Windows in the ICU and Postoperative Delirium: A Retrospective Cohort Study

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OBJECTIVES: The ICU built environment—including the presence of windows—has long been thought to play a role in delirium. This study investigated the association between the presence or absence of windows in patient rooms and ICU delirium.

DESIGN: Retrospective single institution cohort study. Delirium was assessed with the Confusion Assessment Method for the ICU.

SETTING AND PATIENTS: ICU patients between January 1, 2020, and September 1, 2023, were categorized into windowed or nonwindowed groups based on their ICU room design. The primary outcome was the presence or absence of delirium at any time during the patient's ICU stay. Secondary outcomes included the presence of delirium during the first 7 days of the ICU stay, hospital length of stay, ICU length of stay, in-hospital mortality, pain scores, and Richmond Agitation-Sedation Scale scores.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: A total of 3527 patient encounters were included in the final analysis, of which 1292 distinct patient encounters were admitted to a room without windows (37%). Delirium was observed in 21% of patients (460/2235) in windowed rooms and 16% of patients (206/1292) in nonwindowed rooms. In adjusted analyses, patients in windowed rooms were associated with an increase in the odds of the presence of delirium (odds ratio, 1.29; 95% CI, 1.07–1.56; $p = 0.008$). Patients in windowed rooms were found to have longer hospital (adjusted hazard ratio [aHR], 0.94; 95% CI, 0.87–1.00) and ICU length of stay (aHR, 0.93; 95% CI, 0.87–1.00) compared with patients in the nonwindowed rooms, although this was not statistically significant in adjusted analyses ($p = 0.06$ and 0.05, respectively). No statistically significant difference was observed in other secondary outcomes.

CONCLUSIONS: The current study provides insightful information regarding associations between a component of the ICU built environment, specifically the presence or absence of windows, and the frequency of delirium.

KEYWORDS: architecture; delirium; evidence-based design; intensive care unit; windows

Delirium is characterized by an acute change in cognition, accompanied by changes in attention with either altered consciousness or disorganized thinking (1, 2), and is common in the post-surgical ICU (SICU) setting, affecting between 50% and 70% of those admitted, depending on individual risk profiles (3, 4). Delirium can be triggered by a multitude of factors including underlying and acute medical conditions, pharmacologic agents, or treatment regimens including surgery (5). ICU delirium is associated with higher morbidity and mortality (6, 7) including a risk of the development of dementia (8–10), prolonged length of hospital stay (11–13), and increased mortality (7, 11–13). Currently, there is no definitive consensus on

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KEY POINTS

Question: In this retrospective cohort study, the association between windows and delirium in a surgical ICU (SICU) was investigated. It was hypothesized that patients admitted to a room with windows would experience a decreased risk of delirium as compared with patients admitted to a room without windows.

Findings: Windowed rooms were associated with an increase in the odds of developing delirium when compared with patient rooms without windows.

Meaning: The presence of windows did not improve the frequency of delirium for patients admitted to the SICU. Future studies are needed to determine the effect of windows, particularly natural light and views, in preventing and reducing the duration of delirium in critically ill patients.

drug interventions that aid in the prevention of delirium (14) or its treatment (15–17).

The built environment, namely the human-made surroundings, has been thought to play a role in inciting delirium, including design factors such as single or multibed rooms (18), window access (19, 20), and light and sound levels (21). Increasingly, the design of healthcare buildings is being recognized as a valid medical intervention given the impact on health outcomes (22). While prior studies have found windows to be beneficial, resulting in a lower delirium frequency (23), similar studies in ICU settings reported less promising results, with no difference found in the frequency (24, 25) of ICU delirium or in the number of in-hospital days with delirium (25, 26) between patients bedded in rooms with and without windows. Therefore, a lack of consensus in the literature remains regarding the benefit of natural light for ICU patients. In this retrospective cohort study, the association between a component of the built environment, namely windows, and delirium in the ICU was investigated. It was hypothesized that patients admitted to an ICU room with windows would experience a decreased risk of delirium, length of stay, in-hospital mortality, pain, and improved sedation scores as compared with patients admitted to a room without windows.

