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CLINICAL INVESTIGATION

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Association of ICU Room Characteristics With Mortality and Length of Stay

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OBJECTIVES: In addition to medical considerations, economic factors are increasingly influencing hospital planning. While guidelines suggest ICU room design and layout likely affect outcomes, data supporting current recommendations are scarce. The aim of this study was to investigate the association of shared rooms vs. single rooms, high vs. low visibility, and distances of nurses' and doctors' charting areas to patients' rooms with mortality and length of stay in a large, mixed-discipline cohort.

DESIGN: Retrospective observational cohort study.

SETTING: Four ICUs at the University Medical Center Mannheim, Germany.

PATIENTS: Critically ill adults with ICU admission between January 2019 and May 2022 for at least 24 hours.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Associations of the index variables with in-hospital mortality and ICU length of stay were assessed by multivariate regression, adjusting for biological sex, Simplified Acute Physiology Score II, need for vasopressors, need for ventilation, and medical vs. surgical admission. Five thousand two hundred ninety-three patient stays with a mortality rate of 18% and a mean length of stay of 6.3 ± 9.2 days in survivors were eligible for this analysis. In the overall cohort, none of the index variables showed associations with mortality. Patients admitted to single rooms showed a mean length of stay increase by 0.81 days (95% CI, 0.04–1.57 d; $p = 0.039$) compared with shared rooms with up to three beds.

CONCLUSIONS: In this mixed cohort of medical and surgical ICUs, neither single rooms compared with shared rooms, high-visibility rooms compared with low-visibility rooms, nor distances to nurses' or doctors' charting areas were associated with mortality. The observed increase in length of stay associated with single room admission highlights the need to balance privacy and infection control benefits with potential implications for ICU capacity and operational efficiency.

KEYWORDS: evidence-based design; health architecture; intensive care unit layout; length of stay; mortality

The aging population and increasing healthcare expectations are driving up demand for critical care, while labor and infrastructure costs continue to rise. This creates substantial pressure on hospital budgets and necessitates careful planning to ensure that ICU capacity and design are both clinically effective and financially sustainable (1–3). In the design of a new ICU, economic considerations often must be weighed against operative efficiency and patient safety aspects (4, 5). While ward-type rooms, also referred to as multibay areas, require less construction and operational costs, provide better visibility of patients and shorter walking distances, single rooms have been

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KEY POINTS

Question: Are ICU layout aspects associated with mortality or length of stay?

Findings: No layout aspect was associated with mortality. Single room admissions had a mean increase in length of stay by 0.8 days.

Meaning: ICUs may not be required to consist solely of single-bed rooms.

associated with better long-term cost-effectiveness (6). This could be attributed to downstream savings by reduction in nosocomial infection rates and delirium prevalence of single rooms when compared with multibay areas (7–11). Furthermore, single rooms offer patient-centered benefits such as enhanced privacy and fewer disturbances, still some individuals may favor shared accommodations to maintain social connection (12, 13). A conditional recommendation was made in favor of single rooms over open bay layouts in the current Society of Critical Care Medicine guidelines (5). Importantly, no study has investigated mortality as a primary endpoint when comparing the number of beds per ICU room. Furthermore, shared rooms with a lower number of beds could provide a compromise between single rooms and multibay areas. There are, to our knowledge, currently no available studies investigating the effects of smaller shared rooms.

High visibility of patients in their rooms is strongly encouraged by the current Society of Critical Care Medicine guideline, despite low certainty evidence (5, 14, 15). High-visibility rooms are commonly described as rooms where patients are directly visible from staff charting areas. This could have a positive effect on treatment outcomes, as visual inspection can detect certain problems that cannot be immediately identified by monitoring devices, for example, if a patient is accidentally disconnected from the ventilator. There are only a few negative aspects of high-visibility rooms, such as reduced privacy, which are thought to have limited impact on outcomes in an ICU.

There are no recommendations for the exact proximity of nurses' charting areas to ICU patient rooms, but evidence and guidelines support placing charting areas close enough to facilitate patient observation, efficient workflow, and staff satisfaction, while maintaining flexibility and infection control (4, 5, 16). Importantly, no investigations studying the impact on length of stay or mortality in ICU patients have been conducted. While these distances are closely linked to visibility, response times to emergencies could also be influenced and negatively impact outcomes of rooms farthest away from staff charting areas.

