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Original Article

The impact of windows on the outcomes of medical intensive care unit patients

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SUMMARY

Backgrounds: The knowledge about the window effect on the outcomes of intensive care unit (ICU) patients remains limited and uncertain. This retrospective study investigated the impact of windows on the outcomes of patients admitted to the medical ICU.

Methods: It was conducted in a medical ICU with 14 adult ICU beds including 7 window and 7 no-window rooms. The outcomes including length of ICU stay, in-ICU mortality and in-hospital mortality were measured.

Results: During the study period, a total of 281 patients were admitted to the ICU, with 126 patients in window rooms and 155 in no-window rooms. These two groups of patients had similar clinical characteristics such as age, gender, disease severity, consciousness level, underlying diseases, and incidence of organ failure (all $p > 0.05$). Additionally, the incidence of delirium (37.3% vs 38.7%, $p = 0.907$), use of sedatives (50.0% vs 51.0%, $p = 0.963$), and use of antipsychotic agents (18.3% vs 18.7%, $p = 0.945$) were the same between these the window and no-window groups. The in-ICU and in-hospital mortality rates were not significantly different between groups (23.8% vs 20.0%, $p = 0.533$ for in-ICU mortality; 27.0% vs 24.5%, $p = 0.734$ for in-hospital mortality), but patients admitted to window rooms had shorter ICU stays than those admitted to no-window rooms (4.8 days vs 5.8 days, $p = 0.045$).

Conclusions: We demonstrated that ICU rooms with windows are associated with shorter ICU stays than those without windows, suggesting that windows may be important in medical ICU rooms.

1. Introduction

In the era of modern medicine, an intensive care unit (ICU) which can provide patient monitoring, respiratory and cardiac support, pain management, emergency resuscitation devices, and other life support equipment is an important part of the hospital. However, the ICU is also associated with a great deal of tension and stress for patients. Sleep disruption is not uncommon. In one survey, 59% of 116 ICU patients reported poor or very poor sleep quality[1]. Another survey of 60 critically ill patients' using polysomnography showed that sleep was fragmented and the quality of sleep was markedly abnormal with significant reductions in stages 3 and 4 and REM, the deeper restorative stages of sleep for these ICU patients[2]. Moreover, sleep disruption has also been associated with increased mortality in both young and old mice after septic insult[3]. In the ICU, the etiologies of sleep disruption are multifactorial, including lack of natural light, frequent interruptions at night, noise, pain, loud talking, and intravenous catheters[1,4]. Setting up an environment to help patients get good quality sleep is an important issue, and windows with natural light may be one solution. Natural light through a window can help maintain or restore the natural circadian rhythms by assisting daytime awakening and facilitating nighttime sleep. For surgical patients, previous studies have shown that exposure to natural light may be associated with

Abbreviations: ICU, intensive care unit; APACHE, Acute Physiology and Chronic Health Evaluation; GCS, Glasgow coma scale.

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shorter hospital stays, early ambulation, and decreased stress, pain, analgesic medication use, pain medication costs, and postoperative delirium[5,6]. Among patients admitted to the cardiac care unit for myocardial infarction, those in sunny rooms had shorter stays and lower mortality rates than those in dull rooms[7]. Wilson compared the incidence of postoperative delirium between 50 surgical patients treated for at least 72 h in windowed and 50 in windowless ICUs[8]. He found that patients in the windowless ICU had a higher incidence of delirium than those in the windowed ICU, especially those with abnormal hemoglobin or blood urea nitrogen levels[8]. In contrast, one recent study of 789 patients with subarachnoid hemorrhage admitted to the ICU found no significant differences in outcomes between patients in window and no-window rooms[9]. The Society of Critical Care Medicine (SCCM), recommends that a new ICU have a window in every room and light that can be dialed up and down to minimize circadian rhythm disruption[10]. Overall, knowledge about the window effect on the outcomes of medical ICU patients remains limited and uncertain, and the impact of natural light may vary according to different groups. Therefore, we conducted this study to investigate the effect of windows on the outcomes of the patients admitted to the medical ICU (MICU).