MATERIALS AND METHODS

Study Design

This retrospective cohort study aimed to evaluate the association between patients being admitted to an ICU room with or without windows and the presence of delirium. This study was performed at Massachusetts General Hospital, a single quaternary care institution in Boston, Massachusetts. Patients were included in the analysis if they were older than 18 years old and were admitted to a single SICU room from January 1, 2020, to September 1, 2023. Patients with ICU stays less than 24 hours or who were transferred between ICU rooms were excluded. The Mass General Brigham Institutional Review Board approved this study ("Intensive Care Unit Design & Delirium," approved April 27, 2023) with a waiver of informed consent (Protocol No. 2023P000457). Procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional) and with the Helsinki Declaration of 1975. All elements of this study were conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.

Built Environment

The SICU evaluated in this study is located on the fourth floor of the main hospital building, constructed in 1994. This closed-format unit serves adult surgical patients and occasional select adult medical patients. It consists of 20 single patient rooms located along the building perimeter and around a central staff station. There are several different types of window conditions within the SICU. However, given the retrospective nature of data collection and inability to discern lighting conditions over time, rooms were categorized based off whether they had at least one window or no windows. A total of seven inpatient rooms were identified as windowless (**Fig. 1**). The exposure of interest was thus defined as whether a patient was admitted, and restricted to, a single ICU room classified as windowed or windowless.

Data Collection

Patient, clinical, and hospital encounter characteristics were abstracted from the patient's electronic medical record (EMR) via structured queries using

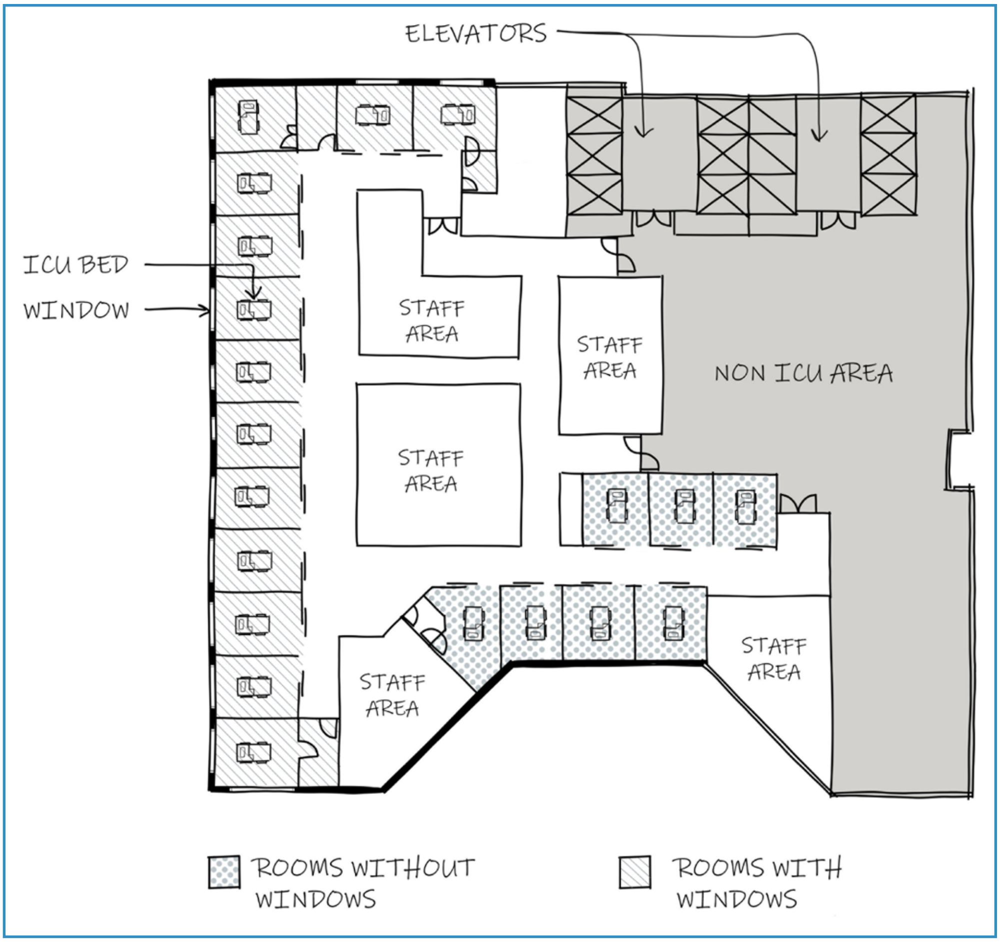

Figure 1. Floor plan sketch of the surgical ICU showing patient room types. Used with permission from S. Blanch.

