ICU Architectural Design Affects the Delirium Prevalence: A Comparison Between Single-Bed and Multibed Rooms*

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Objectives: Delirium risk factors are related to the patients' acute and chronic clinical condition, treatment, and environment. The environmental risk factors are essentially determined by the ICU architectural design. Although there are countless architectural variations among the ICUs, all can be classified as single- or multibed rooms. Our objectives were to compare the ICU delirium prevalence and characteristics (coma/delirium-free days, first day in delirium, and delirium motoric subtypes) of critically ill patients admitted in single- or multibed rooms.

Design: Retrospective.

Setting: ICU of a teaching oncologic hospital with 31 beds. Twenty-three beds distributed in one multibed room with 13 beds and other with 10 beds. Eight beds distributed in single-bed rooms.

Patients: All adult patients admitted from February to November 2011.

Interventions: None.

Measurements and Main Results: We evaluated 1,587 patients and included 1,253 patients. Patients' characteristics at ICU admission and their outcomes along the ICU stay were not different between patients admitted in single- or multibed rooms. One hundred sixty-three patients (13.0%) had delirium, and the prevalence was significantly lower in patients admitted in single-bed rooms (6.8% × 15.1%; $p < 0.01$). This lower prevalence occurred in patients admitted due to a medical (11.0% × 25.6%; $p < 0.01$) or postoperative (5.0% × 11.4%; $p < 0.01$) reason. However, the coma/delirium-free days, the first day in delirium, and the delirium motoric subtypes were not different between the single- and multibed rooms. The risk factors associated with delirium were admission in multibed rooms (odds ratio, 4.03; 95% CI, 2.13–7.62), older age, ICU-acquired infection, and higher Simplified Acute Physiology Score 3 and Sequential Organ Failure Assessment score.

Conclusions: Critically ill patients admitted in single-bed rooms have a lower prevalence of delirium than those admitted in multibed rooms. However, coma/delirium-free days, first day in delirium, and motoric subtypes were not different. (*Crit Care Med* 2014; 42:2204–2210)

Key Words: architecture; delirium; environment; hospital design and construction; intensive care units; risk factors

Delirium is a frequent and relevant complication of critically ill patients because it increases ICU length of stay, costs, morbidity, and mortality and causes persistent cognitive dysfunction (1–5). The risk factors of delirium are related to the patient's acute and chronic clinical condition, treatment, and environment (6).

The environmental risk factors are essentially determined by the ICU architectural design. There are countless architectural variations among the ICUs, but all can be classified as single- or multibed rooms. A single study evaluated if the ICU design was a risk factor for delirium and found that although delirium prevalence had been higher in multibed rooms, the difference was not statistically significant (7). However, the data were extracted from hospitals with different profiles (community, private, and teaching) that probably had different risk factors for delirium and different standards of care, weakening any conclusion about a specific risk factor.

We hypothesized that patients admitted in multibed rooms would present a higher prevalence of delirium than those admitted in single-bed rooms because they had been exposed to further and more intense risk factors such as noise, sleep disruption (8), stress (9), lack of privacy and bad lighting control (10), worse patient-family interaction (7), and higher exposure to unrelated sounds, dialogues, and movements.

Our objectives were to compare the delirium prevalence and characteristics (coma/delirium free days, first day in delirium

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and delirium motoric subtypes) of critically ill patients admitted in single- or multibed rooms.

MATERIALS AND METHODS

Patients and Study Design

In a retrospective study, we evaluated all adult patients (> 18 yr) admitted from February to November 2011. January and December were excluded because those months were scheduled to ICU maintenance, which implied a high reallocation rate of the patients due to the temporary closure of some beds. During the study, the mean occupancy rate of the multibed rooms was 79% for the multibed room with 13 beds and 83% for the multibed room with 10 beds. The mean occupancy rate of the ICU with the single-bed rooms was 89%.

Patients with previous dementia, already admitted in the ICU with delirium, legally blind or deaf, those reallocated from single-bed to multibed rooms or vice versa, those who during their stay never had an adequate level of consciousness to be tested for delirium, and those whose ICU length of stay was less than 24 hours were excluded from the analysis. If the patient had more than one ICU admission, only the first was considered.

The local ethics committee reviewed the study and approved it.

Setting

The hospital is a 290-bed teaching oncologic hospital that previously had 23 ICU beds distributed in two multibed rooms, one with 10 and the other with 13 beds. In April 2010, a new ICU with eight single-bed rooms had opened, totalizing 31 ICU beds. All units are fulltime staffed with intensivists, nurses, and respiratory therapists.

