE.

Results: Out of 874 patients admitted to the hospital's pulmonary wards, 27 patients were transferred to the ICU because of worsening medical status, while another 55 patients died on the ward. Eight patients (30%) experienced a PAE consisting of either inadvertent oxygen removal (n = 4) or aspiration (n = 4) just before requiring transfer to the ICU. Thirteen of the deceased individuals (24%) experienced PAEs just before death, including inadvertent oxygen removals (n = 7), aspiration (n = 4), or oximetry malfunction (n = 2). No specific clinical factors that could be used to predict the occurrence of PAEs were identified.

Conclusion: Preventable adverse events were identified in over a quarter of admitted patients with respiratory disease who required an ICU transfer or died in-hospital. Enhanced surveillance of hospitalized patients with acute respiratory disease is warranted.

Key Words: preventable adverse events, respiratory disease, supplemental oxygen, in-hospital, video monitoring

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Patients with severe lung disease admitted to the hospital often require supplemental oxygen to meet their oxygen needs. Without additional oxygen support for even seconds at a time, patients with acute or end stage lung disease can develop severe hypoxemia which can quickly lead to clinical decompensation, organ failure and/or death.[1] Unfortunately, nasal cannula and masks providing oxygen and noninvasive ventilation can easily be disconnected or inadvertently removed by patients during sleep, mobilization or episodes of delirium or confusion.[2] These patients are also at higher risk of other preventable adverse events (PAEs), such as falls due to connected oxygen tubing[3] pressure ulcers,[4–6] as well as aspirations for those who are bed-bound and immobile due to high flow oxygen needs.[7,8]

Preventing an inadvertent oxygen removal is difficult to achieve, given the unpredictable nature of the event. Oxygen saturation monitor alarms are commonly used by hospitals to continuously monitor patients requiring high flow oxygen at rest; however, these alarms can be difficult to hear behind closed doors in rooms of isolated patients, and are reactionary in nature, as monitors begin alarming after an oxygen mask has already been accidentally removed and the patient has already significantly desaturated, leaving little time for clinical intervention.[9] An alternative to alarm systems is the use of in-person sitters to monitor patients and ensure their oxygen devices remain in place. However, sitters are costly, and mixed results have been reported about their effectiveness in improving patient outcomes.[10–12]

Several technology-based surveillance solutions have been developed that incorporate audio and video surveillance, thermal and motion sensors as well as artificial intelligence to enhance monitoring of patients in-hospital at risk of a PAE, however the cost of implementing these interventions need to be considered in relation to the frequency of events that lead to significant harm, of which there is currently very limited reported literature in patients with respiratory disease.

The objective of this study was to determine the incidence and nature of PAEs leading to significant morbidity or mortality in a cohort of patients admitted with a primary respiratory presentation at an acute care hospital.

METHODS

Study Setting and Cohort

To assess the rate of adverse events, a chart review was conducted for patients admitted to a pulmonary ward at the University of Alberta Hospital, an academic quaternary care teaching hospital, between January 1, 2020 and April 19, 2021. Patients admitted to the pulmonary medicine service must have at least one established respiratory diagnosis. The inclusion criteria for this study consisted of adult patients admitted to a pulmonary ward who subsequently died or were transferred to the intensive care unit (ICU) during the study period. This study was

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Outcome Variables and Definitions

Relevant clinical information, including demographic information of all patients who were transferred to the ICU or died in the hospital, were obtained retrospectively through chart review and are outlined in Table 1. Using electronic medical records, clinical notes from physicians; nurses; and allied health staff in the 3 days preceding death or ICU transfer were reviewed for any indication of an event that may have led to clinical decompensation or death. Events were reviewed independently by 2 clinicians to determine whether an adverse event was felt to contribute to either ICU transfer or death, as well as whether the event was potentially preventable, with consensus required to be classified as such.

Respiratory ward protocols at our hospital recommend that patients requiring 6 litres or more of supplemental oxygen at rest be placed on continuous oximetry monitoring in their room, with an audible alarm from the vitals monitor if oxygen saturations fall below 88%. For patients experiencing severe hypoxemia; hypercapnia; or clinical instability, a medical emergency team (MET) comprised of an intensivist; ICU nurse; and critical care respiratory therapist (RT) can be called urgently by ward staff to assess admitted patients who demonstrate clinical deterioration and may benefit from ICU admission. Notes from these encounters were reviewed, however, patients were only classified as requiring ICU transfer if they were moved to the critical care unit for further monitoring or intervention.

