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The Effects of Weekend Admission on the Mortality of Patients Admitted to Intensive Care Units: The Role of Organizational Factors

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Abstract

Objectives: To assess whether intensive care unit (ICU) organizational and staffing patterns are related to the association between weekend admission and worse outcomes in critically ill patients.

Design: Prospective cohort study

Setting: 78 participating Brazilian ICUs

Participants: 59,614 patients admitted during 2013

Primary and Secondary Outcomes Measures: Weekend admission was defined as admission from Friday 7pm until Monday 7am. We assessed the association between weekend admission with hospital mortality using a mixed logistic regression model controlling for both patient-level (illness severity, age, comorbidities, performance status and admission type) and ICU-level confounders (decrease in nurse/bed ratio on weekend, intensivist full-cover, use of checklists on weekends and number of institutional protocols). Secondary analyses were performed in scheduled surgical admissions.

Results: A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) on weekends. In univariate analysis, weekend admitted patients had higher ICU (10.9% vs. 9.0%, p<0.001) and hospital (16.5% vs. 13.5%, p<0.001) mortality. After adjusting for confounders, weekend admission was not associated with higher hospital mortality (OR 1.05, 95% CI 0.99-1.12, p=0.095). However, a “weekend effect” was still observed in scheduled surgical admissions, as well as in ICUs not holding checklists during the weekends. For unscheduled admissions, no “weekend effect” was observed regardless of ICU´s characteristics. For scheduled surgical admissions, a “weekend effect” was present only in ICUs with a reduction in the nurse/bed ratio during weekends, without weekend checklists and with a low number of implemented protocols

Conclusions: Weekend admission is associated with higher mortality in situations related to potentially modifiable factors.

Strengths and limitations of this study

- Large prospective cohort of 78 Brazilian ICUs; results may not be generalized to other settings (for example, where elective surgeries do not occur on weekends or where nurse/bed ratio is consistently higher)
- Appropriate assessment of illness severity, comorbidities and reasons for admission
- Independent effect of weekend admission assessed while controlling for patient-level and center-level variables
- Other relevant endpoints besides hospital mortality, such as ICU or hospital readmissions, were not assessed

Ethical approval: This study was locally approved in all participating intensive care units. Consent form was waived due to the retrospective nature of the analysis.

Availability of data: Data is not publically available due to local ethical restrictions.

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Conflicts of interest: Dr. Soares and Dr. Salluh are founders and equity shareholders of Epimed Solutions®, which commercializes the Epimed Monitor System®, a cloud-based software for ICU management and benchmarking. The other authors declare that they have no conflict of interest.

Introduction

Higher mortality for patients admitted during the weekends has been repeatedly reported in studies carried out in both wards (1,2) and intensive care units (ICU) (3,4). The so-called "weekend effect" is often ascribed to the imbalance of organizational and staffing features available on weekdays, which either do not occur or are suboptimal during the weekends (5). This notion has driven several health care policies, especially in England, where working scales for medical residents were reinforced on weekends to mitigate the impact on patients outcomes (6). This was followed by a great deal of discussion on the veracity of weekend effect due to uncertainties on the reliability of disease coding on admission during weekends (6,7) and biases related to different profiles of illness severity and comorbidities in weekend admitted patients (8,9).

Specifically, in the ICU setting, organization and staffing features do not include only intensivist full coverage (limiting the recognition and treatment of potentially life threatening complications and the establishment of a plan of care) and changes in nurse staff levels (which could compromise proper administration of prescription drugs, lower incidence of device removal, better pain control, among others (10)). Use of tools designed to sustain the continuity of care such as the use of checklists on weekends and number of institutional protocols available could also play a role (11). However, the association between these organizational characteristics and the weekend effect in ICUs were not thoroughly evaluated. We hypothesized that weekend effect would only occur in some scenarios when a clear disruption in the continuity of care would occur due to changes in ICU organization, staffing or clinical practices during the weekends. In the present study, we examined whether admissions during the weekends are associated with hospital mortality in a cohort of patients admitted to several ICUs. In addition, we investigated the

hypothesis that differences in ICU organizational features could explain an eventual increased mortality in weekend admitted patients.

Methods

Population: This was a *post hoc* analysis of a large cohort study in critically ill patients admitted in 78 Brazilian ICUs during 2013 from January 1st until December 31th (The ORCHESTRA Study) (11). From the initial database of 59,693 patients, we excluded 82 patients with missing admission date/hour, leaving 59,614 patients for analysis. In case of readmissions during the study period, we considered only the first ICU admission.

Exposure definitions: We defined weekend admission as any admission to the ICU occurring between Friday 7 pm and Monday 7 am.

Organizational factors: We considered several organizational factors in the analysis including the use of checklists (structured evaluations using a digital or printed instrument with multiple components focused on prevention of common ICU complications and adherence to best practices) during weekends, the implementation of protocols in the ICU (among a pre-defined set of ten protocols aiming at the adherence to best practices and prevention of acquired complications for frequent conditions in the ICU), the presence of intensivist full cover 24/7 in the ICU, mean nurse/bed ratio and ICU type. Intensivist full-cover was defined as the presence of a board-certified intensivist in the ICU 24 hours a day, 7 days a week. A low nurse/bed ratio was defined as any value ≤ 0.20 inside the ICU (that is, the mean nurse/bed ratio considering all shifts in the ICU was lower or equal to 0.20). This 0.20 cutoff was established after inspecting the univariate association between nurse/bed ratio and hospital mortality in a generalized additive model (sFigure 1; see Electronic Supplementary Material – ESM – for details).

Patient factors: We estimated organ failures and the severity of illness using the Sequential Organ Failure Assessment (SOFA) score (12) and the Simplified Acute Physiology Score (SAPS) 3 (13). The Charlson Comorbidity Index was calculated as previously reported (14). Baseline performance status was defined according to the impairment degree as absent/minor, moderate and severe corresponding to performance classes of Eastern Cooperative Oncology Group (ECOG) of 0-1, 2 or 3-4, respectively as previously described (15). Hospital length of stay before ICU admission was collected and stratified in tertiles for the analysis.

Missing values: No outcome data was missing. Baseline performance status was missing in 3,476 patients. Multiple imputation using random forest was used to impute missing values for this variable, as previously described (15). There were no other missing values in the variables included in the analysis.

Statistical Analysis: We used a mixed multivariate logistic regression to assess the independent association between each variables and hospital mortality at the patient level. The admission ICU was added as a random effect (random intercept) in the model while all the other variables were added as fixed effect. Continuous variables were scaled and centered before entering the mixed model. The following variables were included in the main model: age, SOFA score, Charlson Comorbidity Index, performance status impairment, admission type (medical, elective surgery, non-elective surgery), length-of-stay (LOS) before ICU admission stratified in tertiles, use of checklists during the weekends, presence of intensivist full-cover, low baseline nurse/bed ratio, ICU type (medical/surgical or other) and weekend admission. No stepwise selection was performed. Type of funding (public versus private) was not added to the model due to large colinearity with most organizational features.

Subgroup analyses: We defined that sensitivity analysis for the following subgroups would be performed: admission type; quartiles of baseline SAPS 3 score, patients admitted due to sepsis, patients admitted on mechanical ventilation, ICUs with or without a decrease in nurse/bed ratio during weekends, ICUs stratified per presence intensivist full cover, ICUs with or without checklist during the weekends, and according to number of ancillary protocols in the ICU (above or below the median values of protocols per ICU). We repeated the subgroups analyses of organizational features (decrease in nurse staff, absence of intensivist full cover, absence of checklist, and number of ancillary protocols) after stratifying our sample according to scheduled surgical versus non-scheduled ICU admissions (both emergency surgery and clinical) (16). Scheduled surgery admissions are defined as any admission after a surgical procedure which was scheduled at least 24 hours before its start and for which an ICU bed was requested before the procedure started.

Propensity score analysis: In an additional analysis, we performed a propensity score 1:1 analysis pairing patients per their predicted probability of weekend admission based solely on the patients' factors. The probability of weekend admission was obtained by creating a logistic regression with the following variables included as predictors: age, SOFA score, SAPS 3 score, Charlson Comorbidity Index, degree of performance status impairment, LOS before ICU admission and admission type. Patients were matched using the nearest neighbor method considering the logit as the distance method. At each matching, the unit with the closest logit still unmatched was used. After checking the balance of the propensity-matched groups, we compared hospital mortality for propensity-matched patients using chi-squared test.

All analyses were performed in R-project version 3.2.2 (17) with packages ggplot2, lme4, dplyr, tidyr and gridextra. A p value below 0.05 was considered significant. This report follows the STROBE guideline(18).

Results

Patients and ICU features:

Out of 59,693 patients admitted to the participating ICUs during the study period, 59,614 (99.9%) had available ICU admission date and hours and were elected for analysis. Main ICU and hospital characteristics are depicted in sTable 1 (see ESM). Most ICUs were private (sTable 1). A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) were admitted on weekends. The number of admissions decreased at weekends especially due to a decrease in elective surgeries but also due to a decrease in medical admissions (Figure 1). A comparison between patients admitted at weekend versus weekdays is shown in Table 1 and in sFigure 2. Patients admitted on weekends were more severely ill (higher SOFA and SAPS 3 scores) and more frequently admitted due to medical reasons than patients admitted during weekdays (Table 1). When compared to patients admitted during weekdays, a slightly lower percentage of weekend admissions occurred in ICUs with a low nurse/bed ratio (49.8% versus 48.6%, respectively; $p = 0.007$) and in units with less than eight protocols (46.9% versus 45.4%, respectively; $p = 0.001$) as shown in sFigure 2.