All ICU beds are adjacent and at the same floor. There are one single and common medical, nurse, and respiratory-therapist director, and the staff periodically rotates among the single- and multibed rooms. The clinical practices, quality and safety policies, temperature control of the rooms, the use of physical restraints, dimming lights at night, the visiting hours, patient-to-nurse ratio, and sedation guidelines are the same in the single- and multibed rooms. Patients are admitted in the first available bed.

The multibed rooms are large rooms with outdoor windows and two or three large toilets for all patients. Their beds are furnished with a hospital bed designed for critically ill patients, one chair suitable for the patient use and other for one visitor. The temperature is set to 22–24°C (71.6–75.2°F) without individual control (the temperature is the same for all patients). Patients are exposed to natural light through windows without coverings. The patients face exclusively the interior of the unit, and at the foot of bed, there is a curtain that is kept opened most of the time, but can be closed at the discretion of the ICU staff (**Fig. 1**). General lighting has adjustable levels, but the individualization is minimal and patients had only the option to control a reading light. The lighting of the room is decreased from midnight to 4 AM.

The single-bed rooms have a larger outdoor window and a dedicated toilet and are also furnished with a hospital bed designed for critically ill patients and one chair suitable for patient use and the other for one visitor. The temperature of the room is also set to 22–24°C (71.6–75.2°F) without the option of individual control. Patients are exposed to natural light through a large window that allows the patients to face the outside and has coverings that can be controlled. At the other side of the room, there is a sliding door (Fig. 1). General lighting has adjustable levels, and the room lighting is fully controllable. The corridor lighting is decreased from midnight to 4 AM.

Data Collection

Data were obtained from the electronic chart. In our ICU, trained nurses and physicians routinely assess and record the level of consciousness four times a day and delirium twice a day. Level of consciousness is assessed using the Richmond Agitation Sedation Scale (11) or Glasgow Coma Scale (12), as appropriate. Delirium is evaluated using the Confusion Assessment Method for ICU (CAM-ICU) and its motoric subtype is classified as hypoactive, hyperactive, or mixed (13).

Although the ICU admission policy do not discriminate patients to single- or multibed rooms, in order to guarantee that the patients were comparable, we recorded data from patient's admission and during the ICU stay. From the admission were obtained the Simplified Acute Physiology Score (SAPS) 3 (14), Sequential Organ Failure Assessment (SOFA) score (15), Charlson comorbidity score (16), the Eastern Cooperative Oncology Group (ECOG) score (17), presence of infection, creatinine level, active smoking, active alcoholism, type of ICU admission (medical or postoperative), main reason for ICU admission, type of cancer (solid or hematological), and metastatic status. In order to characterize the clinical evolution along the ICU stay, we recorded the ICU length of stay, use of invasive positive pressure ventilation greater than or equal to 24 hours, use of renal replacement therapy, and infections acquired on ICU and ICU mortality.

For all patients, we recorded the coma/delirium-free days, the first day in delirium, and the delirium motoric subtypes.

Statistical Analysis

Results are expressed as mean (±SD). Categorical variables were compared using the chi-square or Fisher exact test, as appropriate. Continuous variables were compared by Student *t* test.

To confirm that admission in a multibed room is a delirium risk factor and to explore other risk factors, we performed a logistic regression analysis. To avoid model overfitting, we did not use stepwise procedures and elected the independent variables based on the univariate analysis yielding ($p < 0.20$), their clinical relevance, and the number of events (cases of delirium). Sixteen independent variables (age, multibed room, weight, height, creatinine at admission, type of ICU admission, main reason for admission, type of cancer, infection at ICU admission, SAPS 3 at admission, SOFA at admission,