data from the time of ICU admission. Delirium was assessed with the Confusion Assessment Method for the ICU (CAM-ICU), recorded in the electronic health record flowsheet once per 12 hours shift by nursing staff. To assess patient acuity, Sequential Organ Failure Assessment (SOFA) scores were calculated based on the first 24 hours of the patient's ICU stay. Drug classes commonly associated with delirium were abstracted from the home medication list upon admission to the hospital, as defined in **Supplemental Table 2** (http://links.lww.com/CCM/H658). This included antipsychotics, benzodiazepines, opioids, and diuretics. A prior history of a major neurocognitive disorder, dementia, delirium, and/or Alzheimer's disease was abstracted from the electronic health recording using *International Classification of Diseases*, 10th Edition (ICD-10) codes. A complete list of ICD-10 codes related to underlying conditions that are thought to have an association with delirium is reported in **Supplementary Table 3** (http://links.lww.com/CCM/H658).

Outcomes

The primary outcome, presence of delirium during the patient's ICU stay, was defined as the presence of any positive CAM-ICU score during the patient's ICU stay using clinical documentation in the electronic health record. The CAM-ICU is a common, validated tool in the intensive care setting for assessment of delirium, which is defined by an acute onset and fluctuating course, inattention, and either disorganized thinking or an altered level of consciousness (27). For the primary outcome, patients were considered delirious if they experienced a positive CAM-ICU assessment at any time while admitted to the ICU.

Secondary outcomes included the presence of a positive CAM-ICU score during the first 7 days of the patients ICU stay, hospital and ICU length of stay in hours, in-hospital mortality, pain scores, and sedation scores. Pain scores were evaluated using an 11-point scale (0–10), with higher values reporting increased pain. Sedation was assessed using the Richmond Agitation-Sedation Scale (RASS) scores as a continuously scaled variable ranging from –5 (unarousable) to +4 (combative), with a value of zero anchored to patients who are alert and calm. Both pain and sedation scores were evaluated using repeated measures of clinically documented scores from the electronic health record.

Statistical Analysis

Descriptive data were reported as median (interquartile range [IQR]) or frequency (percentage) depending on the variable type. Imbalances between the windowed and nonwindowed group were estimated and evaluated using absolute standardized differences (ASDs), with values greater than 0.10 suggesting imbalance between groups (28). The primary analysis examined the relationship between the presence of a windowed ICU room and a binary outcome determined by the presence or absence of delirium through unadjusted and adjusted logistic regression models. Results are presented as odds ratio (OR), 95% CI, and its associated *p* value. The preliminary unadjusted model included a fixed effect for group (presence or absence of a window). The model was then adjusted for prespecified prognostic covariates based on their conceptual relationship with the exposure and outcome prior to any review of the data, including year of admission as a categorical variable, age, sex, English language preference, presence of delirium-related pharmaceuticals in the home medication list upon admission, previous delirium-related diagnosis (e.g., underlying diagnosis of dementia), current or previous history of sensory impairment, and SOFA score upon admission to the ICU—all documented risk factors for delirium in the ICU setting (29, 30).

Variables for inclusion were based on previously defined associations with delirium and their availability of documentation in the electronic health record. Notably, given their ubiquitous use throughout a patients stay in the SICU, delirium-inducing medications such as benzodiazepines could not be included in the model. In a subsequent post hoc sensitivity analysis, the primary model was respecified to address detection bias. Given that patients with longer stays may have more opportunities for delirium to develop, the model was adjusted to account for the frequency of delirium assessments during their intensive care stay (**Supplementary Table 1**, http://links.lww.com/CCM/H658). Additionally, the primary model was further revised to adjust for initial mechanical ventilation duration in hours and then hospital admission status in post hoc analyses.