Table 1 – Comparisons between weekend and weekday admissions

	Weekday	Weekend	p
Number of Patients	41,894	17,720	-
Age (mean (SD))	61.99 (19.08)	63.10 (19.81)	<0.001
Male (n (%))	20,932 (50.0)	8,795 (49.6)	0.466
SAPS 3 (points) (mean (SD))	42.10 (14.94)	45.17 (14.71)	<0.001
SOFA score (points) (mean (SD))	2.31 (3.01)	2.49 (3.15)	<0.001
CCI (points) (mean (SD))	1.42 (1.87)	1.46 (1.91)	0.007
Performance status Impairment (n (%))			<0.001
Absent/Minor	32,107 (76.6)	13,079 (73.8)	
Moderate	7,165 (17.1)	3,288 (18.6)	
Severe	2,622 (6.3)	1,353 (7.6)	
Hospital LOS before ICU admission (median [IQR])	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	<0.001
Admission type (n (%))			<0.001
Medical	26,088 (62.3)	13,716 (77.4)	
Surgical (elective)	13,638 (32.6)	2,999 (16.9)	
Surgical (urgent)	2,168 (5.2)	1,005 (5.7)	
Admission Source (n (%))			<0.001
Operating Room	13,710 (32.7)	3,589 (20.3)	
Emergency	20,498 (48.9)	10,813 (61.0)	
Ward	2,925 (7.0)	1,530 (8.6)	
Home-care	147 (0.4)	70 (0.4)	
Other	168 (0.4)	63 (0.4)	
Other unit	793 (1.9)	310 (1.7)	
Hemodynamic Room	1,845 (4.4)	284 (1.6)	

Other hospital	1,495 (3.6)	907 (5.1)	
Step down unit	313 (0.7)	154 (0.9)	
Sepsis (n (%))	7,272 (17.4)	3,834 (21.6)	<0.001
Mechanical Ventilation on ICU Admission (n (%))	6,453 (15.4)	2,590 (14.7)	0.016
Mechanical Ventilation during ICU stay (n (%))	7,739 (19.1)	3,192 (18.7)	0.341
Vasopressors on ICU admission (n (%))	5,371 (12.9)	2,260 (12.8)	0.856
Vasopressors during ICU stay (n (%))	5,938 (14.6)	2,585 (15.2)	0.102
Renal replacement therapy on ICU admission (n (%))	1,074 (2.6)	597 (3.4)	<0.001
Renal replacement therapy during ICU stay (n (%))	1,922 (4.7)	1,034 (6.1)	<0.001
ICU LOS (median [IQR])	2.00 [1.00, 4.00]	2.00 [1.00, 5.00]	<0.001
Hospital LOS (median [IQR])	6.00 [2.00, 14.00]	7.00 [3.00, 16.00]	<0.001
ICU mortality (n (%))	3,790 (9.0)	1,918 (10.8)	<0.001
Hospital Mortality (n (%))	5,691 (13.6)	2,863 (16.2)	<0.001

Legend: SD=standard deviation; SAPS=Simplified Acute Physiology Score; SOFA=Sequential Organ Failure Score; CCI=Charlson Comorbidity Index; LOS=length of stay; ICU=intensive care unit; IQR=25%-75% interquartile range

Univariate analysis:

The overall ICU and hospital mortality rates were 9.5% and 14.4%. While hospital mortality for medical admissions per admission week day slightly fluctuated over the week, higher mortality was seen for elective surgical patients admitted on Sunday (Figure 2). For non-elective surgeries, large fluctuations were seen with a peak mortality for those admitted

on Tuesday (Figure 2). In univariate analysis, hospital mortality was significantly higher for patients admitted at weekends (16.2 versus 13.6%, OR 1.22, 95% CI 1.17-1.29; p<0.001).

Mixed model logistic regression:

After adjusting for relevant patient-level and ICU-level characteristics in the multivariable analysis, weekend admission was no longer associated with increased hospital mortality (OR 1.05, 95% CI 0.99-1.11; p = 0.095; full model reported in sTable 2; mixed effects shown on sFigure 3; center effect was markedly present). We present the results of the effect of weekend admission on hospital mortality in the several prespecified subgroups in Figure 3 and in sTables 3-19. A "weekend effect" was apparent for elective surgical admissions (OR 1.34; 95% CI 1.10-1.64; p=0.004; Figure 3 and sTable 4), in patients admitted to ICUs without checklists during the weekends (OR 1.08; 95% CI 1.00-1.17; p=0.045; Figure 3 and sTable 17). We did not find association between other organizational characteristics (nurse/bed ratio, presence of intensivist full cover 24/7 or the number of protocols) and increased mortality in patients admitted during the weekends.

Scheduled Surgical versus Unscheduled ICU admissions:

We repeated the analysis in separate for scheduled surgical admissions and unscheduled admissions (42,977 and 16,637 admission, respectively). Results are shown on Figure 4 and in sTables 20-37 of the ESM. A "weekend effect" was observed in scheduled surgical admissions. Accordingly, weekend effect was only present on scheduled surgical admissions when there was a decrease in weekend nurse/bed ratio (OR 1.40; 95% CI 1.09-1.79, p = 0.008), no weekend checklists (OR 1.41; 95% CI 1.09-1.83, p = 0.009) or a lower number of protocols (OR 1.42; 95%CI 1.06-1.89, p = 0.018) (Figure 4). There was no "weekend effect" in unscheduled admissions.

Propensity score results:

Out of the study population, 35,440 patients (17,720 weekend admissions and 17,720 weekdays admissions) were matched in the propensity score analysis. The distribution of variables in matched patients stratified per weekend effect is shown in supplementary Figure 4. Mortality was 15.5% for patients admitted on weekdays and 16.1% for those admitted during weekends (p=0.112).

Discussion

In the present study, we provide evidence that, after proper consideration of illness severity, patient´s background features and reason for admissions, the "weekend effect" is limited to specific scenarios such as for scheduled surgical admissions and/or when some organizational factors that are associated with disrupted continuity of care and adherence to best practices are present.

Although previous studies suggested an increase in mortality in patients admitted during the weekend(4), the "weekend effect" concept has been recently challenged (6). Criticism on reports suggesting the presence of weekend effect identified three major pitfalls in analysis: 1. Studies were performed using administrative databases and might suffer with inconsistent coding; 2. Comorbidities may have not been properly considered and 3. Illness severity might not be adequately accounted for. Black (6) cited three studies in which, after correction of these issues, the "weekend effect" was no longer significant.

In the present analysis, we intended to overcome some of the limitations summarized by Black (6). We based our analysis on a quality improvement administrative database that does not consider only International Classification of Diseases (ICD) coding for diagnosis, but it includes major predefined medical diagnosis (11). This database includes robust prospective clinical data collected at the bedside and not only

administrative and/or procedures notes. We also considered the presence of comorbidities and baseline health status by not only adjusting for Charlson Comorbidity Index but also to performance status impairment (14,15). Finally, severity of illness admission was assessed using well validated and widely accepted scores of severity of illness and organ failure (12,19,20). Our work does not corroborate with the hypothesis that the "weekend effect" is a universal feature in the ICUs. This is highlighted by both the main mixed regression model and by the propensity score analysis performed. In fact, when only unscheduled admissions were considered, no evidence of weekend effect was found regardless of the presence/absence of organizational features in the ICU; this is in accordance with recent reports of absence of weekend on unplanned ICU admissions (21). We could find evidence of a weekend effect only in secondary subgroup analyses, suggesting that it might be restricted to scenarios when there is a break in continuity of care during weekends, specifically the absence of patient-centered checklists (11,16), or for schedule admissions.

The case for worse outcomes for elective surgical admissions on weekends is complex, with both ICU and hospital features being able to explain, at least partly, this association (22,23). Differences in surgical care on weekends may play an important role. For example, early recognition and treatment of surgical complications may be delayed on weekends and even the adopted surgical procedure may be different for similar scenarios during weekends (24,25). In this way, checklists may aid at prompt recognition of complications (both clinical (26) and surgical (27)) and improve adherence to daily goals of care (28). Higher nurse staffing may also aid at reducing postoperative complications(10). In our analysis, there was no weekend effect in scheduled surgical admissions in units that did not have a decrease in nurse/bed ratio on weekends or that applied checklists on weekends, thereby corroborating to this concept.

Interestingly, several factors potentially related to worse care on weekends did not reach statistical significance in the whole studied population. Despite the rationale for increased mortality when there is a decrease in nurse/bed ratio during weekend (29) or when there is an absence of full intensivist coverage (30), we did not find evidence of weekend effect in both scenarios when all admissions types were considered. It is conceivable that well-structured ICUs with weekend checklists and protocols would be less susceptible to the variation in care driven by the decrease in staff during weekends, thereby mitigating the effect of the latter on mortality. This, however, was only apparent for scheduled surgical admissions in our analysis.