2. Materials and methods

2.1. Setting and patients

This retrospective study was conducted at a regional teaching in an MICU with 14 adult ICU beds including seven window and seven no-window rooms. The care in the ICU was covered by intensivists, nurse practitioners, nurses, respiratory therapists, dietitians, physical therapists, and clinical pharmacists. The ICU team made rounds at least once daily and the patient-to-nursing staff ratio was 2:1. The ICU discharge criteria included (1) stable hemodynamic parameters, (2) stable respiratory status, airway patency, and oxygen requirements not more than FiO_2 of 50%, (3) intravenous inotropic/vasopressor support and vasodilators are on low dose or no longer used, (4) cardiac arrhythmias are under controlled, (5) neurologic stability without seizure. However, decisions concerning extubation and transfer to the general ward were made by the in-charge intensivist. All patients admitted to this MICU between January 1, 2015 and June 30, 2015 were enrolled in this study. However, readmissions to the ICU patients during the same hospitalization and patients transferred between rooms or ICUs during the same ICU course were excluded from the analysis. In addition, we excluded the patients who were transferred from our ICU to other hospital due to the unknown outcome of these patients. The data were retrospectively collected on a routine basis and analyzed. Therefore, no informed consent was required and was specifically waived by the Institutional Review Board. Ethics approval was obtained from the Institutional Review Board of Chi Mei Medical Center.

Using electronic records, we obtained the room numbers of all ICU patients during their ICU stay to determine whether they were in a window or no-window room. The assignment of ICU rooms was based on availability and patients could not be transferred between window and no-window rooms. All patients had two 30-min periods of family visitation per day. The information collected included age, gender, reason for ICU admission, Acute Physiology and Chronic Health Evaluation II (APACHE II) scores, and Glasgow coma scale (GCS) scores on ICU admission, underlying comorbidities including dementia, hypertension, chronic obstructive pulmonary disease, congestive heart failure, stroke, chronic kidney disease, liver cirrhosis, and malignancy. We also collected the use of steroids, mechanical ventilator and continuous renal replacement therapy, use of sedatives and antipsychotic agents, and incidence of organ failure and delirium during ICU stay. Additionally, outcomes including length of ICU stay, and in-ICU and in-hospital mortality were collected.

2.2. Definitions

As in previous studies[11–13], pulmonary failure was defined as the need for ventilatory assistance with a fraction of inspired oxygen of 0.40 or more and positive end-expiratory pressure of 10 cm H_2O or more. Cardiovascular failure was defined as systolic blood pressure of $\leq$90 mmHg or a mean arterial pressure (MAP) $\leq$ 65 mmHg for at least 1 h despite adequate fluid resuscitation, or the need for vasoactive agents to maintain SBP $\geq$ 90 mmHg or MAP $\geq$ 65 mm Hg. Hematologic failure was defined as a platelet count <80,000/mm^3 or a 50% decrease in the platelet count from the highest values recorded over the previous 3 days. Renal failure was defined as oliguria with an average urine output <0.5 mL/kg/h for 4 h despite adequate fluid resuscitation or creatinine level $\geq$2 mg/dL. Hepatic failure was defined as a markedly increased serum bilirubin level $\geq$4 mg/dL with elevation of the glutamate dehydrogenase level >10 mU/ml or twice normal. The diagnosis of delirium in ICU was made by intensivists based on the clinical manifestations including acute onset or fluctuating course, inattention, disorganized thinking, and altered level of consciousness according CAM-ICU. Sedatives used in our ICU included benzodiazepines (e.g. midazolam, lorazepam, and diazepam) and short-acting intravenous anesthetics agent (e.g. propofol)[14].

2.3. Statistical analysis

Continuous variables were reported as mean and standard deviation (SD). Categorical variables were presented as frequency counts with percentages. Continuous variables were compared using the Student's independent *t*-test. Categorical variables were compared using the chi-square test or Fisher's exact test. Because ICU length of stay can be significantly right skewed, it was modeled as ordinal and tested using non-parametric statistical methods (Rank test) for analysis. All statistical analyses were conducted using the statistical package SPSS for Windows (Version 11.0, SPSS, Chicago, Il, USA).