Secondary outcomes included variables with several measurement types. These outcomes were evaluated conditional on the presence of a window and the same prespecified covariates outlined above, with models initially unadjusted and later refined using those variables. Delirium within 7 days of the patient's ICU stay and in-hospital mortality were evaluated using an unadjusted and adjusted logistic regression models, reported as OR, 95% CI, and *p* value. Hospital and ICU length of stay were evaluated using Cox proportional hazard regression models, with results presented as hazard ratio (HR), 95% CI, and *p* value. Repeated pain scores and RASS scores were evaluated using a generalized linear mixed effects model with a gaussian distribution, identity link, and the patient identification included as a random intercept, with results reported as mean difference (MD), 95% CI, and *p* value. Similar to the models for the primary outcome, sensitivity models were constructed for delirium within 7 days, pain and RASS scores, and adjusted for the number of measurements.

No a priori power or sample size calculation was performed and all available data during the study period was analyzed. R 4.4.0 (R Foundation for Statistical Computing, Vienna, Austria) and R Studio 2024.04.0 (Posit team, RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA, 2024; http://www.posit.co/) were used for all analyses. For all analyses, two-sided *p* values of less than 0.05 were considered statistically significant. No adjustment for multiple testing was performed.

RESULTS

Data was abstracted on a total of 4341 patient encounters, of which 665 were excluded because the duration of stay in the ICU was less than 24 hours. After excluding patients admitted or transferred between ICU rooms within the same unit during their ICU stay, a total of 3527 patient encounters were included in the final analysis (**Fig. 2**). Of these, 1292 patients (37%) were admitted to a room that did not have windows.

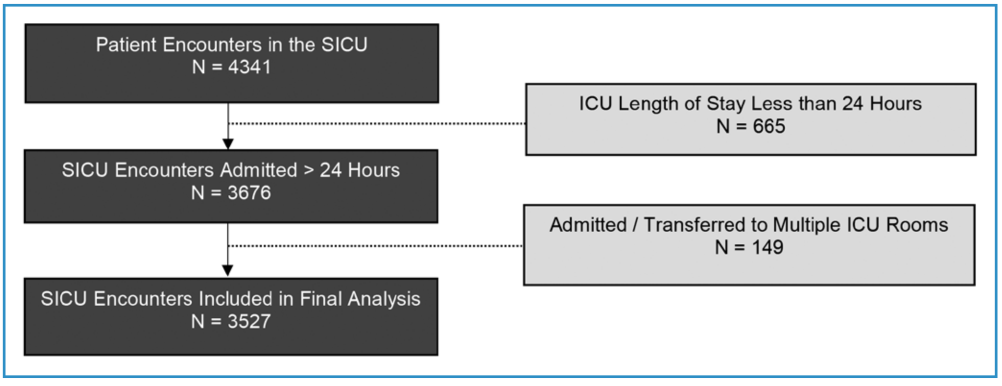

Figure 2. Flow diagram of patient inclusion criteria. Of the patients admitted to the surgical ICU (SICU) a total of 3527 met inclusion criteria and were analyzed.

The overall cohort was primarily male (61%), with a median age of 65 years (IQR, 52–74 yr), and had English as their preferred language (89%). Patients in the rooms with windows experienced slightly higher SOFA scores upon admission to the ICU (median 4 [2–9] vs. 4 [1–8] points; ASD = 0.13), although no other imbalances between window groups were observed for patient characteristics upon admission (**Table 1**).

Association With Delirium

Delirium was observed in 460 patients (21%) of the windowed rooms group and 206 patients (16%) of the nonwindowed rooms group (**Table 2**). In both unadjusted (OR, 1.37; 95% CI, 1.14–1.64; $p = 0.001$) and adjusted analyses (adjusted OR [aOR], 1.29; 95% CI, 1.07–1.56; $p = 0.008$), patients in windowed rooms had an increased odds of developing delirium. These results were consistent with the odds of developing delirium within 7 days (aOR, 1.26; 95% CI, 1.04–1.54; $p = 0.02$). In sensitivity analyses that controlled for the number of delirium assessments, the association for delirium within 7 days and windowed rooms persisted (aOR, 1.25; 95% CI, 1.01–1.54; $p = 0.04$), while the association with delirium at any time did not (aOR, 1.21; 95% CI, 0.99–1.49; $p = 0.07$). When adjusting for mechanical ventilation hours and hospital admission status, the association between windows and delirium at any time remained largely unchanged (Supplementary Table 1, http://links.lww.com/CCM/H658).