Considering the discrepancy between this urgent issue and the very limited evidence, we designed this study to assess whether ICU room design and layout are associated with in-hospital mortality and ICU length of stay in a monocentric, retrospective all-comers investigation.

MATERIALS AND METHODS

Patient Eligibility Criteria

All patients admitted to one of the four ICUs at the University Medical Center Mannheim, Germany, between January 1, 2019, and May 31, 2022, for at least 24 hours were eligible for inclusion in the final analysis. Any recurrent stay of the same patient was treated as an independent stay, irrespective of the interval between stays. Cases that were accommodated in more than one room during the index stay were excluded from the analysis to ensure a consistent exposure to room characteristics.

Included ICUs

All four adult ICUs at the University Medical Center Mannheim, Germany, were included in this study. There are two operative and two medical ICUs, comprising 44 rooms with a total of 66 beds. There are 26 single rooms, 14 two-bed rooms, and four three-bed rooms. Layout plans of the included ICUs are displayed in **Figure 1**. Both high-visibility rooms and single rooms are not evenly spread across the included ICUs; thus, distances from the rooms to the nurses' and doctors' charting areas were chosen as additional index variables. All ICUs included in this study comprise of a nurses' charting area with a surrounding set of rooms and an adjoining corridor from which further rooms branch off. The documentation areas for nursing staff are open-plan spaces that either offer an unobstructed view (medical ICUs) or feature large windows extending from desk height to the ceiling (surgical ICUs),