Our analysis has several constrains. First, albeit the large number of ICUs involved, our results refer to a selected sample of units from a single country and caution is needed when generalizing to other settings. Second, most patients were mostly admitted to private units and had a medium-low illness severity, thereby resulting in a low average mortality. However, no weekend effect was demonstrated in the subgroup analysis per the severity of illness and in septic or mechanically ventilated patients. Third, some local particularities should be considered when interpreting our manuscript, such as the low nurse/bed ratio reported which is common in Brazil and are in accordance with local regulations (up to 10 beds per nurse in the ICUs) and the occurrence of elective surgeries during weekends (which is common due to ICU beds shortage). Forth, we were unable to assess interactions between the several organizational features. Frequently several organizational features occur together and may have synergistic (or even antagonist) effects that should be properly explored in the future. Fifth, we only assessed ICU organizational factors; structure, organizational and staffing patterns at the emergency departments and wards may also play

an important role in determining hospital outcome. Finally, we did not assess other relevant outcomes such as readmissions and longer follow-up mortality.

Conclusion

After considering an appropriate disease coding and accounting for comorbidities, illness severity and ICU organization characteristics a "weekend effect" was noticed in patients admitted after scheduled surgical admissions. Other factors such as decrease in nurse/bed ratio and absence of checklists during the weekend and low number of ICU protocols could also explain weekend effect.

List of abbreviations:

CI – Confidence Interval

ECOG - Eastern Cooperative Oncology Group

ESM – Electronic Supplementary Material

ICU – Intensive Care Unit

LOS – Length of Stay

OR – Odds ratio

SAPS - Simplified Acute Physiology Score

SOFA – Sequential Organ Failure

Authors' contributions: FGZ, MS, JIS, TDC and TCL developed the concept of the manuscript. All authors collect data and obtained approval at their local ethics committee. FGZ, MS, JIS, TDC and TCL wrote the manuscript; the remaining authors reviewed the

manuscript for important intellectual content. FGZ, MS and JIS performed statistical analyses. All authors approved the final version of the manuscript.

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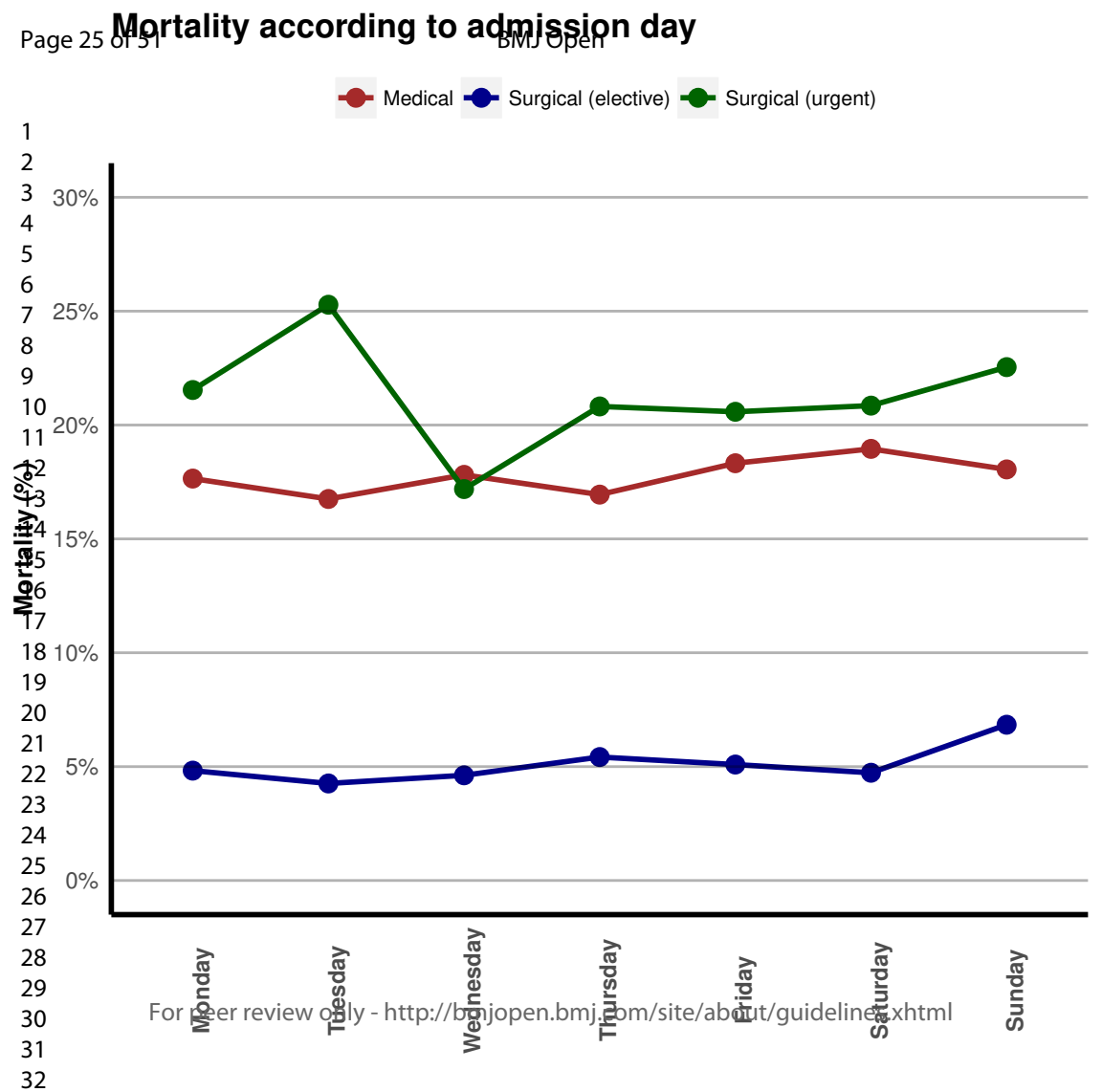
Figure Legends

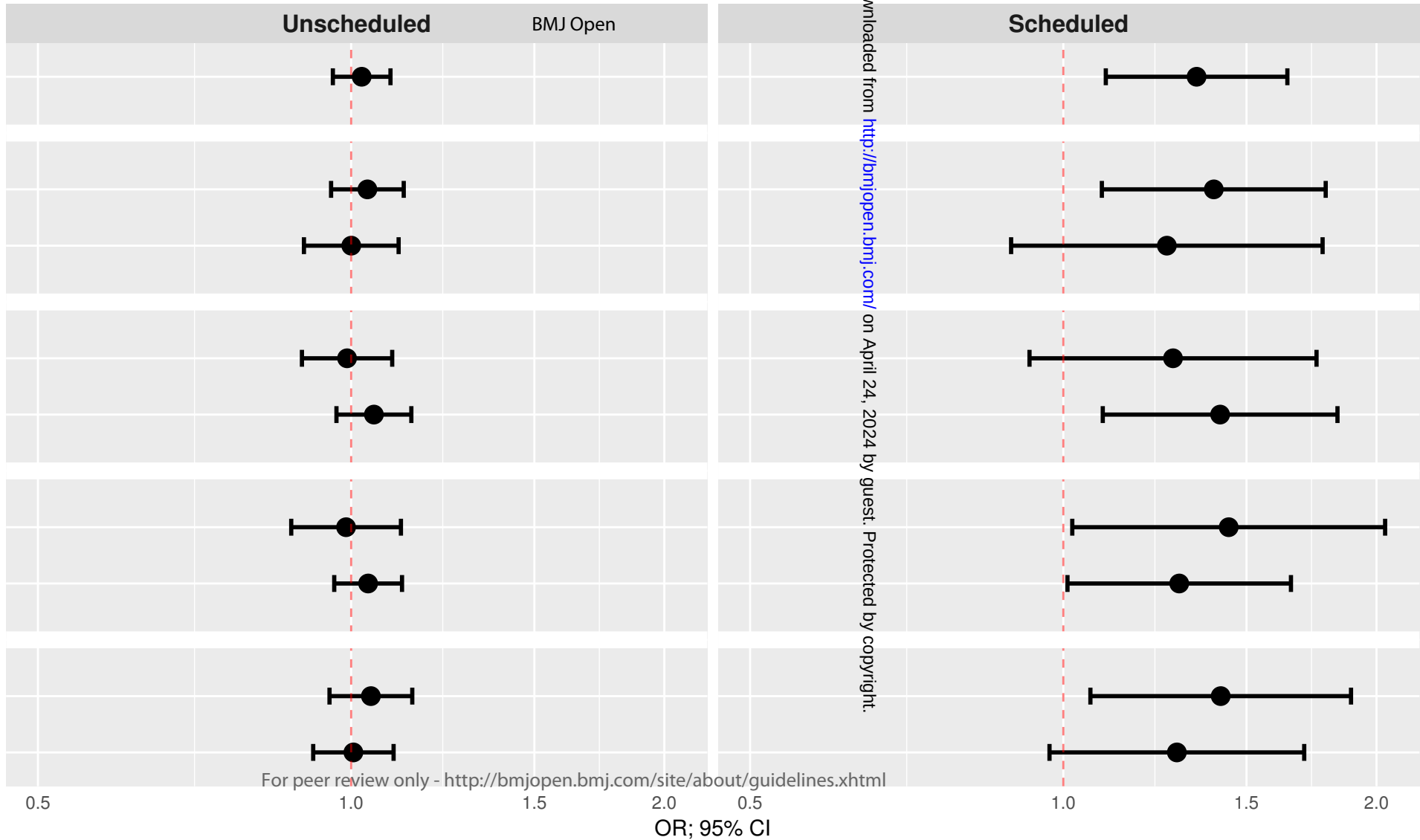
Figure 1 – (A) Number of patients admitted to the ICU at each day of the week; (B) Distribution of admission types at each week day.