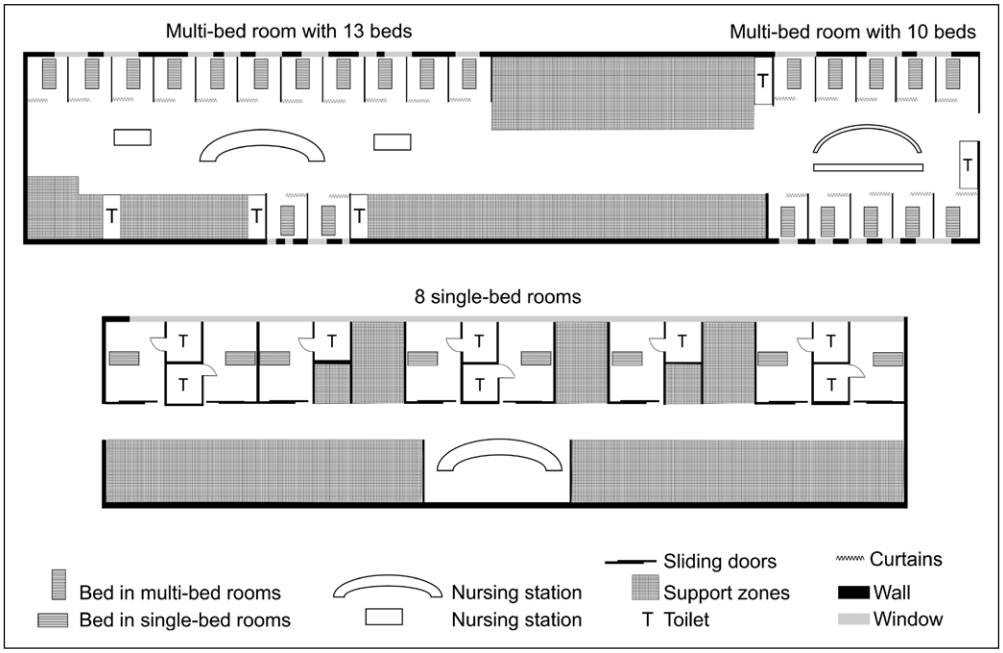

Figure 1. Layout of the single-bed and multibed rooms.

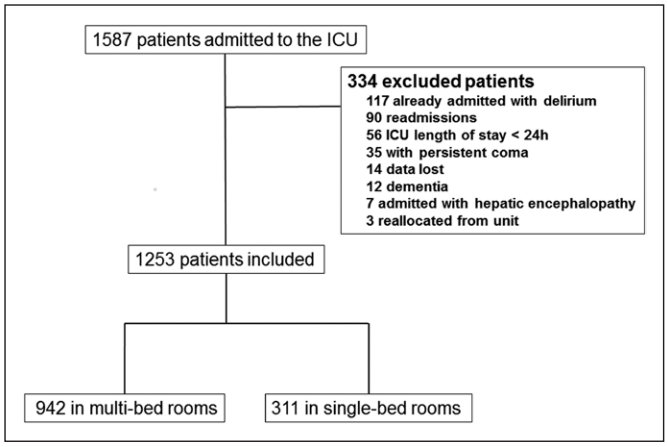

Figure 2. Study flowchart with the number of patients included and excluded.

Charlson, ECOG, use of invasive positive pressure ventilation for ≥ 24 hr, ICU-acquired infection, and renal replacement therapy) were selected for the logistic regression. A p value of less than or equal to 0.05 was considered statistically significant. Statistical tests were performed using the SPSS 17.0 (IBM, Armonk, NY).

RESULTS

Patients

We evaluated 1,587 patients and included 1,253 patients (**Fig. 2**). At ICU admission, the patients' acute and chronic clinical conditions were not different (**Table 1**). Also the use of invasive mechanical ventilation, ICU-acquired infections, use of renal replacement therapy, ICU length of stay, and mortality were not different between patients admitted in single- or multibed rooms (Table 1).

Delirium Prevalence and Characteristics

One hundred sixty-three patients (13.0%) had delirium, and the prevalence was significantly lower for patients in single-bed rooms (6.8% × 15.1%; $p < 0.01$). The delirium prevalence was significantly lower for patients admitted due to a medical or postoperative reason (**Table 2**). However, once the delirium occurred, the coma/delirium-free days, the first day in delirium, and the delirium motoric subtypes were not different from patients in single- or multibed rooms (Table 2).

Delirium Risk Factors

The risk factors associated with delirium were admission in multibed rooms (odds ratio, 4.03; 95% CI, 2.13–7.62), older age, ICU-acquired infection, and higher SAPS 3 and SOFA at admission (**Table 3**).

DISCUSSION

We showed that critically ill patients admitted in single-bed rooms have a lower prevalence of delirium than patients admitted in multibed rooms, although the delirium characteristics are not different.

Hypotheses for the Difference in Delirium Prevalence

The belief that the design can contribute to the well-being has influenced the modern architecture, and the relationship between hospital design and patient outcomes is longstanding.