TABLE 1. Characteristics and Rates of Events of Patients Admitted to a Pulmonary Ward With Subsequent ICU Transfer or Death

Characteristic	Transfer Cohort (n = 27)	Deceased Cohort (n = 55)
Median age (range); y	61 (31-85)	74 (36-90)
Age group (y); no./total n (%)		
18-44	4/27 (15)	2/55 (4)
45-64	13/27 (48)	12/55 (22)
65-79	9/27 (33)	25/55 (45)
≥ 80	1/27 (4)	16/55 (29)
Male sex; n/total n (%)	16/27 (59)	28/55 (51)
Mean BMI (range); kg/m^2	26 (12-63)	26 (14-59)
Presence of specific comorbidities; n/total n (%)		
COPD	7/27 (26)	22/55 (40)
ILD	11/27 (41)	15/55 (27)
Cardiomyopathy/heart failure	5/27 (19)	10/55 (18)
Malignancy	8/27 (30)	24/55 (44)
Home oxygen use; n/total n (%)	13/27 (48)	29/55 (53)
Median LOS (range); d	26 (2-85)	12 (2-148)
Lung transplant status; n/total n (%)		
Pre-list (assessed)	1/27 (4)	3/55 (5)
Listed	8/27 (30)	6/55 (11)
Posttransplant	3/27 (11)	6/55 (11)
GCD at admission; n/total n (%)		
R-level	27/27 (100)	23/55 (42)
M-level	0/27 (0)	30/55 (55)
C-level	0/27 (0)	2/55 (4)
GCD at transfer to ICU; n/total n (%)		
R-level	27/27 (100)	NA
M-level	0/27 (0)	NA
C-level	0/27 (0)	NA
GCD at discharge and/or death; n/total n (%)		
R-level	11/27 (41)	2/55 (4)
M-level	2/27 (7)	12/55 (22)
C-level	14/27 (52)	41/55 (75)

BMI indicates body mass index; C, Comfort; COPD, chronic obstructive pulmonary disease; GCD, goals of care designation; ICU, intensive care unit; ILD, interstitial lung disease; LOS, length of stay; M, medical; R, resuscitation.

Statistical Analysis

Continuous variables were summarized as means with SDs or medians with ranges. Categorical variables were summarized as frequencies and percentages. A frequency table was generated for variables of interest. We used univariable logistic regression to assess the association between select patient clinical factors and the occurrence of a potentially preventable adverse event. Statistical significance was defined as a P-value of <0.05. All analyses were performed using STATA version 18 software (StataCorp).

RESULTS

A total of 874 patients were admitted to a pulmonary ward between January 1, 2020 and April 19, 2021. Of these patients, 27 (3.1%) required transfer to the ICU and 55 (6.3%) patients died on the ward (Fig. 1), referred to as the ICU transfer and deceased cohorts, respectively.

Intensive Care Unit Transfer Cohort

The median age of the transfer cohort was 61 years (range: 31 to 85), and patients were predominantly male (n = 16, 59%). Patients in the transfer cohort had a median of 5 comorbidities (range: 2 to 8), with the most common respiratory diagnosis being interstitial lung disease (ILD; n = 11, 41%). Thirteen patients (48%) required home oxygen before admission. Additional demographic information about the cohort is provided in Table 1.

The median length of stay in hospital was 26 days (range: 2 to 85) for patients transferred to the ICU. All (n = 27) patients in the transfer cohort required at least one MET activation, with 3 patients having 2 MET calls during their admission. Seventeen (57%) ICU transfers occurred on night shifts between the hours of 7:00 p.m. and 7:00 a.m. The most common reason for transfer to the ICU was hypoxia (n = 20, 67%), followed by hypercapnia (n = 7, 23%) and hypotension (n = 3, 10%). Eight (30%) patients in the transfer cohort experienced significant events that were deemed to be PAEs and temporally related to the ICU transfer. Significant PAEs included inadvertent oxygen removal (n = 4, 15%) and aspiration events (n = 4, 15%). Of the 27 patients transferred to the ICU, 3 patients were transferred to the ICU on 2 separate occasions. Detailed information about the outcomes and proportion of PAEs in this cohort is provided in Table 2. All 8 patients transferred to the ICU due to a PAE required mechanical ventilation, and 3 patients subsequently required extracorporeal life support (ECLS), including one patient who was transferred due to an inadvertent oxygen removal. Overall, 63% (n = 5) of patients experiencing PAEs transferred to the ICU died while in critical care or subsequent to being transferred back to the ward. All 4 patients transferred to the ICU for inadvertent oxygen removal subsequently died while on mechanical ventilation.