Figure 2 – Mortality at each day of the week stratified by admission type.

Figure 3 – Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality in the whole population (upper line) and in selected subgroups (see main text for details).

Figure 4 - Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality stratified in unscheduled (left) and scheduled surgical (right) admissions. Further subgroup analyses according to presence/absence of organizational factors are presented





The Effects of Weekend Admission on the Mortality of Patients Admitted to Intensive Care Units: The Role of Organizational Factors

ELECTRONIC SUPPLEMENTARY FILE

ICU and Hospital Features

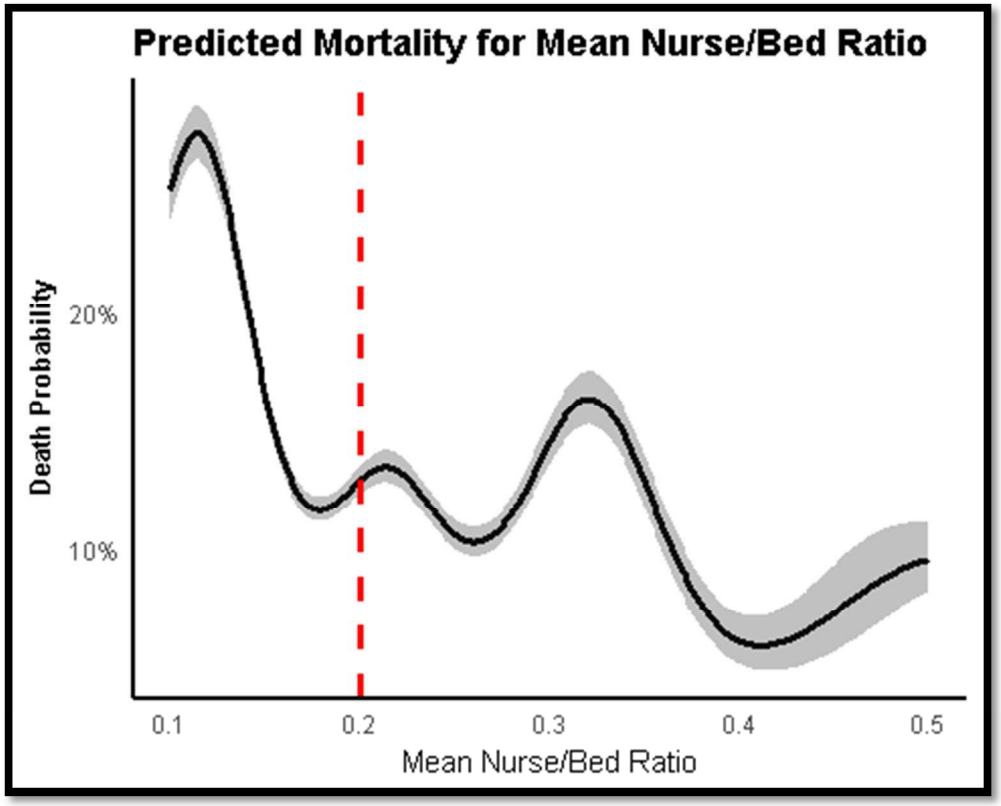
Supplementary Table 1: ICU Features

Number of Units	78
Bed per unit, mean (SD)	17.53 (11.38)
Private hospital, n (%)	67 (85.9)
Accreditation	
None	24 (30.8)
National	30 (38.5)
International	24 (30.8)
Weekend checklists, n (%)	36 (46.2)
Intensivist Full cover, n(%)	16 (20.5)
Nurse/Bed ratio < 0.2	41 (52.6)
Protocols, mean (SD)	6.96 (2.88)
Medical/Surgical Unit, n (%)	62 (79.5)

Univariate Analysis

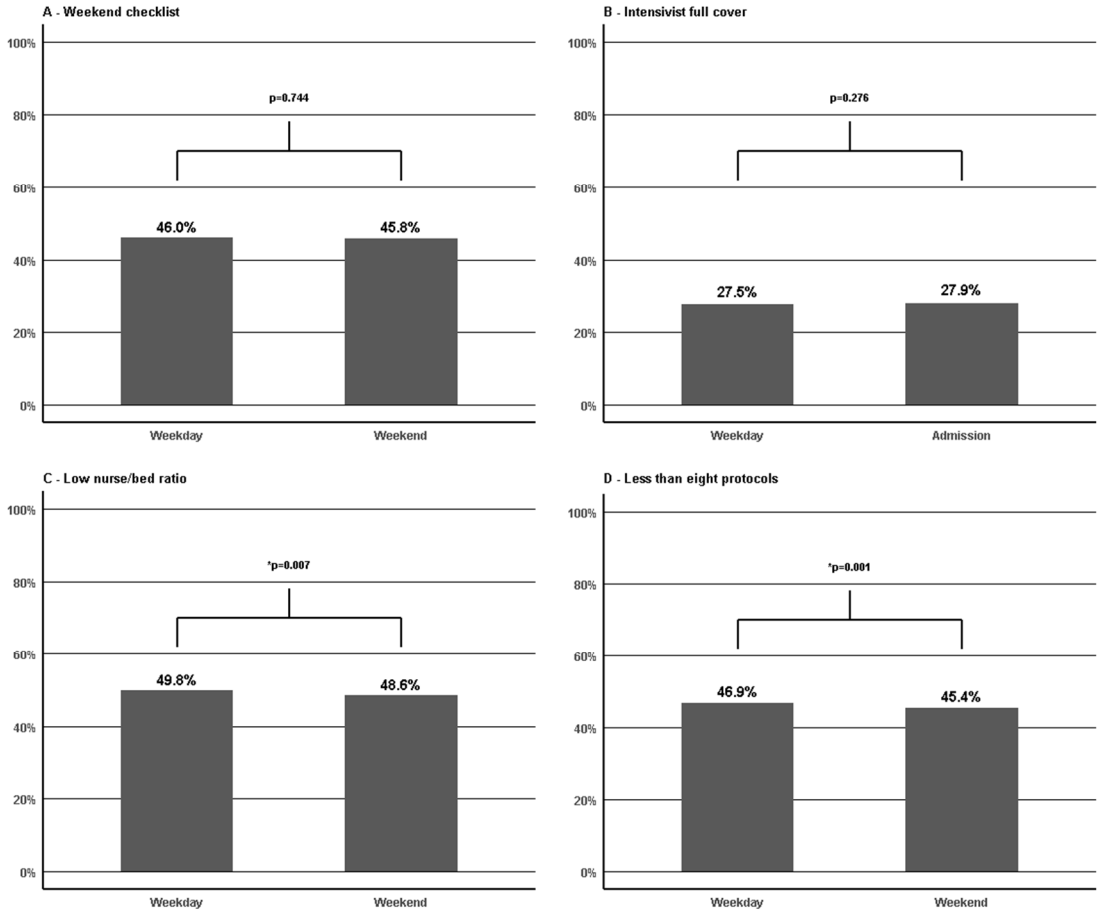
Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

The association between nurse/bed ratio and hospital mortality was assessed using a generalized additive model using the mgcv package. The 0.2 cutoff was chosen by inspecting the plot of predicted probabilities and hospital mortality (red dashed line in the plot).



Percentage of admissions to unit with specific organizational feature

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B - Intensivist fullcover; C - Low nurse/bed ration; D - Less than eight protocols