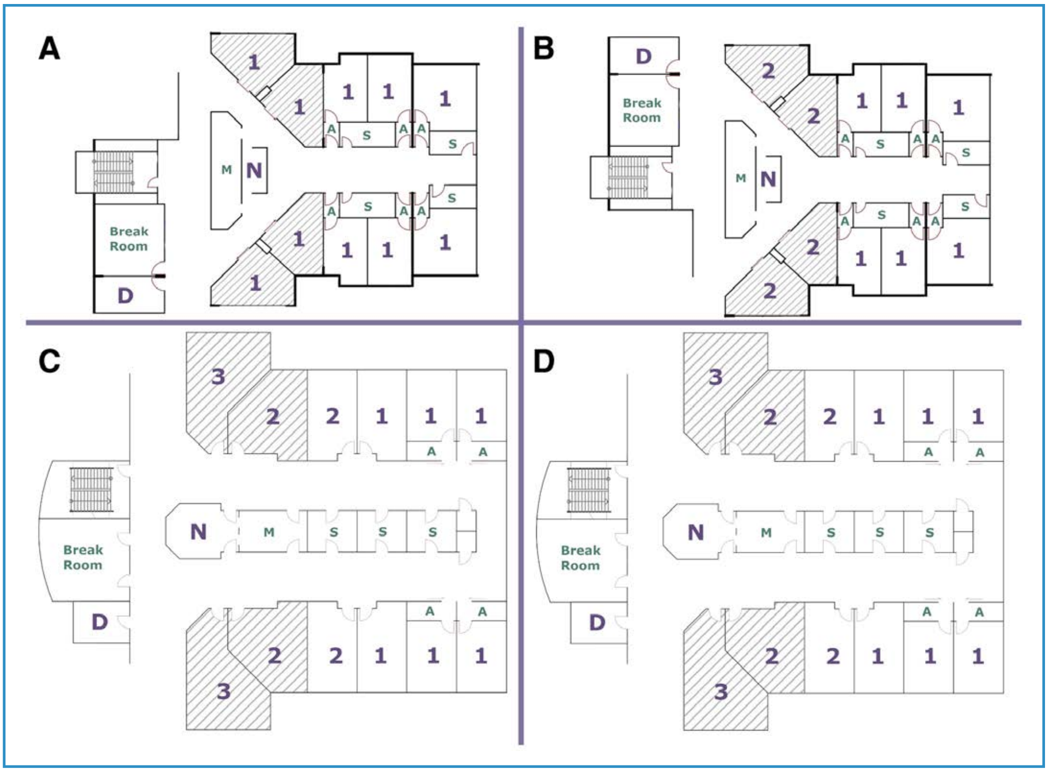

Figure 1. Schematic floor plans of the included ICUs. Schematic floor plans of the medical (**A** and **B**) and surgical (**C** and **D**) ICUs. Images are based on the original floor plans; figure not to scale. The medical ICUs were built in 2002, and the surgical ICUs were built between 2012 and 2013. No structural alterations were made to either unit by the end of the study period. 1 = single room, 2 = shared room (two beds), 3 = shared room (three beds), A = anteroom, D = doctors' charting area, hatched areas = high-visibility room, M = medication room, N = burses' charting area, S = supplies room.

with the panoramic view being obstructed only by the medication rooms (Fig. 1). Rooms accommodate between one and three patients at a time. None of the ICUs has a bay area with patient beds directly on the corridor or rooms that can accommodate more than three patients at a time. National requirements for nurse-to-patient ratios are set by the government: in adult ICUs, generally one nurse is required per two patients during day shifts and one nurse per three patients during night shifts. Uninterrupted presence of at least one medical trainee (resident physician postgraduate years 2–5) per ICU is guaranteed by a three-shift system on all ICUs included in this analysis. For each of the ICUs, a board-certified intensivist conducts daily rounds together with residents. Anytime outside of these hours, at least one intensivist is available on call for the two medical ICUs and one for the two surgical ICUs. Doctors' charting areas are designed as separate rooms on the ward. More detailed information on institutional and regulatory conditions is described in the **Supplemental Material** (https://links.lww.com/CCM/I47).

Definition of Index Variables

Single rooms were defined as rooms that were designed to accommodate only one patient at a time. Any room with usual capacity for more than one patient was considered as a shared room. High-visibility rooms were defined as those where patients inside the rooms were in direct line-of-sight from the nurses' charting area, either through an open door or large window. Distances between rooms and nurses' or doctors' charting areas were measured digitally on electronic ward plans as the shortest distance between the entrances.

Selection of Covariates and Handling of Missing Data

Simplified Acute Physiology Score II (SAPS II), vasopressor use, and ventilation use and type were chosen as covariates for multivariate regressions as they represent key dimensions of disease severity and were also expected to be available in most cases, as information is routinely collected in the electronic patient file. Specialty of the admitting ICU (medical vs. surgical) was also considered as a covariate, as the eligible medical and surgical ICUs differ in case-mix and ward layout. Medical admission, scheduled, and unscheduled surgical admission types, as well as age and arterial pressure, are represented in the SAPS II scoring system and were thus not considered as additional covariates to avoid multicollinearity and overadjustment. Lactate levels were expected to produce missing values and to not provide substantial additional information on disease severity to the selected covariates, especially SAPS II scores. Although lactate levels provide immediate, dynamic information about acute metabolic derangement and risk, SAPS II offers a comprehensive, validated estimate of overall disease severity and mortality risk. Combining lactate with SAPS II may improve prognostic accuracy in specific subgroups, but SAPS II remains the more robust tool for global severity assessment (17, 18).

It was decided to only include this variable in the multivariate regression if the rate of missing data was less than 5%. Body mass index (BMI) has been associated with mortality and length of stay in critically ill patients; however, prior studies report heterogeneous and nonlinear effects across BMI categories (19–21). Given this complexity and the inclusion of covariates that more directly reflect acute disease severity (e.g., SAPS II score and vasoactive drug use), BMI was not prioritized as a covariate in the models. Biological sex is associated with differences in illness severity, treatment, and mortality among ICU patients (22–24). It was thus included in the models.

Outcome Measures

ICU length of stay and in-hospital mortality were chosen as primary outcome measures.

Data Acquisition

All patient data obtained during hospital stay are captured in the electronic health records and stored at the Data Integration Center of the University Medical Center Mannheim, Germany. Data were transferred to a relational database and specific data points were retrieved using a standard database query language.

Ethics Statement

This retrospective study was conducted according to the principles of the 1964 Helsinki declaration and its later amendments. The ethics committee II of the university Heidelberg, medical faculty Mannheim approved this study (original study title "Predictors of Ventilation and Outcomes in Critically Ill Patients," approval number 2022-824, approval date April 14, 2022) and waived the requirement for informed consent due to the retrospective nature of the study.