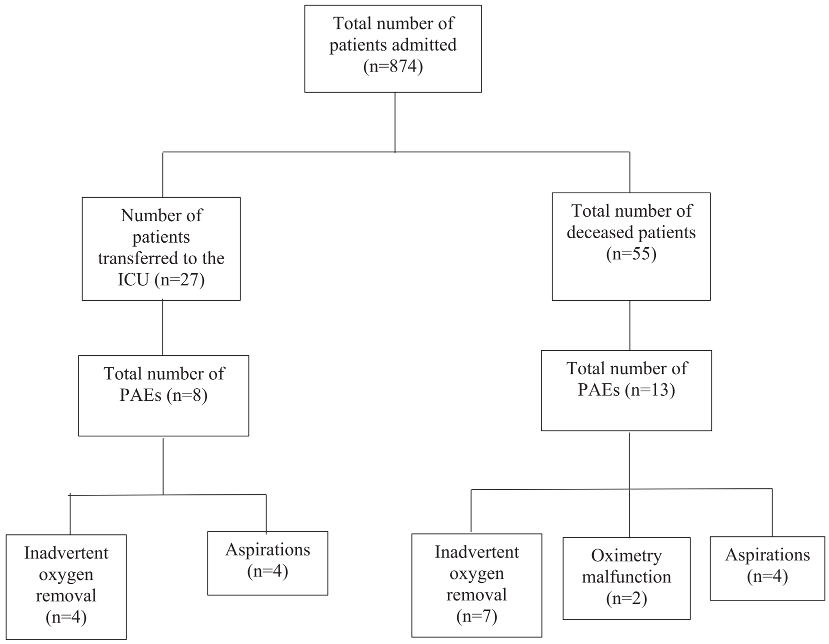

FIGURE 1. Flowchart demonstrating the number of patients and the number of specific preventable adverse events in each cohort.

Deceased Cohort

The median age of patients in the deceased cohort was 74 years (range: 36 to 90) with 51% (n = 28) being males. Patients in the deceased cohort had a median of 5 comorbidities (range: 1 to 11). The most common respiratory diagnosis in this cohort was malignancy with lung involvement (n = 24, 44%), followed by chronic obstructive pulmonary disease (COPD; n = 22, 40%); ILD (n = 15, 27%); and pulmonary edema secondary to cardiomyopathy/heart failure (n = 10, 18%), with 29 patients already using supplemental oxygen at home (53%). Additional demographic information about the deceased cohort is provided in Table 1.

Twenty-seven patients (49%) were pronounced dead during a daytime shift (7:00 a.m. to 7:00 p.m.), while the other 28 patients (51%) were pronounced dead during a night shift (7:00 p.m. to 7:00 a.m.). The median length of stay for this deceased cohort was 12 days (range: 2 to 148). In contrast to the transfer cohort, only 24% of patients (n = 13) in the deceased cohort required MET activation, as 75% of this cohort (n = 41) were classified as having a Comfort (C) goals of care designation (GCD) at the time of death. Thirteen (24%) patients in the deceased cohort experienced significant events that were deemed to be preventable and temporally related to their death. Significant PAEs included inadvertent oxygen removal (n = 7, 13%); aspiration events

TABLE 2. Outcomes and Rates of Events of Patients Admitted to a Pulmonary Ward With Subsequent ICU Transfer or Death

Outcomes	Transfer Cohort	Deceased Cohort
Significant events during admission; n/total n (%)	8/27 (30)	13/55 (24)
Inadvertent oxygen removal identified	4/27 (15)	7/55 (13)
Possible aspiration events identified	4/27 (15)	4/55 (7)
Falls	0/27 (0)	0/55 (0)
Continuous oximetry malfunction	0/27 (0)	2/55 (4)
ICU consult/MET team activation; n/total n (%)	30/30 (100)	13/55 (24)
Daytime shift ICU/MET team activation; n/total n (%)	13/30 (43)	NA
Evening shift ICU/MET team activation; n/total n (%)	17/30 (57)	NA
Median days from ICU admission to intubation/mechanical ventilation; d (range)	0 (0-19)	NA
Palliative care consultation if GCD designation changed to comfort care; n/total no. C-level care (%)	NA	16/41 (39)
Discharge and/or death diagnosis		
Infection	8/27 (30)*	9/55 (16)
Interstitial lung disease	7/27 (26)	10/55 (18)
Malignancy	2/27 (7)	11/55 (20)*
Heart failure	2/27 (7)	5/55 (9)
Chronic obstructive pulmonary disease	1/27 (4)	9/55 (16)
Daytime shift death pronouncement; n/total n (%)	NA	27/55 (49)
Evening shift death pronouncement; n/total n (%)	NA	28/55 (51)

*Denotes most common "most responsible diagnosis" at discharge or death in cohort.
GCD indicates goals of care designation; ICU, intensive care unit; MET, medical emergency team.