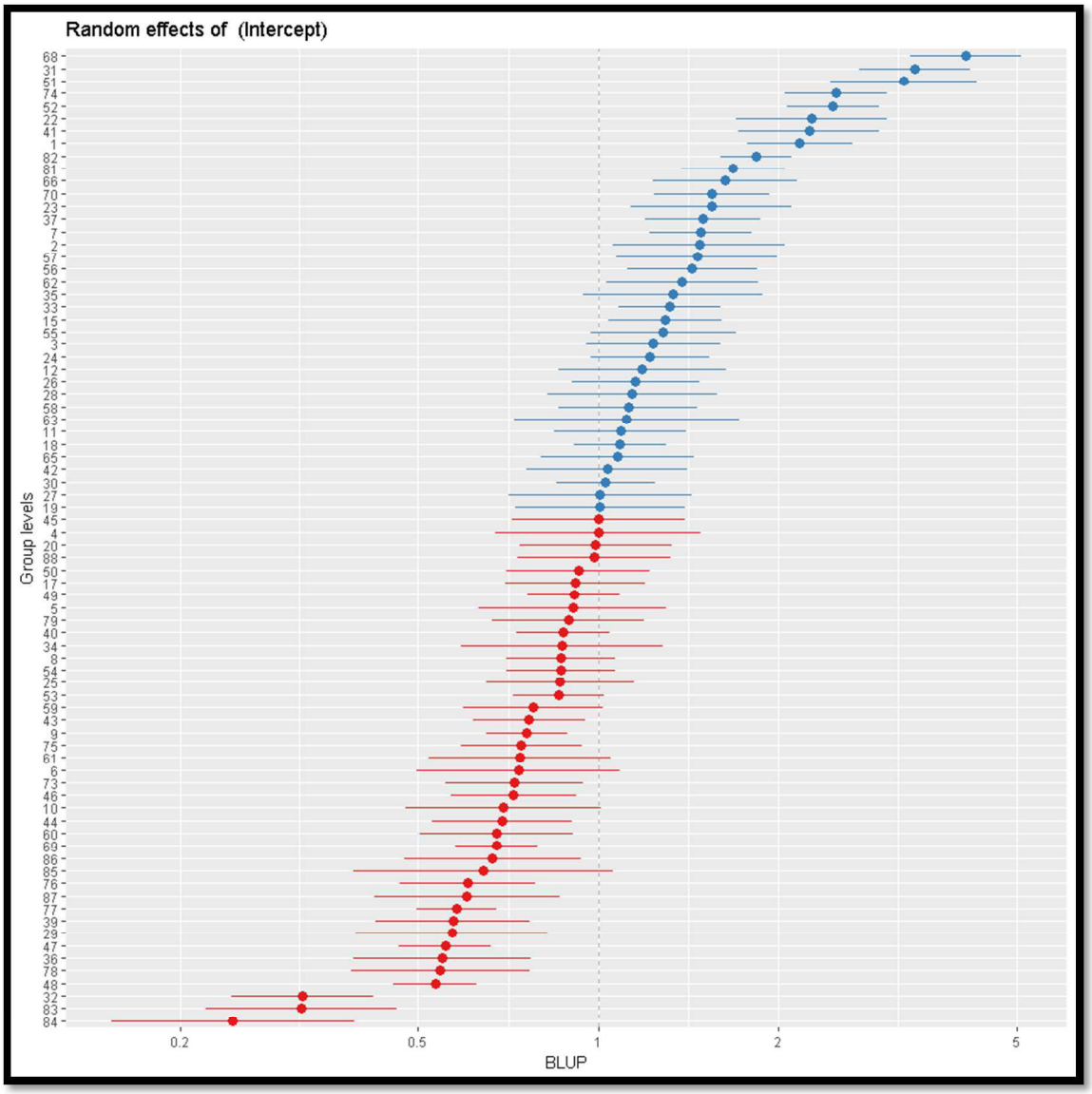
Models Results

Synthax: Mortality ~ Age + SOFA + Charlson Comorbidity Index + Performance Status Impairment + LOS before ICU admission (tertile) + Admission Type + Checklist on Weekends + Intensivist Full Cover + Nurse/Bed lower than 0.2 + Number of Protocols + Medical/Surgical Unit + ICU (random intercept).

Note: Continuous variables were scaled and centered to reduce non-convergence issues; marked with an * through document.

Supplementary Table 2: Results for main model

	OR	CI	p
Age*	1.60	1.55-1.66	<0.001
SOFA*	2.50	2.43-2.57	<0.001
CCI*	1.44	1.41-1.48	<0.001
Moderate Impairment	1.32	1.22-1.42	<0.001
Severe Impairment	2.04	1.86-2.24	<0.001
LOS 1 day	1.17	1.07-1.27	<0.001
LOS >= 2 days	2.44	2.26-2.62	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.76	0.67-0.86	<0.001
Weekend Checklist	0.97	0.74-1.26	0.814
Intensivist full cover	0.98	0.72-1.33	0.887
Nurse/Bed <0.2	1.32	1.03-1.7	0.027
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.45	1.06-1.98	0.018
Weekend Admission	1.05	0.99-1.12	0.095



Supplementary Figure 3: Plot of Random Effects

Subgroups

Supplementary Table 3: Medical Patients

	OR	CI	p
Age*	1.56	1.50-1.62	<0.001
SOFA*	2.49	2.42-2.58	<0.001
CCI*	1.46	1.42-1.51	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	1.94	1.76-2.15	<0.001
LOS 1 day	1.14	1.04-1.26	0.008
LOS >= 2 days	2.54	2.34-2.76	<0.001
Weekend Checklist	0.96	0.74-1.24	0.742
Intensivist full cover	1.04	0.77-1.41	0.802
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.41	1.04-1.91	0.028
Weekend Admission	1.02	0.96-1.09	0.498

Supplementary Table 4: Elective Surgical Patients

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Intensivist full cover	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.1-1.64	0.004

Supplementary Table 5: Urgent Surgical Patients

	OR	CI	p
Age*	1.97	1.73-2.24	<0.001
SOFA*	2.51	2.27-2.77	<0.001
CCI*	1.38	1.23-1.54	<0.001
Moderate Impairment	1.10	0.82-1.48	0.526
Severe Impairment	2.34	1.50-3.65	<0.001
LOS 1 day	0.98	0.73-1.31	0.891
LOS >= 2 days	1.43	1.10-1.85	0.008
Weekend Checklist	0.88	0.53-1.47	0.635
Intensivist full cover	0.86	0.50-1.49	0.596
Nurse/Bed <0.2	1.30	0.81-2.11	0.279
Protocols	0.87	0.80-0.95	0.002
surgicalu/Surgical Unit	1.07	0.56-2.05	0.837
Weekend Admission	1.01	0.8-1.27	0.956

Supplementary Table 6: SAPS Quartile 1(5-34)

	OR	CI	p
Age*	1.72	1.43-2.06	<0.001
SOFA*	2.35	1.96-2.82	<0.001
CCI*	1.18	0.96-1.46	0.108
Moderate Impairment	2.11	1.41-3.15	<0.001
Severe Impairment	3.68	1.83-7.39	<0.001
LOS 1 day	1.13	0.77-1.66	0.518
LOS >= 2 days	2.70	1.90-3.83	<0.001
Surgical (elective)	0.37	0.25-0.55	<0.001
Surgical (urgent)	0.86	0.46-1.63	0.655
Weekend Checklist	0.93	0.57-1.52	0.778
Intensivist full cover	1.06	0.63-1.77	0.827
Nurse/Bed <0.2	1.07	0.67-1.68	0.786
Protocols	0.83	0.76-0.90	<0.001
Medical/Surgical Unit	1.40	0.78-2.52	0.257
Weekend Admission	1.34	0.98-1.82	0.070

Supplementary Table 7: SAPS Quartile 2 (34-42)

	OR	CI	p
Age*	1.38	1.22-1.57	<0.001
SOFA*	2.08	1.84-2.36	<0.001
CCI*	1.47	1.33-1.62	<0.001
Moderate Impairment	1.34	1.04-1.73	0.022
Severe Impairment	2.75	1.87-4.06	<0.001
LOS 1 day	1.32	1.02-1.71	0.035
LOS >= 2 days	2.62	2.04-3.36	<0.001
Surgical (elective)	0.55	0.41-0.72	<0.001
Surgical (urgent)	0.70	0.47-1.04	0.079
Weekend Checklist	0.94	0.62-1.42	0.766
Intensivist full cover	0.83	0.52-1.32	0.422
Nurse/Bed <0.2	1.38	0.94-2.02	0.104
Protocols	0.91	0.84-0.98	0.009
Medical/Surgical Unit	1.81	1.10-2.97	0.020
Weekend Admission	1.17	0.96-1.43	0.117

Supplementary Table 8: SAPS Quartile 3 (42-53)

	OR	CI	p
Age*	1.23	1.15-1.32	<0.001
SOFA*	1.98	1.85-2.13	<0.001
CCI*	1.32	1.25-1.39	<0.001
Moderate Impairment	1.44	1.26-1.65	<0.001
Severe Impairment	2.44	2.05-2.90	<0.001
LOS 1 day	1.18	1.02-1.38	0.030
LOS >= 2 days	2.39	2.07-2.77	<0.001
Surgical (elective)	0.52	0.42-0.63	<0.001
Surgical (urgent)	0.74	0.59-0.93	0.011
Weekend Checklist	1.06	0.81-1.40	0.651
Intensivist full cover	0.98	0.71-1.35	0.902
Nurse/Bed <0.2	1.30	1.00-1.68	0.047
Protocols	0.93	0.89-0.98	0.007
Medical/Surgical Unit	1.40	1.01-1.94	0.041
Weekend Admission	1.05	0.94-1.17	0.393

Supplementary Table 9: SAPS Quartile 4 (53-132)

	OR	CI	p
Age*	1.15	1.09-1.21	<0.001
SOFA*	1.92	1.85-2.00	<0.001
CCI*	1.26	1.22-1.30	<0.001
Moderate Impairment	1.18	1.07-1.30	0.001
Severe Impairment	1.66	1.47-1.86	<0.001
LOS 1 day	1.07	0.95-1.20	0.283
LOS >= 2 days	1.91	1.74-2.10	<0.001
Surgical (elective)	0.42	0.33-0.52	<0.001
Surgical (urgent)	0.99	0.84-1.17	0.931
Weekend Checklist	0.92	0.72-1.17	0.488
Intensivist full cover	0.92	0.70-1.22	0.567
Nurse/Bed <0.2	1.35	1.08-1.70	0.009
Protocols	0.94	0.90-0.98	0.005
Medical/Surgical Unit	1.33	1.00-1.78	0.053
Weekend Admission	1.00	0.92-1.09	0.979