Associations With Secondary Outcomes

Patients in rooms with windows were found to have longer hospital (median 235 hr [146–451 hr] vs. 227 hr [141–390 hr]) and ICU lengths of stay (81 hr [48–147 hr] vs. 74 hr [47–136 hr]) compared with patients in the nonwindowed rooms (Table 2). In adjusted analyses, patients in windowed rooms experienced a 6% reduction in the adjusted HR (aHR, 0.94; 95% CI, 0.87–1.00; $p = 0.06$) for hospital length of stay and 7% reduction in the HR for ICU length of stay (aHR, 0.93; 95% CI, 0.87–1.00; $p = 0.05$).

No evidence of differences in pain (adjusted MD [aMD], –0.04 points; 95% CI, –0.18 to 0.10; $p = 0.55$) or sedation scores (aMD, –0.01 points; 95% CI, –0.07 to 0.05 points; $p = 0.79$) was observed between those admitted to rooms with windows compared with those admitted to rooms without windows. Results from sensitivity analyses, which adjusted for the number of measurements, showed similar findings (Supplementary Table 3, http://links.lww.com/CCM/H658). Although in-hospital mortality was increased in windowed rooms (9% vs. 8%), after adjusting for prespecified covariates, evidence of a difference was not observed between groups (OR, 1.07; 95% CI, 0.82–1.39; $p = 0.64$).

DISCUSSION

In this study, the association between presence of a window in the patients' room—a component of the built environment—and the frequency of delirium was assessed. Contrary to the initial hypothesis, results from this study suggest that patients in rooms with windows experienced increased rates of delirium, and potentially longer lengths of stay in the hospital and ICU, without differences in pain or sedation scores, or rates of in-hospital mortality.

Prior studies to date have demonstrated mixed evidence regarding the effect of windows on delirium and other clinical outcomes. In several studies, an ICU stay in a windowless room was found to be an independent risk factor for delirium (18, 31, 32), whereas in another, exposure to natural light via windows was not associated with reduced delirium burden in the ICU (25). A recent 2019 prospective study found no reduced delirium burden when compared with rooms without windows, but natural light exposure was found to be associated with a reduced risk of severe agitation and hallucinations (24). While it can be challenging to extrapolate findings from previous studies given the varied definitions ranging from hallucinations to delirium, and the built environment (e.g., light, views, windows), the current study adds value to existing literature given its large sample size and its methodological rigor.

Although an increased trend in the length of stay was observed in this study for rooms with windows, conflicting results from previous studies extend to this secondary outcome. Prior studies have reported proximity to a window (33) and access to natural light via windows (32) correlating to a shorter length of hospital stay, whereas others have not established a relationship between light level and length of stay (34, 35).

One consideration for the present study may be the quality and content of the window view itself. In the study ICU, the window views included a neighboring

TABLE 1.
Patient Demographic and Clinical Characteristics Stratified by Presence or Absence of a Window