TABLE 3. Association of Clinical Characteristics and the Occurrence of PAEs

Risk Factor	Odds Ratio (95% CI)	*P*
Sex	0.852 (0.322-2.253)	0.748
Age	1.005 (0.970-1.041)	0.970
Body mass index	0.983 (0.926-1.043)	0.571
Number of comorbidities	1.013 (0.808-1.269)	0.913
Home oxygen use	2.052 (0.755-5.577)	0.159
Listed for transplant	1.765 (0.520-5.987)	0.362
Post-lung transplant	0.500 (0.037-6.683)	0.600

(n = 4, 7%); and continuous oximetry malfunction (n = 2, 4%). Forty-three (78%) patients in the deceased cohort had their GCD changed to comfort/palliative care during their hospitalization. Five patients in the deceased cohort who experienced a PAE in hospital had goals of care consistent with full resuscitation (R1) at the time of admission.

Understanding the Nature of Potentially Preventable Adverse Events

Several cases in these cohorts illustrate how potentially preventable events contributed to sudden deterioration. In several instances, patients experiencing delirium or agitation repeatedly removed their oxygen devices while unattended, despite being critically dependent on them. One patient was transferred to the ICU after being found with a non-rebreather mask on the floor and saturations of 66%, while another patient, nearing the end of life, was discovered with the mask in their lap, raising difficult questions about safety, dignity, and comfort in their final moments. Even for patients receiving continuous monitoring with oximetry, adverse events occurred. In one situation, the oximeter alarm was inaudible despite the patient being in hypoxic distress with significant desaturations on the monitor and another instance where the oximeter demonstrated normal saturations despite a breathless patient with severe hypoxemia on arterial blood gas PaO2 measurement. In addition to inadvertent oxygen removals, patients in both the transfer and deceased cohorts experienced aspirations, many of which could have been potentially avoided with closer surveillance. A patient admitted with aspiration pneumonia but otherwise improving aspirated while lying supine while eating and progressed to cardiac arrest within 30 minutes, a decline that might have been avoided with basic precautions such as upright positioning.

Delirium was common among patients experiencing a PAE (9 of 21, 43%). Nine of 11 (82%) patients who inadvertently removed their oxygen devices and subsequently required critical care or died were already familiar with oxygen delivery devices, as they were on supplemental oxygen or nocturnal noninvasive ventilation (NIV) at home.

PAEs were unpredictable, and clinical factors such as age; sex; body mass index (BMI); and number of comorbidities (Table 3) were not associated with the occurrence of a PAE. Patients listed for lung transplantation did not have a higher incidence of potentially preventable events compared with those not listed ($P = 0.362$), nor did post-lung transplant patients compared with patients without lung transplant ($P = 0.600$).

DISCUSSION

This study assessed the incidence of PAEs leading to death or the need for critical care in a cohort of patients admitted with a primary respiratory presentation at an acute care hospital. To our knowledge, this is the first study to examine preventable adverse events in patients hospitalized for respiratory disease that includes rates of inadvertent oxygen removal. The results of this study demonstrate that there are opportunities for improved patient monitoring practices, as over a quarter of patients in the ICU transfer and the deceased cohorts combined experienced a preventable adverse event that contributed to clinical deterioration. Patients with respiratory failure are one of several patient cohorts that are at significantly increased risk of adverse events, and respiratory failure has been demonstrated to be the leading cause of unplanned ICU transfers.[13,14]

A preventable adverse event in a hospitalized patient that leads to either death or the need for critical care can have ramifications far beyond the adverse outcome itself. These preventable events are devastating for patients and families and can cause a significant breakdown in trust with health care staff that can lead to formal complaints or litigation.[15–17] PAEs also lead to significant deterioration in the morale of frontline staff and can cause both psychological distress to health care workers and posttraumatic stress disorder with long-lasting effects.[18,19]

PAEs such as falls and ICU transfers are linked to both morbidity and mortality,[20–22] resulting in prolonged hospital stays, increased need for therapeutic interventions, and substantial costs to the health care system.[23,24] With staffing shortages becoming more pervasive, studies demonstrate that the frequency of patient falls while in hospital is increasing.[25] With existing and novel challenges such as health care staff shortages, a higher acuity of illness on inpatient wards, and increased isolation protocols since the COVID-19 pandemic that keep patients behind closed doors,[26–28] there is a need for a cost-effective solution to monitor patients more effectively and identify and intervene upon preventable adverse events before they occur.