Supplementary Table 10: Patients admitted due to sepsis

	OR	CI	p
Age*	1.51	1.42-1.60	<0.001
SOFA*	2.19	2.08-2.30	<0.001
CCI*	1.42	1.35-1.49	<0.001
Moderate Impairment	1.31	1.15-1.50	<0.001
Severe Impairment	1.55	1.34-1.80	<0.001
LOS 1 day	1.08	0.92-1.25	0.353
LOS >= 2 days	2.18	1.91-2.50	<0.001
Weekend Checklist	0.90	0.69-1.19	0.460
Intensivist full cover	0.95	0.69-1.30	0.755
Nurse/Bed <0.2	1.49	1.15-1.92	0.002
Protocols	0.92	0.88-0.97	0.001
Medical/Surgical Unit	1.24	0.87-1.78	0.232
Weekend Admission	1.02	0.91-1.13	0.737

Supplementary Table 11: Patients that required mechanical ventilation on day 1

	OR	CI	p
Age*	1.61	1.52-1.71	<0.001
SOFA*	1.74	1.66-1.83	<0.001
CCI*	1.30	1.24-1.37	<0.001
Moderate Impairment	1.18	1.02-1.35	0.022
Severe Impairment	1.03	0.87-1.21	0.769
LOS 1 day	1.01	0.87-1.18	0.878
LOS >= 2 days	1.64	1.45-1.86	<0.001
Surgical (elective)	0.17	0.15-0.20	<0.001
Surgical (urgent)	0.59	0.50-0.69	<0.001
Weekend Checklist	0.99	0.72-1.36	0.959
Intensivist full cover	0.91	0.64-1.29	0.590
Nurse/Bed <0.2	1.42	1.06-1.90	0.018
Protocols	0.96	0.91-1.01	0.133
Medical/Surgical Unit	1.12	0.76-1.66	0.553
Weekend Admission	1.07	0.96-1.2	0.228

Supplementary Table 12: ICUs with nurse decrease on weekends

	OR	CI	p
Age*	1.52	1.45-1.59	<0.001
SOFA*	2.50	2.41-2.59	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.31	1.2-1.44	<0.001
Severe Impairment	1.88	1.67-2.12	<0.001
LOS 1 day	1.17	1.05-1.30	0.004
LOS >= 2 days	2.46	2.25-2.69	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.73	0.63-0.85	<0.001
Weekend Checklist	1.14	0.85-1.52	0.391
Intensivist full cover	0.92	0.65-1.30	0.629
Nurse/Bed <0.2	1.31	0.99-1.73	0.056
Protocols	0.92	0.87-0.98	0.007
Medical/Surgical Unit	1.17	0.80-1.73	0.421
Weekend Admission	1.07	0.99-1.15	0.085

Supplementary Table 13: ICUs with no nurse decrease on weekend

	OR	CI	p
Age*	1.76	1.66-1.86	<0.001
SOFA*	2.50	2.38-2.62	<0.001
CCI*	1.45	1.39-1.52	<0.001
Moderate Impairment	1.34	1.18-1.51	<0.001
Severe Impairment	2.37	2.03-2.76	<0.001
LOS 1 day	1.17	1.02-1.34	0.025
LOS >= 2 days	2.39	2.11-2.71	<0.001
Surgical (elective)	0.24	0.21-0.28	<0.001
Surgical (urgent)	0.81	0.66-0.99	0.040
Weekend Checklist	0.74	0.45-1.20	0.222
Intensivist full cover	1.08	0.62-1.88	0.783
Nurse/Bed <0.2	1.50	0.93-2.42	0.094
Protocols	0.94	0.87-1.01	0.085
Medical/Surgical Unit	1.97	1.18-3.27	0.009
Weekend Admission	1.02	0.93-1.13	0.642

Supplementary Table 14: ICUs with intensivist fullcover

	OR	CI	p
Age*	1.63	1.53-1.74	<0.001
SOFA*	2.21	2.09-2.33	<0.001
CCI*	1.33	1.26-1.40	<0.001
Moderate Impairment	1.35	1.16-1.57	<0.001
Severe Impairment	2.12	1.73-2.59	<0.001
LOS 1 day	1.03	0.87-1.23	0.695
LOS >= 2 days	2.40	2.10-2.75	<0.001
Surgical (elective)	0.21	0.17-0.25	<0.001
Surgical (urgent)	0.65	0.51-0.82	<0.001
Weekend Checklist	1.27	0.65-2.48	0.493
Nurse/Bed <0.2	1.49	0.77-2.87	0.240
Protocols	0.90	0.81-0.98	0.022
Medical/Surgical Unit	1.13	0.49-2.64	0.773
Weekend Admission	1.03	0.92-1.16	0.584

Supplementary Table 15: ICUs without intensivist fullcover

	OR	CI	p
Age*	1.60	1.54-1.67	<0.001
SOFA*	2.62	2.53-2.71	<0.001
CCI*	1.49	1.44-1.53	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	2.02	1.82-2.25	<0.001
LOS 1 day	1.21	1.10-1.34	<0.001
LOS >= 2 days	2.42	2.22-2.64	<0.001
Surgical (elective)	0.26	0.23-0.29	<0.001
Surgical (urgent)	0.80	0.70-0.93	0.002
Weekend Checklist	0.91	0.69-1.22	0.535
Nurse/Bed <0.2	1.33	1.02-1.74	0.034
Protocols	0.95	0.90-1.00	0.057
Medical/Surgical Unit	1.47	1.06-2.03	0.020
Weekend Admission	1.06	0.99-1.14	0.094

Supplementary Table 16: ICUs with checklists

	OR	CI	p
Age*	1.69	1.60-1.79	<0.001
SOFA*	2.56	2.44-2.68	<0.001
CCI*	1.45	1.40-1.51	<0.001
Moderate Impairment	1.41	1.25-1.58	<0.001
Severe Impairment	2.30	2.00-2.64	<0.001
LOS 1 day	1.23	1.08-1.41	0.003
LOS >= 2 days	2.57	2.29-2.89	<0.001
Surgical (elective)	0.28	0.24-0.32	<0.001
Surgical (urgent)	0.70	0.57-0.86	0.001
Intensivist full cover	1.16	0.71-1.91	0.554
Nurse/Bed <0.2	1.18	0.85-1.64	0.314
Protocols	0.97	0.91-1.04	0.44
Medical/Surgical Unit	1.56	1.04-2.34	0.031
Weekend Admission	1.01	0.92-1.11	0.816

Supplementary Table 17: ICUs without checklist

	OR	CI	p
Age*	1.55	1.49-1.63	<0.001
SOFA*	2.46	2.37-2.55	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.25	1.14-1.38	<0.001
Severe Impairment	1.84	1.62-2.09	<0.001
LOS 1 day	1.13	1.01-1.26	0.034
LOS >= 2 days	2.35	2.15-2.58	<0.001
Surgical (elective)	0.22	0.20-0.25	<0.001
Surgical (urgent)	0.78	0.67-0.90	0.001
Intensivist full cover	0.91	0.61-1.35	0.627
Nurse/Bed <0.2	1.53	1.04-2.25	0.032
Protocols	0.91	0.86-0.97	0.003
Medical/Surgical Unit	1.53	0.94-2.49	0.086
Weekend Admission	1.08	1.00-1.17	0.045

Supplementary Table 18: ICUs with less than 8 protocols

	OR	CI	p
Age*	1.67	1.59-1.75	<0.001
SOFA*	2.48	2.38-2.58	<0.001
CCI*	1.42	1.37-1.48	<0.001
Moderate Impairment	1.36	1.22-1.51	<0.001
Severe Impairment	2.25	1.94-2.60	<0.001
LOS 1 day	1.20	1.06-1.35	0.005
LOS >= 2 days	2.11	1.90-2.34	<0.001
Surgical (elective)	0.26	0.23-0.30	<0.001
Surgical (urgent)	0.84	0.71-0.99	0.042
Weekend Checklist	0.76	0.51-1.12	0.168
Intensivist full cover	1.06	0.68-1.67	0.790
Nurse/Bed <0.2	1.68	1.13-2.51	0.011
Medical/Surgical Unit	2.17	1.23-3.82	0.007
Weekend Admission	1.08	0.99-1.18	0.088

Supplementary Table 19: ICUs with at least 8 protocols

	OR	CI	p
Age*	1.54	1.46-1.62	<0.001
SOFA*	2.51	2.42-2.61	<0.001
CCI*	1.46	1.41-1.51	<0.001
Moderate Impairment	1.29	1.17-1.43	<0.001
Severe Impairment	1.93	1.70-2.18	<0.001
LOS 1 day	1.13	1.01-1.27	0.035
LOS >= 2 days	2.78	2.52-3.07	<0.001
Surgical (elective)	0.22	0.19-0.25	<0.001
Surgical (urgent)	0.68	0.57-0.80	<0.001
Weekend Checklist	0.99	0.75-1.30	0.930
Intensivist full cover	0.80	0.55-1.15	0.231
Nurse/Bed <0.2	1.15	0.88-1.49	0.307
Medical/Surgical Unit	1.17	0.87-1.57	0.298
Weekend Admission	1.03	0.95-1.12	0.474