Characteristic	Overall, *n* = 3527	No Window, *n* = 1292	Window, *n* = 2235	Absolute Standardized Difference
Age, yr	65 (52–74)	65 (53–74)	64 (51–74)	0.05
Male	2141 (61)	781 (60)	1360 (61)	0.01
English language preference	3130 (89)	1145 (89)	1985 (89)	0.01
Hospital admission type				0.09
Elective	835 (24)	323 (25)	512 (23)	
Emergency	1783 (51)	657 (51)	1126 (50)	
Urgent	904 (25)	312 (24)	592 (27)	
Missing	5 (0)	0 (0)	5 (0)	
Presence of home medications with drug classes commonly associated with delirium[a]	2246 (64)	839 (65)	1407 (63)	0.04
Prescence of known diagnosis associated with delirium[b]	62 (2)	29 (2)	33 (2)	0.06
Sensory impairment[c]	232 (7)	80 (6)	152 (7)	0.03
Year				0.05
2020	938 (27)	349 (27)	589 (26)	
2021	988 (28)	361 (28)	627 (28)	
2022	957 (27)	335 (26)	622 (28)	
2023	644 (18)	247 (19)	397 (18)	
Sequential Organ Failure Assessment score	4 (2–8)	4 (1–8)	4 (2–9)	0.13
Presence of mechanical ventilation	1425 (40)	480 (37)	945 (42)	0.11
Hours of initial mechanical ventilation[d]	39 (17–90)	36 (16–74)	40 (17–98)	0.10

[a]Drug classes include antipsychotics, benzodiazepines, opioids, and diuretics. More details can be found in Supplementary Table 1 (http://links.lww.com/CCM/H658).

[b]Diagnoses include major neurocognitive disorder, dementia, and Alzheimer's disease. More details can be found in Supplemental Table 2 (http://links.lww.com/CCM/H658).

[c]Sensory impairments include patient flags of deaf, hard of hearing, blind, and low vision.

[d]Hours of initial mechanical ventilation represent the first instance, and not subsequent periods, of mechanical ventilation.

Data are presented as median (interquartile range) or frequency (precent) depending on variable type.

building in close proximity without any natural elements (e.g., trees) and limited sky views. Furthermore, the patient beds were oriented away from the window resulting in no direct view by the patient. A 1984 study found that surgical patients who recovered on a hospital unit with windows looking out on a natural scene had shorter postoperative hospital stays, and took fewer analgesics, compared with those with windows facing a brick wall (36). While much of the existing literature focuses on positive effects of a natural view (37, 38) including patient satisfaction and experience (39), there is insufficient consideration of window views that include human-made elements. Additionally, it has been suggested that the overall quality of a window view is complex and involves multiple factors such as content, access, and clarity, which need to be taken into account within the cultural, demographic, economic, social, and physical context of the building (40). The current study results suggesting that patients in rooms with windows experienced increased rates of delirium may relate in part back to the particular window view without nature or long range visibility.

Modifications in ICU room design may require more than the presence of windows and natural light

TABLE 2.
Associations of Windowed Rooms Versus Nonwindowed Rooms in Primary and Secondary Outcomes

Outcome			Univariable Models		Multivariable Models	
Variable	**No Window, *n* = 1292**	**Window, *n* = 2235**	**Estimate (95% CI)**	***p***	**Estimate (95% CI)**	***p***
Delirium (primary)	206 (16)	460 (21)	1.37 (1.14–1.64)	0.001	1.29 (1.07–1.56)	0.008
Days to delirium	1 (0–4)	1 (0–4)	–	–	–	–
Delirium positive days	2 (1–4)	2 (1–5)	–	–	–	–
Delirium within 7 d of ICU stay	185 (14)	405 (18)	1.32 (1.10–1.60)	0.004	1.26 (1.04–1.54)	0.02
Hospital length of stay, hr	227 (141–390)	235 (146–451)	0.89 (0.84–0.96)	0.001	0.94 (0.87–1.00)	0.06
ICU length of stay, hr	74 (47–136)	81 (48–147)	0.89 (0.83–0.95)	0.001	0.93 (0.87–1.00)	0.05
In-hospital mortality	103 (8)	209 (9)	1.19 (0.93–1.52)	0.17	1.07 (0.82–1.39)	0.64
Pain scores	2 (0–5)	2 (0–4)	−0.07 (−0.22 to 0.08)	0.35	−0.04 (−0.18 to 0.10)	0.55
Richmond Agitation-Sedation Scale scores	0 (−1 to 0)	0 (−1 to 0)	−0.08 (−0.15 to −0.01)	0.03	−0.01 (−0.07 to 0.05)	0.79