A significant number of patients in both the transfer cohort (n = 8, 30%) and deceased cohort (n = 13, 24%) experienced a PAE such as inadvertent oxygen removal; aspiration event; or oximetry malfunction. Despite these alarmingly high rates of events, we do not believe these findings are specific to our institution. A previous study examining the incidence of adverse events in hospitalized patients in Canada conducted by Baker[29] reported that preventable adverse events ranging from mild to severe, occurred in ~37% of patients. A similar scoping review of the types of adverse events occurring in hospitals found that close to 50% of adverse events were preventable.[30] The patients included in these studies are noted to be generally older, frail, and at risk of falls. However, in our study, falls were not a common event, and most PAEs were related to a failure of oxygen delivery or monitoring, which highlights a unique but common risk for those suffering from severe respiratory disease.

The need to integrate technology into hospitals to enhance care became more apparent during the challenges faced during the COVID-19 pandemic, during which there was an increased focus on closer monitoring of the acutely ill on the ward and an emphasis on ensuring the safety of frontline staff by reducing their exposure to patients requiring isolation while maintaining a high level of care for these patients.[31] The pandemic has led to a change in culture in hospitals where acutely ill patients once only managed in the ICU now continue to be managed on the ward[32,33] and as the population ages, hospital wards will

TABLE 4. Surveillance Options for Monitoring Hospitalized Patients With Respiratory Failure

Surveillance Intervention	Advantages	Disadvantages
Invasive continuous monitoring[36,37]	Provides accurate real-time measurements Early detection of patients developing complications	Highly invasive and uncomfortable. Requires intensive nursing care Not practical for general wards
Continuous pulse oximetry (fixed/wearables)[38–41]	Real-time SpO2 and heart rate monitoring Early detection of hypoxemia Integrates with hospital systems	False alarms due to motion artifacts Alarm fatigue for staff Requires continuous probe placement
Capnography (end-tidal CO_2 monitoring)[42–44]	Detects respiratory depression earlier than pulse oximetry Lack of oxygen and heart rate data	Requires special nasal cannula or mask (can be uncomfortable) Chronic CO2 retainers can tolerate high values
Early warning score (EWS) systems[45–48]	Uses multiple vital signs to predict deterioration Standardized and hospital-wide application	Relies on frequent and accurate data entry May not detect sudden deterioration
Bed alarms[49,50]	Alerts staff when a patient attempts to leave bed unsafely	Frequent false alarms can cause desensitization May not prevent falls, signals only after movement
Positional alarms (chair alarms, floor sensors)[49,50]	Detects patient movement from a chair or bed. Useful for high-risk patients who frequently attempt to mobilize unsafely	Can trigger too many false alarms Requires patient compliance
In-person sitters[11]	Provides continuous real-time monitoring Can intervene immediately to prevent falls or respiratory distress	High labor cost Requires staffing availability Not scalable for all high-risk patients
Video monitoring (e.g., telemonitoring; virtual sitters)[10,11,12,51–53]	Allows remote real-time visual monitoring One attendant can monitor several patients at once Can utilize AI to predict PAEs	Requires dedicated monitoring staff Privacy concerns for patients High setup costs Not suitable for all patients
Automated clinical decision support systems (CDSS) with AI integration[54,55]	Analyzes trends to predict respiratory failure and fall risks Reduces human error in monitoring. Integrates with EHRs	Requires complex IT system integration Risk of excessive alerts leading to desensitization. High implementation costs Requires custom-trained data models to achieve accuracy and precision
Thermal monitoring (infrared sensors for motion detection)[56,57]	Can detect patient movement patterns without physical contact Less intrusive than video monitoring	Expensive setup Can have difficulty distinguishing between patient repositioning and actual exit attempts

AI indicates artificial intelligence; CO_2, carbon dioxide; EHR, electronic health record; ICU, intensive care unit; IT, information technology; PAE, preventable adverse events; SpO2, oxygen saturation.

encounter more acutely ill patients requiring more attention and monitoring. Thus, this is an opportunity to leverage technology to aid in caring for hospitalized patients. We have initiated the implementation of a continuous video monitoring system to enhance surveillance of respiratory inpatients at high risk of PAEs, given the findings of our review. There are, however, important challenges to consider associated with the implementation and adoption of patient observation programs such as video monitoring into acute care, such as identifying appropriate patients who will benefit from monitoring[34]; developing the appropriate clinical workflow for smooth integration; and building the appropriate network and information technology infrastructure[35] to support continuous video monitoring.