Statistical Analysis

Summaries of categorical variables are given in absolute numbers and group related percentages; summaries of metric variables are given as means and SD. For the primary endpoint, mortality risk evaluation of index variables and covariates, time-to-event analyses were conducted using Cox proportional hazards regression. To calculate the association between index variables and covariates and the secondary endpoint of length of stay, multivariate linear regression was used. Sensitivity analyses were performed by ventilation and medical vs. surgical ICUs.

As the study period largely overlapped with the COVID-19 pandemic, there may have been more frequent temporary placements of a single patient in a shared room due to an increased need for isolation rooms or staff shortages. To account for this potential source of misclassification, a sensitivity analysis was performed for both mortality and length of stay, excluding cases that were accommodated in shared rooms but never had a roommate.

Statistical analyses were performed using IBM SPSS Statistics, Version 29.0.1.0 (IBM, Armonk, NY).

RESULTS

Patients and Baseline Characteristics

There were 7889 patient stays identified with an ICU admission of at least 24 hours. Of those, 42 cases (0.5%) had no record of the appointed room and 1532 (19.4%) had changed rooms throughout their ICU stay and were thus excluded from this study. Descriptive analyses of cases excluded due to room change are reported in **eFigures 1–3** (https://links.lww.com/CCM/I47). One thousand twenty-two cases (13.0%) had no SAPS II data and were also excluded. All 5293 remaining cases (67.1%) had information on ICU length of stay, in-hospital mortality, vasopressor use, ventilation, and SAPS II obtainable and were included in the final analysis. Data were missing for lactate level in 388 cases (7%); thus, the variable was not included in the final analyses. **Figure 2** shows the study flow chart. Baseline characteristics collected within the first 24 hours of ICU stay are displayed in **Table 1**.

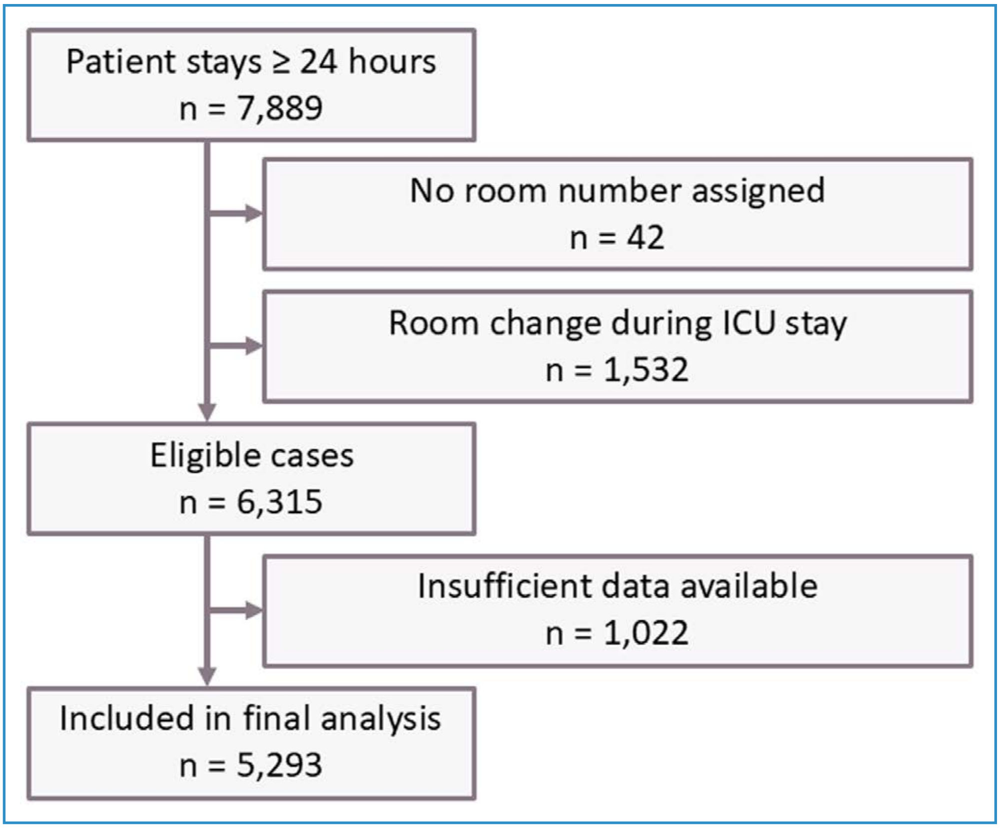

Figure 2. Study flow chart.