We hypothesize that higher noise levels, lack of individualized lighting, lack of privacy, worse patient-family interaction, and higher exposure to sounds, dialogues, and movements not related to the patient are responsible for the increase in delirium prevalence in the multibed rooms.

The noise level is higher in multibed than single-bed rooms (8, 10, 18), and noise increases subjective stress, annoyance, sympathetic nervous system activation (19), and sleep disruption (8). It has been proved that sleep disruption and the consequent deprivation are associated with an increase in delirium prevalence (20) and confirming that association, the use of ear plugs during the night decreases the delirium prevalence in ICU patients (21). In addition, high levels of noise decrease the sustained attention and memory (22), both present in delirium. In order to improve the ICU management, few years ago, we measured the noise in the multibed and single-bed rooms. We did that during 1 month and evidenced that the noise in the multibed rooms was louder than in the single-bed rooms. The basal noise level was equal between the rooms, and it was

TABLE 1. Admission Characteristics and ICU Outcomes of Patients Admitted to Single-Bed or Multibed Rooms

Characteristics	All Patients *n* = 1,253	Multibed Room *n* = 942	Single-Bed Room *n* = 311	*p*
Age (yr)	59 ± 15	59 ± 15	59 ± 14	0.74
Male (%)	635 (50.7)	491 (52.1)	144 (46.3)	0.08
Weight (kg)	72 ± 17	72 ± 17	72 ± 16	0.91
Height (cm)	165 ± 10	165 ± 9	165 ± 10	0.65
Body mass index (kg/m^2)	26 ± 6	27 ± 6	27 ± 5	0.67
Active alcoholism (%)	54 (4.3)	39 (4.1)	15 (4.8)	0.97
Active smoking (%)	106 (8.6)	78 (8.3)	26 (9.3)	0.93
Creatinine at admission (mg/dL)	1.1 ± 1.5	1.1 ± 1.7	1.0 ± 0.8	0.27
Type of admission (%)				0.45
Medical	333 (26.6)	242 (25.7)	91 (29.3)	
Postoperative	920 (73.4)	700 (74.4)	220 (70.7)	
Reason for admission (%)				0.29
Postoperative monitoring	896 (71.5)	683 (72.5)	213 (68.5)	
Acute respiratory distress	107 (8.5)	73 (7.7)	34 (10.9)	
Sepsis	85 (6.8)	69 (7.1)	18 (5.8)	
Hemodynamic instability	80 (6.4)	61 (6.5)	19 (6.1)	
Decreased level of consciousness	23 (1.8)	16 (1.7)	7 (2.3)	
Others	62 (4.9)	42 (4.5)	20 (6.4)	
Type of cancer (%)				0.74
Solid	1,109 (88.5)	838 (89.0)	271 (87.1)	
Hematological	66 (5.3)	46 (4.9)	20 (6.4)	
No cancer	78 (6.2)	58 (6.2)	20 (6.4)	
Metastatic cancer (%)	480 (38.3)	355 (37.7)	125 (40.2)	0.46
Infection at admission (%)	325 (25.9)	244 (25.9)	81 (26.0)	0.80
Simplified Acute Physiology Score 3 at admission	49.6 ± 16.4	49.3 ± 16.3	50.4 ± 16.6	0.31
Sequential Organ Failure Assessment score at admission	2.2 ± 1.9	2.2 ± 1.9	2.2 ± 1.9	0.80
Charlson comorbidity score	4.8 ± 3.0	4.7 ± 3.0	4.9 ± 3.1	0.40
Eastern Cooperative Oncology Group Performance Status score (%)				0.19
0	507 (40.5)	370 (39.3)	137 (44.1)	
1–2	279 (22.3)	219 (23.4)	59 (19.0)	
3–4	467 (37.3)	352 (37.4)	115 (37.0)	
Use of invasive mechanical ventilation for ≥ 24 hr (%)	101 (8.8)	77 (8.9)	24 (8.4)	0.80
ICU-acquired infection (%)	64 (5.1)	54 (5.7)	12 (3.9)	0.19
Renal replacement therapy (%)	38 (3.0)	26 (2.8)	9 (3.0)	0.99
ICU length of stay (d)	3.3 ± 4.4	3.3 ± 4.3	3.5 ± 4.6	0.44
ICU mortality (%)	102 (8.1)	84 (8.5)	18 (5.8)	0.18

Vasoactive amines considered were noradrenaline, dobutamine, and dopamine at any dosage. Hemodynamic instability was any hemodynamic instability other than sepsis. Postoperative type of admission included scheduled and emergency surgeries.