3. Results

During the study period, a total of 281 patients were admitted to the ICU and their mean age was 69.5 (±16.3) years. The average APACHE II and GCS scores were 15.1 (±11.0) and 11.4 (±4.3), respectively. Pulmonary disease was the most common reason for ICU admission (n = 77, 27.4%), followed by infectious disease (n = 74, 26.3%), neurologic disease (n = 33, 11.7%), gastrointestinal and hepatobiliary disease (n = 33, 11.7%), and cardiovascular disease (n = 31, 11.0%). Hypertension (n = 154, 54.8%) and diabetes mellitus (n = 130, 46.3%) were the two most common comorbidities. Two hundred and forty-four (86.8%) patients had failure of at least one organ. Respiratory failure was most common (n = 200, 71.2%), followed by cardiovascular system (n = 144, 51.2%), and renal failure (n = 103, 36.7%). There were 189 (67.3%) patients who required mechanical ventilation and 14 (5.0%) who required continuous renal replacement therapy. In addition, 107 (38.1%) patients had delirium while in the ICU. A total of 142 (50.5%) and 52 (18.5%) patients received sedatives and antipsychotic agents, respectively. Overall, the average length of stay (LOS) in the ICU was 5.4 (±4.1) days. The all cause in-ICU and in-hospital mortality rates were 21.7%, and 25.6%, respectively.

The 155 patients admitted to no-window rooms and 126 patients admitted to window rooms had similar clinical characteristics regarding age, gender, diseases severity (APACHEII scores), consciousness level (GCS), frequency of underlying diseases, and incidence of organ failure (all $p > 0.05$) (Table 1). Additionally, the incidence of delirium (37.3% vs 38.7%, $p = 0.907$), use of sedatives (50.0% vs 51.0%, $p = 0.963$), and use of antipsychotic agents (18.3% vs 18.7%, $p = 0.945$) were the same between these the window and no-window groups. The in-ICU and in-hospital mortality rates were not different between the window and no-window groups (23.8% vs 20.0%, $p = 0.533$ for in-ICU mortality; 27.0% vs 24.5%, $p = 0.734$ for in-hospital mortality). The only significant difference was that patients admitted to window rooms had shorter ICU LOS than those admitted to no-window rooms (4.8 days vs 5.8 days, $p = 0.045$). When it was further modeled as ordinal and tested using non-parametric statistical methods (Rank test), p value remained <0.0001.

4. Discussion

This study investigating the effect of windows on the outcomes of MICU patients has several significant findings. We found that the patients admitted to window rooms had shorter LOS than those admitted to no-window rooms. In this observational study, the assignment of ICU rooms was based on availability and the baseline characteristics of these two groups (window vs no-window rooms), including age, gender, underlying diseases, and disease severity, were balanced. Therefore, our study was close to a randomized controlled trial. In the study period, major clinical decisions, such as timing of weaning, extubation, general ward transfer from the ICU, and treatment policy, were all made by only one in-charge intensivist. In summary, all of these indicate that the results regarding the effect of windows in the MICU in this study should be convincing.

Several plausible mechanisms can explain the positive impact of windows on the outcome of the MICU patients in this study. Critically ill patients often have disruption of circadian rhythm and poor sleep quality in the ICU, both of which are associated with poor outcomes[2,3]. Additionally, several investigations[15–17] have demonstrated impairment of the circadian rhythm associated with decreased melatonin secretion in critically ill patients. Therefore, it is supposed that natural light from windows in the ICU may help "reset" the circadian rhythm and help patients receive cues of day versus night. Finally, natural light through windows can help improve the outcomes of ICU patients, such as shorter ICU stays as shown in this study.

The significant association between windows and ICU stay is consistent with the findings in the Beauchemin and Hays study[7] showing that patients treated in sunny rooms had a shorter LOS than patients treated in dull rooms in the setting of patients with myocardial infarction in the CCU (2.3 days vs 3.3 days, $p < 0.006$). Two previous studies[5,6] demonstrated that exposure to natural light had a significant positive impact on early ambulance and length of hospital stay in surgical patients. In contrast, Wunsch et al[9] indicated that the presence or absence of natural light from a window did not affect any outcomes of ICU patients with subarachnoid hemorrhage, including LOS and mortality in the ICU and hospital. These different findings may be due to different study populations and designs, so further large scale study is warranted to confirm the benefit of window rooms in the ICU. Previous reports showed no negative effects of ICU rooms with windows on patient outcomes, but window rooms had some positive impacts in some

Table 1
Comparison between patients admitted to window and no-window rooms.