Overall Association of ICU Room Design and Layout Characteristics With Mortality and Length of Stay

None of the assessed index variables were associated with mortality in the primary analysis (**Table 2**).

Out of all index variables, only single rooms were associated with length of stay in both survivors and nonsurvivors. Compared with shared rooms, the mean length of stay was 0.81 days (95% CI, 0.04–1.57 d; $p = 0.039$) longer in survivors who had been admitted to single rooms (Table 2). Similarly, the mean length of stay was 1.73 days (95% CI, 0.16–3.30 d; $p = 0.031$) longer in nonsurvivors admitted to single rooms (**eTable 1**, https://links.lww.com/CCM/I47).

Sensitivity Analyses

Sensitivity analysis excluding cases in shared rooms that never had a roommate showed no association of any index variable with mortality or length of stay (**eTable 2**, https://links.lww.com/CCM/I47).

Sensitivity analysis by type of ventilation (none vs. noninvasive vs. mechanical ventilation) showed no association of any of the index variables with mortality or length of stay in these three subgroups (**eTable 3**, https://links.lww.com/CCM/I47).

Sensitivity analyses according to admission to medical vs. surgical ICU also showed no association of any index variable with mortality or length of stay in both groups, except for high-visibility rooms, which were associated with an increased mortality hazard compared with low-visibility rooms (hazard ratio [HR], 2.12; 95% CI, 1.07–4.21; $p = 0.032$) in surgical ICUs, but not medical ICUs (HR, 0.92; 95% CI, 0.70–1.23; $p = 0.581$; **eTable 4**, https://links.lww.com/CCM/I47).

DISCUSSION

Our retrospective study comprises the largest dataset to date assessing the association between aspects of ICU room design and layout and mortality as well as length of stay. The primary analysis, which included a mixed cohort of two medical and two surgical ICUs, suggests that single rooms compared with shared rooms with up to three beds, high-visibility rooms compared with low-visibility rooms, and the distances to both nurses' and doctors' charting areas are not associated with in-hospital mortality; however, admission to a single room is associated with increased length of stay.

We could not demonstrate reduced in-hospital mortality in single ICU rooms compared with shared rooms. It is possible that enclosed spaces with up to three patients do not negatively influence outcomes compared with single rooms.

This investigation is the first to undertake an adjusted mortality risk analysis for ICU architectural aspects. Previous studies that have reported mortality in relation to single rooms only provided univariate analyses as none of these studies had assessed mortality as a primary outcome, and mortality rates differed

TABLE 1.
Baseline Characteristics

No. of Participants, *n* (%)	5293	Missing Data, *n* (%)
Age (yr), mean ± SD	65 ± 16	0
Body mass index (kg/m^2), mean ± SD	27±6	335 (6)
Female sex, *n* (%)	2091 (40)	0
Simplified Acute Physiology Score II, mean ± SD	38±14	0
Mean arterial pressure (mm Hg), mean ± SD	82±11	0
Vasopressors, *n* (%)	2775 (52)	0
Lactate (mmol/L), mean ± SD	2.0±2.5	388 (7)
Ventilation, *n* (%)		0
None	2077 (39)	
Noninvasive	855 (16)	
Invasive	2361 (44)	
Admission: medical (vs. surgical), *n* (%)	3025 (57)	0
Admission to single room[a], *n* (%)	2888 (55)	0
Admission to high-visibility room[b], *n* (%)	2139 (40)	0
Distance nurse' charting area (m), mean ± SD	8±4	0
Distance doctors' charting area (m), mean ± SD	17±6	0
Length of stay, survivors (d), mean ± SD	6.3±9.2	0
Length of stay, nonsurvivors (d), mean ± SD	7.7±8.4	0
Mortality, *n* (%)	975 (18)	0

[a]Vs. shared room with up to three beds.
[b]Vs. low-visibility room.

greatly, ranging between 2.4% and 31.2% (9–11, 13, 25, 26). Different practices of patient allocation to single or shared rooms can affect the result of an unadjusted analysis.