TABLE 2. Delirium Prevalence and Characteristics of Patients Admitted to Single-Bed or Multibed Rooms

Prevalence and Characteristics	All Patients *n* = 163	Multibed Room *n* = 142	Single-Bed Room *n* = 21	*p*
Delirium prevalence (%)				
All patients	163 (13.0)	142 (15.1)	21 (6.8)	< 0.01
Medical admissions (*n* = 333)	72 (21.6)	62 (25.6)	10 (11.0)	< 0.01
Postoperative admissions (*n* = 920)	91 (9.9)	80 (11.4)	11 (5.0)	< 0.01
Coma/delirium-free days				
All patients (*n* = 163)	4.1 ± 6.0	4.2 ± 6.2	3.8 ± 4.6	0.80
Medical admissions (*n* = 72)	3.9 ± 5.8	3.8 ± 6.0	4.6 ± 4.2	0.79
Postoperative admissions (*n* = 91)	4.3 ± 6.2	4.4 ± 6.4	3.1 ± 4.9	0.65
No. of days with delirium	3.5 ± 3.6	3.6 ± 3.8	2.8 ± 1.9	0.33
First day in delirium	2.8 ± 3.0	2.8 ± 2.9	3.1 ± 3.5	0.71
Delirium motoric subtype (%)				0.34
Hypoactive	108 (66.3)	94 (66.2)	14 (66.7)	
Mixed	30 (18.4)	28 (19.7)	2 (9.5)	
Hyperactive	25 (15.3)	20 (14.1)	5 (23.8)	

Postoperative type of admission included scheduled and emergency surgeries.

between 50 and 60 dB; however, multibed rooms recorded more noise peaks, some of them around 80 dB.

A previous study showed that during the day, the light level in single-bed rooms is higher than in multibed rooms due to a higher area of windows (10). Also in the present study, patients admitted in single-bed or multibed rooms were exposed to natural light; however, the patients in single-bed rooms were exposed to an increased number of windows and to a more controllable lighting (more intense light during the day and less during the night). It is well known that a better cycled lighting improves circadian rhythm and sleep and decreases agitation in institutionalized elderly subjects (23). Also it had been suggested that high levels of natural light and window reduce the patient's pain perception and length of stay (24).

Single-bed rooms increase privacy that could have decreased the patients' stress and anxiety. These associations of single-bed rooms and lower stress and anxiety have already been proved in nurses working in a neonatal ICU (18, 25).

Patients admitted in multibed rooms are intensely exposed to sounds, dialogues, and movements not related to them. Besides the already mentioned sleep disruption, this exposure could cause misperception leading to stress, anxiety, and agitation. Two studies showed that disruptive behaviors were decreased when patients with dementia were moved from a high-density unit with a high-stimulation environment to a low-density unit with low-stimulation environment (26, 27).

Finally, we hypothesize that a worse patient-family interaction in the multibed rooms could have increased the delirium prevalence. The extreme of this view is the absence of patient-family interaction, an already proved risk factor for delirium (7).

Clinical Implications

The delirium management is focused on prevention (6), but most of the delirium risk factors are not modifiable, turning indispensable the control of the modifiable risk factors. Most of the modifiable risk factors are related to the environment, and in a building, the environment is fundamentally determined by its architectural design. So a correct hospital architecture is indispensable to decrease delirium prevalence, and the results of the present study may guide hospital managers during the building of a new ICU or renovation of an old one. Also the present study alerts physicians and nurses to a now recognized delirium risk factor—the admission in multibed rooms.

The present study showed that delirium prevalence is higher even in postoperative patients admitted in multibed rooms. We could believe that those patients with low risk for delirium and with short ICU length of stay would not be negatively impacted by the ICU design. However, the results of the present study contradict the belief that multibed rooms could be a suitable design for a surgical ICU.