A review of currently available interventions for monitoring hospitalized patients with respiratory failure is listed in Table 4, along with advantages and disadvantages of each. While many solutions exist, many are not ideal for dealing with oxygen removals: some are only reactionary in nature; others have high false positive rates; and many are costly and require up-front expenditure for equipment and infrastructure upgrades. Nevertheless, additional solutions to prevent PAEs in hospitalized respiratory patients are important to consider given the high frequency of events with standard care.

There are limitations to this study as patient charts were reviewed retrospectively. As a result, adverse events may have been missed if they were not clearly recorded in the chart by health care staff. There were no falls documented in either cohort, however, falls are reported at our hospital through a voluntary reporting system and may underestimate the number of falls that occurred in these cohorts. Furthermore, identified preventable events may not have been the sole cause leading to a clinical deterioration, but determining the degree of causality of an adverse event can be difficult to achieve through chart review.

CONCLUSIONS

This study identified that more than a quarter of patients admitted to a pulmonary service who died on the ward or required ICU transfer experienced a preventable adverse event that likely contributed to the negative outcome, highlighting a call to action to identify solutions to minimize the occurrence of PAEs and improve patient safety. Solutions to better monitor hospitalized patients with respiratory disease should be considered to reduce adverse outcomes and improve patient safety in this high-risk patient cohort.