High-visibility rooms showed no improved survival or length of stay in our overall cohort, similar to previous studies (14, 15). In the surgical subgroup, however, high-visibility rooms were associated with an increased mortality hazard. While more critically ill surgical or trauma patients have an inherently higher baseline mortality risk, these individuals are often prioritized to high-visibility rooms, which can confound association of room visibility and outcomes (14). Leaf et al (15) had reported an increased mortality in low vs. high-visibility rooms only in the most severely ill patients. Although our analysis was adjusted for established variables that represent patient acuity, differences in care complexity and room allocation might still have affected our results. Furthermore, all high-visibility rooms in this analysis were enclosed spaces with direct view to the patient only through the door of the room. There is no universally accepted definition on what constitutes a high-visibility room. Some relevant details may have been lost due to this partially obstructed view. Open bay areas with a complete view of the entire bed and the surrounding equipment could be advantageous in this respect.

Distances of nurses' and doctors' charting areas had no influence on mortality or ICU length of stay in this analysis. This is, to our knowledge, the first investigation with this question in an ICU setting. One previous report had shown no correlation of mortality and distances to charting areas in non-ICU wards (27). Charting area distances affect clinical outcomes by influencing staff fatigue, efficiency, frequency of patient contact, teamwork, and risk of error, as demonstrated by time and motion studies and human factors research in ICU settings (16, 28–30). Distances in our study ranged between 4.2 and 17.5 m (nurses) and 6.9 and 26.2 m (doctors). Our findings suggest that these

TABLE 2.
Overall Mortality and Length of Stay Risk Assessments

Mortality		
Index Variables	**Hazard Ratio (95% CI)**	***p***
Single room	0.89 (0.74–1.07)	0.223
High-visibility room	1.07 (0.87–1.30)	0.542
Distance to nurses' charting area	1.01 (0.98–1.04)	0.482
Distance to doctors' charting area	0.99 (0.97–1.01)	0.175
Covariates		
Female sex	0.89 (0.78–1.02)	0.088
SAPS II	1.05 (1.04–1.05)	< 0.001
Vasopressors	1.59 (1.32–1.93)	< 0.001
Mechanical ventilation	1.08 (0.93–1.27)	0.304
Admission: medical (vs. surgical)	1.30 (1.08–1.57)	0.005
Length of Stay (Survivors)		
Index Variables	**Regression Coefficient (95% CI)**	***p***
Single room	0.81 (0.04–1.57)	0.040
High-visibility room	0.09 (–0.74 to 0.91)	0.836
Distance to nurses' charting area	0.04 (–0.10 to 0.17)	0.594
Distance to doctors' charting area	0.01 (–0.07 to 0.09)	0.762
Covariates		
Female sex	0.71 (0.17–1.25)	0.010
SAPS II	0.05 (0.03–0.07)	< 0.001
Vasopressors	1.82 (1.17–2.48)	< 0.001
Mechanical ventilation	3.10 (2.45–3.75)	< 0.001
Admission: medical (vs. surgical)	−1.44 (−2.22 to −0.65)	< 0.001

SAPS II = Simplified Acute Physiology Score II.

distances might not notably affect overall survival or length of stay in ICU patients; however, only distance between locations, not actual response time to emergencies or other human factor outcomes, could be investigated in this retrospective study.

We found an association of single rooms with a mean increase in length of stay by almost 1 day in the overall cohort. However, when cases that were accommodated in a shared room but never had a roommate during their ICU stay were excluded, there was no difference between single and shared rooms in both mortality and length of stay. A previous investigation had reported a 10% decrease in length of stay when a hospital changed from two 12-bed rooms to a single-room-only ICU (31), and another did not find differences in length of stay with a similarly designed study (9). As the largest shared rooms in our analysis accommodated a maximum of three patients at a time, comparability between the cited studies and ours is thus limited. Why there were no clear benefits of single rooms for the investigated outcomes in our analysis is uncertain. Our findings might be influenced by clinical workflow patterns, including isolation requirements, extended palliative treatment phases, or delayed transfer processes, which might be more prevalent in single rooms. However, these aspects could not be investigated in this retrospective study.