We believed that the multibed room design would be a trigger and a perpetuator of delirium, but the coma/delirium-free days were not different between single- and multibed rooms. One hypothesis is that the occurrence of delirium in multibed rooms encouraged the physicians to discharge clinically stable patient to the ward as part of their delirium treatment. The ICU design did not influence the delirium motoric subtype

TABLE 3. Comparison Between Patients With and Without Delirium

Characteristics	Without Delirium *n* = 1,090	Delirium *n* = 163	*p*	Delirium OR (95% CI)
Age (yr)	58 ± 15	66 ± 13	< 0.01	1.03 (1.01–1.05)
Multibed room (%)	800 (73.4)	142 (87.1)	< 0.01	4.03 (2.13–7.62)
Male (%)	548 (50.3)	87 (53.4)	0.50	
Weight (kg)	72 ± 17	69 ± 16	0.11	
Height (cm)	165 ± 10	163 ± 10	0.08	
Body mass index (kg/m^2)	26 ± 6	26 ± 5	0.51	
Active alcoholism (%)	46 (4.2)	6 (3.7)	0.92	
Active smoking (%)	93 (8.5)	13 (8.0)	0.99	
Creatinine at admission (mg/dL)	1.0 ± 1.5	1.4 ± 1.7	< 0.01	
Type of admission (%)			< 0.01	
Medical	261 (23.9)	72 (44.2)		
Postoperative	829 (76.1)	91 (55.8)		
Reason for admission (%)			< 0.01	
Postoperative monitoring	805 (73.9)	91 (55.8)		
Acute respiratory distress	81 (7.4)	26 (16.0)		
Sepsis	67 (6.1)	18 (11.0)		
Hemodynamic instability	63 (5.8)	17 (10.4)		
Decreased level of consciousness	15 (1.4)	8 (4.9)		
Others	59 (5.4)	3 (1.8)		
Type of cancer (%)			0.01	
Solid	977 (89.7)	135 (82.8)		
Hematological	49 (4.5)	17 (10.4)		
No cancer	64 (5.9)	11 (6.7)		
Metastatic cancer (%)	417 (38.3)	63 (38.7)	0.93	
Infection at admission (%)	256 (23.9)	69 (42.3)	< 0.01	
Simplified Acute Physiology Score 3 at admission	47.8 ± 15.2	61.9 ± 18.7	< 0.01	1.04 (1.02–1.06)
Sequential Organ Failure Assessment score at admission	2.0. ± 1.7	3.1 ± 2.3	< 0.01	1.13 (1.01–1.27)
Charlson comorbidity score	4.7 ± 3.0	5.3 ± 3.2	0.01	
Eastern Cooperative Oncology Group Performance Status score (%)			0.05	
0	454 (41.7)	53 (32.5)		
1–2	233 (21.4)	46 (28.2)		
3–4	403 (37.0)	64 (39.3)		
Use of invasive mechanical ventilation for ≥ 24 hr (%)	57 (5.7)	44 (29.7)	< 0.01	
ICU-acquired infection (%)	26 (2.4)	38 (23.3)	< 0.01	9.92 (4.91–20.02)
Renal replacement therapy (%)	21 (1.9)	13 (7.8)	< 0.01	
ICU length of stay (d)	2.5 ± 2.7	8.5 ± 7.9	< 0.01	
ICU mortality (%)	62 (5.7)	40 (24.5)	< 0.01	

OR = odds ratio.

Vasoactive amines considered were noradrenaline, dobutamine, and dopamine at any dosage. Hemodynamic instability was any hemodynamic instability other than sepsis. Postoperative type of admission included scheduled and emergency surgeries.

that was commonly the hypoactive subtype, as previously described (13).

The other disadvantage of the single-bed room design is its higher building cost and an unpleasant isolation feeling of some patients (28).

Limitations of the Study

To the best of our knowledge, this is the first study designed to evaluate the relationship between the ICU design and the delirium prevalence. The design and organization of our ICU allowed us the comparison because the different designed ICUs were contiguous and managed by the same team and policies. Besides that, the medical and nurse teams were trained to apply and register the CAM-ICU score as a routine task.

One limitation is the lack of register of some risk factors for delirium, such as hypoglycemia, hypoxemia, and benzodiazepines or opioids use. We do not believe that the use of such drugs was different between the patients in single- or multibed rooms because the ICU staff was the same and there was sedation guideline. Besides the use of drugs, other delirium risk factors were not probably different because at ICU admission, the patients' acute and chronic clinical conditions were not different, and the ICU outcomes and use of invasive procedures were also equal.

Another limitation of the present study is that it was performed in a single oncologic teaching hospital.

CONCLUSIONS

Critically ill patients admitted in single-bed rooms have a lower prevalence of delirium than those admitted in multibed rooms. However, coma/delirium-free days, first day in delirium, and motoric subtypes were not different.

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