Variable	No (%) of patients admitted to window rooms (n = 126)	No (%) of patients admitted to no-window rooms (n = 155)	P value
Age, years (mean ± SD)	71.4 ± 15.7	68.0 ± 16.6	0.081
Male, no. (%)	74 (58.7)	96 (61.9)	0.672
APACHE II score (mean ± SD)	15.3 ± 11.7	15.0 ± 10.5	0.821
Glasgow Coma Scales (mean ± SD)	11.3 ± 4.5	11.5 ± 4.2	0.701
Comorbidity			
Dementia	14 (11.1)	16 (10.3)	0.983
Hypertension	71 (56.3)	83 (53.5)	0.728
Congestive heart failure	26 (20.6)	25 (16.1)	0.413
Chronic obstructive pulmonary disease	17 (13.5)	21 (13.5)	0.861
Stroke	14 (11.1)	31 (20.0)	0.063
Diabetes mellitus	57 (45.2)	73 (47.1)	0.844
Chronic kidney disease	41 (32.5)	40 (25.8)	0.271
Liver cirrhosis	21 (16.7)	28 (18.1)	0.881
Malignancy	29 (23.0)	34 (21.9)	0.939
Autoimmune disease	1 (0.8)	2 (1.3)	0.859
Steroid usage	24 (19.0)	16 (10.3)	0.057
No. of multi-organ failures			
Hematologic	15 (11.9)	17 (11.0)	0.962
Pulmonary	93 (73.8)	107 (69.0)	0.453
Cardiovascular	64 (50.8)	80 (51.6)	0.989
Renal	42 (33.3)	61 (39.4)	0.352
Hepatic	18 (14.3)	27 (17.4)	0.588
Delirium	47 (37.3)	60 (38.7)	0.907
Use of sedatives	63 (50.0)	79 (51.0)	0.963
Use of antipsychotic agents	23 (18.3)	29 (18.7)	0.945
Use of mechanical ventilator	93 (73.8)	107 (69.0)	0.453
Use of continuous renal replacement therapy	7 (5.6)	7 (4.5)	0.884
Outcome, no. (%)			
ICU stay, days	4.8 ± 3.4	5.8 ± 4.6	**0.045**
ICU days among survivors	5.4 ± 3.1	6.5 ± 4.7	0.045
ICU days among mortalities	3.1 ± 3.8	3.1 ± 2.5	0.972
In-ICU mortality	30 (23.8)	31 (20.0)	0.533
In-hospital mortality	34 (27.0)	38 (24.5)	0.734

Bold indicates $p < 0.05$.

studies. Therefore, a new ICU should be equipped with windows as recommended in the SCCM guidelines.

A total of 38% of patients were diagnosed with delirium in this study. This finding is similar to that in previous studies[18–21] in which the incidence of delirium in the ICU ranged from 20% to 87%. We found similar incidences of delirium and use of sedative/antipsychotic agents in patients admitted to window and no-window rooms. This finding is in line with that of Wunsch et al's study[9] of ICU patients with subarachnoid hemorrhage. In contrast, several studies[5,8,22] showed that window rooms could decrease the incidence of delirium. For example, In Wilson's report, the incidence of delirium in the ICU was two to three times greater in the windowless unit that in window rooms[8]. However, most of the results of the above studies[5,8,22] were based on limited case numbers. We need further study enrolling more cases to clarify this issue.

Our study has some limitations. First, because this study was conducted in a single hospital and the number of cases was limited, our findings may not be generalizable to other hospitals. Although the two groups seemed to be balanced in every measurement made, it is probable the findings of a non-significant p value at greater than 0.05 level was due to the small sample size. Therefore, this study may not have enough evidence to rule out the effects of some confounding factors. Second, we only determined the number of patients who used sedative or antipsychotic agents for analysis in this study, so we cannot calculate the dose-effect based on the defined daily dose.

In conclusion, although we did not find any benefit of windows on in-ICU and in-hospital mortality, our findings demonstrated that ICU rooms with windows were associated with shorter ICU stays than windowless rooms. This finding suggests that windows are important in ICU rooms.

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