While literature and prevailing opinion suggest a move away from large multibed rooms, the proportion of single-patient rooms varies significantly by region and hospital type. Albeit most high-income countries transition toward single room only, a large survey across 20 Asian countries in 2020 found only 37% of ICU rooms were single-patient rooms, and many ICUs had no single rooms at all (32). In Australia, there is a trend toward increasing single-room use, but shared rooms are still common (33). Implementation of single-patient rooms has been described to be limited by infrastructure, cost, and local policy (5, 34). Our findings indicate that modern ICUs might not necessarily require a single-room-only design. A certain number of single rooms is necessary for isolation purposes; however, the rest of the ICU consisting of two or three bed rooms was associated with similar mortality and length of stay in our analysis. Albeit single rooms incur higher initial construction and operational costs, a simulation case study suggested an improved 5-year cost efficiency of single rooms (7). This is attributed to meta-analyses and cohort studies demonstrating reduced nosocomial infection rates, multidrug-resistant organism acquisition, and bacteremia compared with multipatient rooms, which could translate to into fewer complications, decreased ICU length of stay, and lower overall costs (8, 25, 31). These reports do, however, contrast with the findings in our study. Prospective multicenter investigations are needed to improve generalizability and account for institutional variability in ICU design and clinical practices to guide future ICU design.

There are several limitations to bear in mind when interpreting our results. First, this is a retrospective study; thus, causal relationships could not be investigated. The design also prohibited investigation of measures of ICU strain, acute care unit bed occupancy, or more detailed therapeutic interventions, and information on isolation status and infection data were unavailable for this analysis. Data on transfer patterns, patient acuity on transfer day, hospital capacity, and other factors that might impact length of stay were also not available. Second, although a mixed cohort of four ICUs was included, due to the monocentric design results cannot be generalized outside of the current setting and country. In addition, previous studies have primarily compared single rooms with open bay areas, which were not present in any of the ICUs in our study. This, as well as varying definitions of high-visibility rooms, further complicate comparability with existing literature. Furthermore, room assignment in this study was not random, but guided by clinical and operational needs such as isolation precautions or bed availability. Therefore, residual confounding by indication cannot be excluded, even after multivariable adjustment. Furthermore, institutional workflow and monitoring structures may influence the relationship between room configuration and outcomes. These organizational aspects could not be investigated in this retrospective cohort. Last, only institutional outcomes were investigated in this study. More patient-centered outcomes, such as privacy, cognitive function, and mental health, could not be investigated, but are highly relevant for decisions regarding ICU design. Mortality and length of stay were used as global outcome measures; however, we acknowledge that they may not capture intermediate safety events potentially influenced by room design (e.g., delayed detection of patient deterioration or device dislodgement), which were not available in this dataset. Our findings do, however, suggest that these aspects of ICU design should be investigated further before any final conclusions can be drawn.

CONCLUSIONS

In this large, mixed cohort comprising medical and surgical ICUs, accommodation in single rooms was not associated with improved mortality or a shorter length of stay in the ICU compared with shared rooms containing up to three beds. Our findings do not support the assumption that the ideal ICU should only consist of single-bed rooms. Differences in distances to nurses' or doctors' charting areas, as well as visibility of patients in the rooms were not associated with the assessed outcomes. Although generalizability of these findings is limited, they add to the literature and should encourage further investigations of ICU design.

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Dr. Lindner takes responsibility for the integrity of the data and the accuracy of the data analysis. Dr. Lindner affirms that the article is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained. Drs. Lindner, Duerschmied, Becher, and Britsch were involved in conceptualization. Dr. Britsch was involved in data curation. Drs. Lindner and Britsch were involved in formal analysis. Drs. Becher and Britsch were involved in project administration. Drs. Duerschmied, Krebs, and Britsch were involved in supervision. Dr. Lindner was involved in writing–original draft. Drs. Britsch, Duerschmied, Conrad, Krebs, Becher, and Britsch were involved in writing–review and editing. All authors had full access to statistical reports and tables.

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The data that support the findings of this study are available from the corresponding author upon reasonable request.

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