REFERENCES

1. Kim V, Benditt JO, Wise RA, et al. Oxygen therapy in chronic obstructive pulmonary disease. *Proc Am Thorac Soc*. 2008;5: 513–518.
2. Eastwood GM, O'Connell B, Gardner A, et al. Patients' and nurses' perspectives on oxygen therapy: a qualitative study. *J Adv Nurs*. 2009;65:634–641.
3. Semasinghe Bandaralage SP, Denniss AR, Syed M, et al. Long-term oxygen therapy-related adverse outcomes resulting in hospitalisation: 3-year experience of an Australian metropolitan health service. *Intern Med J*. 2019;49:1435–1437.
4. Friebel R, Henschke C, Maynou L. Comparing the dangers of a stay in English and German hospitals for high-need patients. *Health Serv Res*. 2021;56(suppl 3):1405–1417.
5. Demir İ, Yilmaz Ö, Sönmez A. Relationship between care dependency, adverse events, trust in nurses and satisfaction with care: The mediating role of patient-reported missed care. *J Adv Nurs*. 2024;80:4171–4186.
6. Jose-Saras S, Valencia-Martín D, Vicente-Guijarro JL, et al. Adverse events: an expensive and avoidable hospital problem. *Ann Med*. 2022;54:3156–3167.
7. Teramoto S, Yoshida K, Hizawa N. Update on the pathogenesis and management of pneumonia in the elderly-roles of aspiration pneumonia. *Respir Investig*. 2015;53:178–184.
8. Teramoto S. The current definition, epidemiology, animal models and a novel therapeutic strategy for aspiration pneumonia. *Respir Investig*. 2022;60:45–55.
9. Hravnak M, Pellathy T, Chen L, et al. A call to alarms: current state and future directions in the battle against alarm fatigue. *J Electrocardiol*. 2018;51:S44–S48.
10. Greeley AM, Tanner EP, Mak S, et al. Sitters as a patient safety strategy to reduce hospital falls: a systematic review. *Ann Intern Med*. 2020;172:317.
11. Lang CE. Do sitters prevent falls?: a review of the literature. *J Gerontol Nurs*. 2014;40:24–33.
12. Wood VJ, Vindrola-Padros C, Swart N, et al. One to one specialling and sitters in acute care hospitals: a scoping review. *Int J Nurs Stud*. 2018;84:61–77.
13. Delgado MK, Liu V, Pines JM, et al. Risk factors for unplanned transfer to intensive care within 24 hours of admission from the emergency department in an integrated healthcare system. *J Hosp Med*. 2013;8:13–19.
14. Boerma LM, Reijners EPJ, Hessels RAPA, et al. Risk factors for unplanned transfer to the intensive care unit after emergency department admission. *Am J Emerg Med*. 2017;35:1154–1158.
15. Rafter N, Hickey A, Condell S, et al. Adverse events in healthcare: learning from mistakes. *QJM*. 2015;108:273–277.
16. Ottosen MJ, Sedlock EW, Aigbe AO, et al. Long-term impacts faced by patients and families after harmful healthcare events. *J Patient Saf*. 2021;17:e1145–e1151.
17. Ang Q, Zhang C, Hines K, et al. Improved hospital safety performance and reduced medicolegal risk: an ecological study using 2 Canadian databases. *Can Med Assoc Open Access J*. 2018;6:E561–E566.
18. Kable A, Kelly B, Adams J. Effects of adverse events in health care on acute care nurses in an Australian context: a qualitative study. *Nurs Health Sci*. 2018;20:238–246.
19. Holden J, Card AJ. Patient safety professionals as the third victims of adverse events. *J Patient Saf Risk Manag*. 2019;24:166–175.
20. Escarce JJ. Admission source to the medical intensive care unit predicts hospital death independent of APACHE II score. *JAMA*. 1990;264:2389–2394.
21. Goldhill DR, McNarry AF, Hadjianastassiou VG, et al. The longer patients are in hospital before intensive care admission the higher their mortality. *Intensive Care Med*. 2004;30: 1908–1913.
22. Hillman KM, Bristow PJ, Chey T, et al. Duration of life-threatening antecedents prior to intensive care admission. *Intensive Care Med*. 2002;28:1629–1634.
23. Bergen G, Stevens MR, Burns ER. Falls and fall injuries among adults aged ≥65 years — United States, 2014. *MMWR Morb Mortal Wkly Rep*. 2016;65:993–998.
24. Florence CS, Bergen G, Atherly A, et al. Medical costs of fatal and nonfatal falls in older adults. *J Am Geriatr Soc*. 2018;66: 693–698.
25. Houry D, Florence C, Baldwin G, et al. The CDC Injury Center's response to the growing public health problem of falls among older adults. *Am J Lifestyle Med*. 2016;10:74–77.
26. Fazzini B, Nourse S, McGinley A. Critical care outreach during the COVID-19 pandemic: an observational study. *Nurs Crit Care*. 2023;28:427–434.
27. Ness MM, Saylor J, Di Fusco LA, et al. Healthcare providers' challenges during the coronavirus disease (COVID-19) pandemic: a qualitative approach. *Nurs Health Sci*. 2021;23: 389–397.
28. Wu H, Soe MM, Konnor R, et al. Hospital capacities and shortages of healthcare resources among US hospitals during the coronavirus disease 2019 (COVID-19) pandemic, National Healthcare Safety Network (NHSN), March 27–July 14, 2020. *Infect Control Hosp Epidemiol*. 2022;43:1473–1476.
29. Baker GR. The Canadian Adverse Events Study: the incidence of adverse events among hospital patients in Canada. *CMAJ*. 2004;170:1678–1686.
30. Schwendimann R, Blatter C, Dhaini S, et al. The occurrence, types, consequences and preventability of in-hospital adverse events-a scoping review. *BMC Health Serv Res*. 2018;18:1–13.
31. Pilosof NP, Barrett M, Oborn E, et al. Inpatient telemedicine and new models of care during COVID-19: Hospital design strategies to enhance patient and staff safety. *Int J Environ Res Public Health*. 2021;18:8391.
32. Al-Dorzi HM, Aldawood AS, Almatrood A, et al. Managing critical care during COVID-19 pandemic: the experience of an ICU of a tertiary care hospital. *J Infect Public Health*. 2021;14: 1635–1641.
33. Zangrillo A, Beretta L, Silvani P, et al. Fast reshaping of intensive care unit facilities in a large metropolitan hospital in Milan, Italy: facing the COVID-19 pandemic emergency. *Crit Care Resusc*. 2020;22:91–94.
34. Peirce SC, Hardisty AR, Preece AD, et al. Designing and implementing telemonitoring for early detection of deterioration in chronic disease: defining the requirements. *Health Inform J*. 2011;17:173–190.