Data are presented as median (quartile1–quartile 3) or frequency (percentage). Effect estimates are reported as odds ratios (binary outcome), mean difference (continuous outcomes) or hazard ratios (time to event outcomes) comparing the windowed group to the nonwindowed group (reference). Models were adjusted for the following variables: year, age (centered and scaled), sex, language preference, home drug classes, delirium-related diagnosis, sensory impairment, and Sequential Organ Failure Assessment score.
Delirium positive days represents the count of days in which a positive Confusion Assessment Method for the ICU (CAM-ICU) score was documented. Time to delirium is the number of days from ICU admission to the first positive CAM-ICU.
Dashes indicate data not applicable.

to reduce delirium. In one study, extensive changes in room interior design were undertaken, including modifications for noise reduction, early mobilization, and workflow optimization, and patient-individualized lighting therapy. Delirium severity was lower for those patients treated in the modified rooms (41). As the cause of delirium is thought to be a multifactorial (42), multicomponent interventions are the most promising methods in preventing and reducing the duration of delirium in ICU patients (43). Within the present study, there were no specific interventions implemented with delirium positive patients (e.g., sleep protocol, mobility protocol, etc). Despite the uncertain findings in prior studies, windows are inherently desirable to patients, staff, and caregivers as they humanize the setting. Many jurisdictions require new ICUs to include windows and this has become a minimum standard in many codes and design guidelines (44, 45).

Our study has notable strengths, including a large number of patients over a 4-year period at an academic institution. The study also leverages the use of the EMR to assess components of the built design and an important clinical and patient-centered outcome, namely delirium. The recentness of the current data is favorable to the existing literature, much of which is dated, especially in the setting of increased clinical awareness and monitoring for delirium. Although contrary to our original hypothesis in direction, the sensitivity analyses demonstrate robust results after considering the number of clinical assessments, suggesting the results are strong and not affected by information bias.

The heterogeneity of light measurement methods, diagnostic criteria for delirium, and fluctuating roles of light either as an independent variable or one of many are potential limitations for effective comparison between existing trial results. The present study is not without limitations, or immune to some of these criticisms. This study was a single-center design, which may limit the generalizability of our findings. Presence of a window was used as a bundled approach to reflect individual components such as light or views that may play a role in the development of delirium. Further, the windows studied included both natural light and distinct views, and these factors were not assessed separately, nor were changes in light levels, views or bed/patient position that might have occurred over the duration of the study period. It is unclear if the findings observed would remain robust in more current ICU designs in accordance with updated building codes.

Because of the distribution of rooms with or without windows in the study ICU, the avoidance of other sources of environmental bias may have not been possible, such as noise, and could not be accounted for in the statistical analysis. Sound levels and whether they differed between windowed and nonwindowed rooms were not directly measured. Over the years, sedation practices have varied in the practice of critical care (46), in addition to our understanding, measurement, and charting of delirium. Nevertheless, the CAM-ICU has a pooled sensitivity of 80% and specificity of 96% (47) and is widely used in all types of critical care settings around the world. Delirium can also present as hypoactive, which is less clinically apparent than the restlessness and agitated behavior of hyperactive delirium (48); therefore, it is possible that hypoactive or mixed cases are not recognized and charted. Because the study timeline included the COVID-19 pandemic, during which delirium rates were highly prevalent in critically ill patients (49), this may have had an impact on results in terms of prolonged needs for mechanical ventilation and lengths of stays, despite the inclusion of admission year as a covariate in all models to address any changes over time. In addition, specific ICU level of care data for each patient was not available from the EMR. The current study had no randomization, and while the SOFA score was chosen as a measure of disease acuity, these scores may be confounded by clinical interventions or may not fully represent patient acuity (50). Additionally, given the retrospective nature of data collection, it is possible that associations are hampered by residual confounding that is not fully accounted for our in our study. Specifically, this project relied upon capacity considerations and bed availability to mimic a pseudorandom assignment; however, it is possible that we are not fully accounting for the room assignment process.

CONCLUSIONS

The current study provides useful information regarding the ICU built environment in regards to the existence of window and windowless rooms and the presence of delirium. Factors such as view quality and other room components require additional research to better understand the role of windows in this context. Additionally, prospective studies with the measurement of lighting levels and view analysis are needed to better understand the role that windows and room design might play in ICU delirium.

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