Analysis on Unscheduled Admissions

Supplementary Table 20: Main model

	OR	CI	p
Age*	1.59	1.53-1.65	<0.001
SOFA*	2.49	2.42-2.57	<0.001
CCI*	1.46	1.42-1.5	<0.001
Moderate Impairment	1.30	1.20-1.41	<0.001
Severe Impairment	1.96	1.78-2.17	<0.001
LOS 1 day	1.12	1.02-1.23	0.013
LOS >= 2 days	2.35	2.18-2.55	<0.001
Weekend Checklist	0.95	0.73-1.23	0.685
Intensivist full cover	1.03	0.76-1.40	0.850
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.002
Medical/Surgical Unit	1.42	1.04-1.92	0.026
Weekend Admission	1.02	0.96-1.09	0.473

Supplementary Table 21: Nurse decrease on weekends

	OR	CI	p
Age*	1.50	1.43-1.57	<0.001
SOFA*	2.49	2.40-2.58	<0.001
CCI*	1.46	1.40-1.51	<0.001
Moderate Impairment	1.30	1.18-1.44	<0.001
Severe Impairment	1.86	1.64-2.11	<0.001
LOS 1 day	1.11	0.99-1.25	0.076
LOS >= 2 days	2.39	2.17-2.63	<0.001
Weekend Checklist	1.09	0.82-1.46	0.55
Intensivist full cover	0.96	0.68-1.36	0.824
Nurse/Bed <0.2	1.37	1.04-1.81	0.026
Protocols	0.92	0.87-0.97	0.005
Medical/Surgical Unit	1.13	0.77-1.67	0.535
Weekend Admission	1.04	0.96-1.12	0.38

Supplementary Table 22: No nurse decrease on weekends

	OR	CI	p
Age*	1.74	1.64-1.85	<0.001
SOFA*	2.49	2.37-2.62	<0.001
CCI*	1.47	1.41-1.54	<0.001
Moderate Impairment	1.31	1.14-1.49	<0.001
Severe Impairment	2.18	1.85-2.55	<0.001
LOS 1 day	1.15	0.99-1.33	0.067
LOS >= 2 days	2.27	1.98-2.60	<0.001
Weekend Checklist	0.74	0.46-1.18	0.206
Intensivist full cover	1.17	0.68-1.99	0.571
Nurse/Bed <0.2	1.51	0.95-2.38	0.080
Protocols	0.94	0.87-1.01	0.075
Medical/Surgical Unit	1.95	1.19-3.19	0.008
Weekend Admission	1.00	0.90-1.11	0.995

Supplementary Table 23: Weekend Checklist

	OR	CI	p
Age*	1.66	1.56-1.76	<0.001
SOFA*	2.54	2.42-2.67	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.38	1.23-1.56	<0.001
Severe Impairment	2.28	1.98-2.63	<0.001
LOS 1 day	1.16	1.00-1.34	0.048
LOS >= 2 days	2.48	2.19-2.81	<0.001
Intensivist full cover	1.22	0.73-2.02	0.450
Nurse/Bed <0.2	1.25	0.90-1.76	0.187
Protocols	0.98	0.91-1.05	0.502
Medical/Surgical Unit	1.48	0.97-2.24	0.066
Weekend Admission	0.99	0.90-1.10	0.860

Supplementary Table 24: No weekend Checklist

	OR	CI	p
Age*	1.54	1.47-1.62	<0.001
SOFA*	2.46	2.36-2.55	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.24	1.12-1.38	<0.001
Severe Impairment	1.72	1.50-1.97	<0.001
LOS 1 day	1.10	0.98-1.24	0.117
LOS >= 2 days	2.27	2.05-2.51	<0.001
Intensivist full cover	0.97	0.66-1.43	0.873
Nurse/Bed <0.2	1.55	1.06-2.25	0.022
Protocols	0.91	0.86-0.97	0.002
Medical/Surgical Unit	1.53	0.96-2.45	0.076
Weekend Admission	1.05	0.97-1.14	0.233

Supplementary Table 25: Intensivist Full Cover

	OR	CI	p
Age*	1.62	1.51-1.73	<0.001
SOFA*	2.21	2.09-2.34	<0.001
CCI*	1.36	1.29-1.44	<0.001
Moderate Impairment	1.29	1.10-1.53	0.002
Severe Impairment	1.98	1.61-2.44	<0.001
LOS 1 day	1.00	0.83-1.21	0.984
LOS >= 2 days	2.30	1.98-2.66	<0.001
Weekend Checklist	1.20	0.65-2.24	0.562
Nurse/Bed <0.2	1.55	0.84-2.85	0.163
Protocols	0.89	0.82-0.98	0.012
Medical/Surgical Unit	1.11	0.50-2.46	0.791
Weekend Admission	0.99	0.88-1.12	0.856

Supplementary Table 26: No Intensivist Full Cover

	OR	CI	p
Age*	1.58	1.51-1.65	<0.001
SOFA*	2.60	2.51-2.70	<0.001
CCI*	1.50	1.45-1.55	<0.001
Moderate Impairment	1.30	1.19-1.43	<0.001
Severe Impairment	1.96	1.76-2.19	<0.001
LOS 1 day	1.16	1.05-1.29	0.005
LOS >= 2 days	2.36	2.15-2.59	<0.001
Weekend Checklist	0.89	0.67-1.19	0.437
Nurse/Bed <0.2	1.36	1.04-1.78	0.025
Protocols	0.95	0.90-1.00	0.065
Medical/Surgical Unit	1.43	1.04-1.98	0.030
Weekend Admission	1.04	0.96-1.12	0.326

Supplementary Table 27: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.67	1.58-1.76	<0.001
SOFA*	2.49	2.38-2.60	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.37	1.22-1.54	<0.001
Severe Impairment	2.15	1.85-2.50	<0.001
LOS 1 day	1.13	0.99-1.30	0.071
LOS >= 2 days	2.05	1.82-2.30	<0.001
Weekend Checklist	0.75	0.51-1.09	0.133
Intensivist full cover	1.14	0.73-1.76	0.566
Nurse/Bed <0.2	1.72	1.17-2.54	0.006
Medical/Surgical Unit	2.08	1.20-3.61	0.009
Weekend Admission	1.04	0.95-1.14	0.349

Supplementary Table 28: At least 8 protocols in ICU

	OR	CI	p
Age*	1.51	1.43-1.59	<0.001
SOFA*	2.49	2.39-2.60	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.26	1.13-1.41	<0.001
Severe Impairment	1.87	1.64-2.13	<0.001
LOS 1 day	1.11	0.98-1.26	0.097
LOS >= 2 days	2.64	2.37-2.94	<0.001
Weekend Checklist	0.96	0.72-1.26	0.757
Intensivist full cover	0.84	0.58-1.22	0.352
Nurse/Bed <0.2	1.19	0.91-1.55	0.203
Medical/Surgical Unit	1.14	0.84-1.55	0.389
Weekend Admission	1.01	0.92-1.10	0.912

Analysis on Scheduled Admissions

Supplementary Table 29: Main model

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Intensivist full cover	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.10-1.64	0.004

Supplementary Table 30: Nurse decrease on weekends

	OR	CI	p
Age*	1.72	1.50-1.96	<0.001
SOFA*	2.44	2.20-2.70	<0.001
CCI*	1.40	1.27-1.53	<0.001
Moderate Impairment	1.40	1.08-1.83	0.012
Severe Impairment	2.62	1.63-4.21	<0.001
LOS 1 day	1.41	1.05-1.89	0.023
LOS >= 2 days	2.60	2.01-3.36	<0.001
Weekend Checklist	1.33	0.81-2.19	0.255
Intensivist full cover	0.75	0.43-1.31	0.303
Nurse/Bed <0.2	1.07	0.67-1.73	0.769
Protocols	0.88	0.79-0.97	0.013
Medical/Surgical Unit	1.24	0.61-2.53	0.556
Weekend Admission	1.40	1.09-1.79	0.008

Supplementary Table 31: No nurse decrease on weekends

	OR	CI	p
Age*	2.01	1.67-2.41	<0.001
SOFA*	2.44	2.13-2.8	<0.001
CCI*	1.37	1.22-1.54	<0.001
Moderate Impairment	1.68	1.18-2.39	0.004
Severe Impairment	5.90	3.61-9.63	<0.001
LOS 1 day	1.25	0.83-1.87	0.282
LOS >= 2 days	2.46	1.70-3.55	<0.001
Weekend Checklist	1.00	0.48-2.09	0.996
Intensivist full cover	0.93	0.44-1.93	0.836
Nurse/Bed <0.2	1.92	0.95-3.89	0.069
Protocols	0.87	0.78-0.97	0.012
Medical/Surgical Unit	1.70	0.86-3.36	0.127
Weekend Admission	1.26	0.89-1.78	0.193

Supplementary Table 32: Weekend Checklist

	OR	CI	p
Age*	2.03	1.70-2.44	<0.001
SOFA*	2.56	2.23-2.93	<0.001
CCI*	1.55	1.38-1.74	<0.001
Moderate Impairment	1.59	1.15-2.20	0.005
Severe Impairment	2.86	1.69-4.82	<0.001
LOS 1 day	1.69	1.15-2.46	0.007
LOS >= 2 days	2.85	2.04-3.98	<0.001
Intensivist full cover	0.91	0.43-1.92	0.800
Nurse/Bed <0.2	1.27	0.70-2.28	0.432
Protocols	0.90	0.78-1.04	0.145
Medical/Surgical Unit	1.76	0.84-3.71	0.135
Weekend Admission	1.27	0.93-1.75	0.134