35. Harsha P, Paul JE, Chong MA, et al. Challenges with continuous puLse oximetry monitoring and wireless clinician notification systems after surgery: reactive analysis of a randomized controlled trial. *JMIR Med Inform*. 2019;7:e14603.
36. Vincent JL, Einav S, Pearse R, et al. Improving detection of patient deterioration in the general hospital ward environment. *Eur J Anaesthesiol EJA*. 2018;35:325–333.
37. Boldt J. Clinical review: Hemodynamic monitoring in the intensive care unit. *Crit Care*. 2002;6:1–8.
38. Areia C, Biggs C, Santos M, et al. The impact of wearable continuous vital sign monitoring on deterioration detection and clinical outcomes in hospitalised patients: a systematic review and meta-analysis.. *Crit Care*. 2021;25:1–17.
39. Weenk M, Bredie SJ, Koeneman M, et al. Continuous monitoring of vital signs in the general ward using wearable devices: randomized controlled trial. *J Med Internet Res*. 2020; 22:e15471.
40. Joshi M, Ashrafian H, Aufegger L, et al. Wearable sensors to improve detection of patient deterioration. *Expert Rev Med Devices*. 2019;16:145–154.
41. Leenen JP, Leerentveld C, van Dijk JD, et al. Current evidence for continuous vital signs monitoring by wearable wireless devices in hospitalized adults: systematic review. *J Med Internet Res*. 2020;22:e18636.
42. Lam T, Nagappa M, Wong J, et al. Continuous pulse oximetry and capnography monitoring for postoperative respiratory depression and adverse events: a systematic review and meta-analysis. *Anesth Analg*. 2017;125:2019–2029.
43. Al-Beltagi M, Saeed NK, Bediwy AS, et al. Pulse oximetry in pediatric care: balancing advantages and limitations. *World J Clin Pediatr*. 2024;13:96950.
44. Pretto JJ, Roebuck T, Beckert L, et al. Clinical use of pulse oximetry: official guidelines from the Thoracic Society of Australia and New Zealand. *Respirology*. 2014;19:38–46.
45. Baig MM, Afifi S, GholamHosseini H, et al. Deterioration to decision: a comprehensive literature review of rapid response applications for deteriorating patients in acute care settings. *Health Technol*. 2020;10:567–573.
46. Gerry S, Bonnici T, Birks J, et al. Early warning scores for detecting deterioration in adult hospital patients: systematic review and critical appraisal of methodology. *Brit Med J*. 2020; 369:m1501.
47. Downey CL, Tahir W, Randell R, et al. Strengths and limitations of early warning scores: a systematic review and narrative synthesis. *Int J Nurs Stud*. 2017;76:106–119.
48. Subbe CP, Duller B, Bellomo R. Effect of an automated notification system for deteriorating ward patients on clinical outcomes. *Crit Care*. 2017;21:1–9.
49. Potter P, Allen K, Costantinou E, et al. Evaluation of sensor technology to detect fall risk and prevent falls in acute care. *Jt Comm J Qual Patient Saf*. 2017;43:414–421.
50. Sahota O, Drummond A, Kendrick D, et al. REFINE (REducing Falls in In-patieNt Elderly) using bed and bedside chair pressure sensors linked to radio-pagers in acute hospital care: a randomised controlled trial. *Age Ageing*. 2014;43: 247–253.
51. Abbe JR, O'Keeffe C. Continuous video monitoring: Implementation strategies for safe patient care and identified best practices. *J Nurs Care Qual*. 2021;36:137–142.
52. Sosa MA, Soares M, Patel S, et al. The impact of adding a 2-way video monitoring system on falls and costs for high-risk inpatients. *J Patient Saf*. 2024;20:186–191.
53. Zimbro KS, Bridges C, Bunn S, et al. Remote patient monitoring improves patient falls and reduces harm. *J Nurs Care Qual*. 2024;39:212–219.
54. Sutton RT, Pincock D, Baumgart DC, et al. An overview of clinical decision support systems: benefits, risks, and strategies for success. *NPJ Digital Med*. 2020;3:17.
55. Khalifa M, Albadawy M, Iqbal U. Advancing clinical decision support: the role of artificial intelligence across six domains. *Comput Methods Programs Biomed Update*. 2024;5: 100142.
56. Sathyanarayana S, Satzoda RK, Sathyanarayana S, et al. Vision-based patient monitoring: a comprehensive review of algorithms and technologies. *J Ambient Intell Humaniz Comput*. 2018;9:225–251.
57. Newaz NT, Hanada E. An approach to fall detection using statistical distributions of thermal signatures obtained by a stand-alone low-resolution ir array sensor device. *Sensors (Basel)*. 2025;25:504.