Supplementary Table 33: No weekend Checklist

	OR	CI	p
Age*	1.68	1.47-1.92	<0.001
SOFA*	2.37	2.14-2.62	<0.001
CCI*	1.32	1.20-1.44	<0.001
Moderate Impairment	1.36	1.03-1.79	0.033
Severe Impairment	4.86	3.11-7.60	<0.001
LOS 1 day	1.16	0.85-1.58	0.347
LOS >= 2 days	2.33	1.77-3.06	<0.001
Intensivist full cover	0.78	0.44-1.38	0.399
Nurse/Bed <0.2	1.30	0.73-2.29	0.373
Protocols	0.87	0.79-0.95	0.002
Medical/Surgical Unit	1.38	0.70-2.73	0.357
Weekend Admission	1.41	1.09-1.83	0.009

Supplementary Table 34: Intensivist Full Cover

	OR	CI	p
Age*	1.90	1.55-2.33	<0.001
SOFA*	2.05	1.77-2.37	<0.001
CCI*	1.24	1.08-1.43	0.002
Moderate Impairment	1.77	1.20-2.61	0.004
Severe Impairment	5.71	2.75-11.88	<0.001
LOS 1 day	0.95	0.62-1.46	0.825
LOS >= 2 days	2.06	1.41-3.01	<0.001
Weekend Checklist	1.39	0.53-3.63	0.502
Nurse/Bed <0.2	1.03	0.38-2.77	0.951
Protocols	0.84	0.72-0.97	0.018
Medical/Surgical Unit	1.12	0.32-3.89	0.856
Weekend Admission	1.44	1.02-2.04	0.038

Supplementary Table 35: No Intensivist Full Cover

	OR	CI	p
Age*	1.79	1.58-2.03	<0.001
SOFA*	2.65	2.40-2.93	<0.001
CCI*	1.46	1.34-1.59	<0.001
Moderate Impairment	1.40	1.08-1.80	0.010
Severe Impairment	3.38	2.30-4.96	<0.001
LOS 1 day	1.57	1.17-2.09	0.002
LOS >= 2 days	2.82	2.19-3.63	<0.001
Weekend Checklist	1.17	0.73-1.88	0.513
Nurse/Bed <0.2	1.34	0.86-2.09	0.190
Protocols	0.88	0.81-0.97	0.007
Medical/Surgical Unit	1.50	0.90-2.53	0.123
Weekend Admission	1.29	1.01-1.66	0.042

Supplementary Table 36: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.70	1.49-1.95	<0.001
SOFA*	2.42	2.16-2.70	<0.001
CCI*	1.32	1.19-1.47	<0.001
Moderate Impairment	1.30	0.97-1.74	0.079
Severe Impairment	3.91	2.36-6.49	<0.001
LOS 1 day	1.50	1.09-2.08	0.014
LOS >= 2 days	2.16	1.61-2.90	<0.001
Weekend Checklist	0.84	0.46-1.52	0.565
Intensivist full cover	0.96	0.51-1.79	0.892
Nurse/Bed <0.2	1.63	0.90-2.94	0.106
Medical/Surgical Unit	2.17	0.98-4.82	0.056
Weekend Admission	1.42	1.06-1.89	0.018

Supplementary Table 37: At least 8 protocols in ICU

	OR	CI	p
Age*	1.94	1.63-2.32	<0.001
SOFA*	2.51	2.23-2.83	<0.001
CCI*	1.46	1.32-1.61	<0.001
Moderate Impairment	1.65	1.22-2.25	0.001
Severe Impairment	3.60	2.28-5.68	<0.001
LOS 1 day	1.18	0.82-1.69	0.372
LOS >= 2 days	2.96	2.19-4.00	<0.001
Weekend Checklist	1.12	0.68-1.83	0.664
Intensivist full cover	0.54	0.28-1.03	0.062
Nurse/Bed <0.2	1.02	0.62-1.69	0.925
Medical/Surgical Unit	1.18	0.67-2.07	0.567
Weekend Admission	1.29	0.97-1.70	0.081

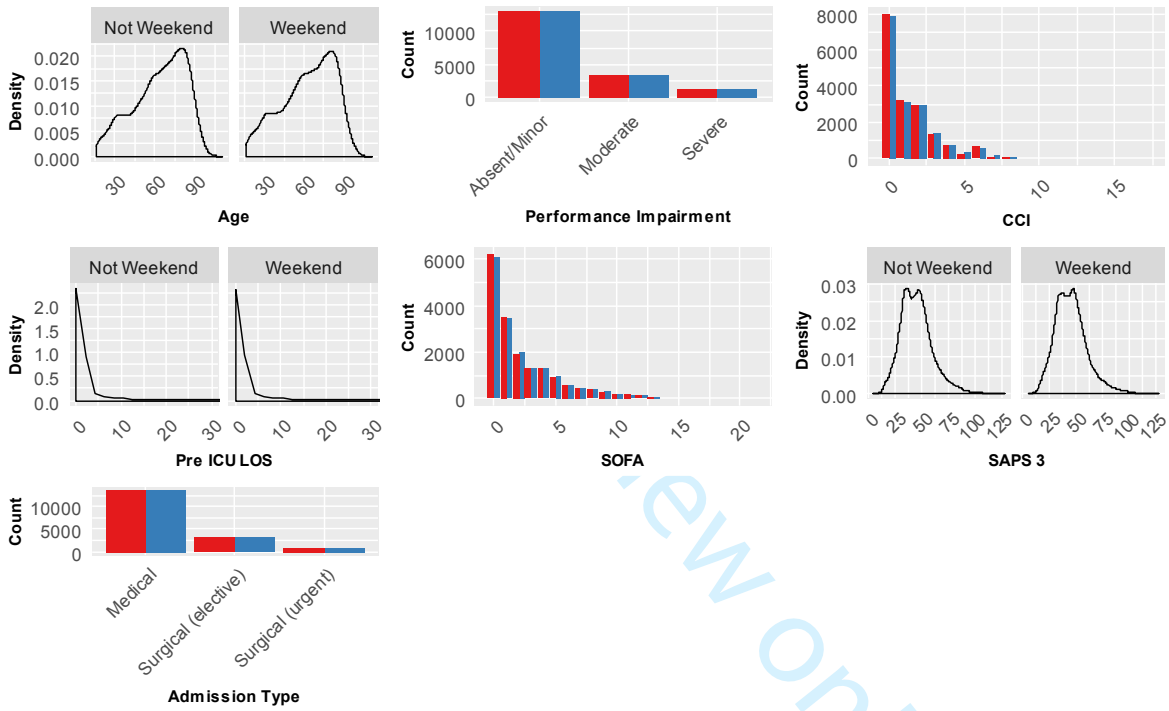
Propensity Score Analysis

Method: 1:1 patient matching controlling for age, CCI, admission type, performance status impairment, LOS before ICU admission, SOFA, SAPS3 and admission type

Results: 35,440 patients (17,720 in each arm) were matched. Mortality was 15.5% for patients admitted on weekdays and 16.1% for patients admitted on weekends (p=0.112)

Matching: Matching was adequate. Figure below shows density plot and barplots for the variables included in the propensity score

Supplementary Figure 4: Variable comparison after propensity score matching



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The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

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Abstract

Introduction: Higher mortality for patients admitted to the intensive care unit during the weekends in intensive care units (ICUs) has been occasionally reported with mixed results that could be related to organizational factors. We assessed whether ICU organizational and staffing patterns are related to the association between weekend admission and worse outcomes in critically ill patients.

Methods: We included 59,614 patients (78 ICUs) admitted to the ICUs participating of the ORCHESTRA study. Weekend admission was defined as admission from Friday 7pm until Monday 7am. We assessed the association between weekend admission with hospital mortality using a mixed logistic regression model controlling for both patient-level (illness severity, age, comorbidities, performance status and admission type) and ICU-level confounders (decrease in nurse/bed ratio on weekend, full-time intensivist coverage, use of checklists on weekends and number of institutional protocols). Secondary analyses were performed for scheduled surgical admissions.

Results: A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) on weekends. In univariate analysis, weekend admitted patients had higher ICU (10.9% vs. 9.0%, p<0.001) and hospital (16.5% vs. 13.5%, p<0.001) mortality. After adjusting for confounders, weekend admission was not associated with higher hospital mortality (OR 1.05, 95% CI 0.99-1.12, p=0.095). However, a “weekend effect” was still observed in scheduled surgical admissions, as well as in ICUs not following checklists during the weekends. For unscheduled admissions, no “weekend effect” was observed regardless of ICU´s characteristics. For scheduled surgical admissions, a “weekend effect” was present only in ICUs with a reduction in the nurse/bed ratio during weekends, without weekend checklists and with a low number of implemented protocols.

Conclusions: Institutional factors, such as decreased nurse to patient ratio, absence of checklists, and fewer standardized protocols may increase ICU mortality on weekends

Strengths and Limitations:

- After controlling for patient and center-level confounder, a "weekend effect" was not observed in Brazilian UTIs
- Secondary exploratory analyses suggested that some organizational factors could explain the observed higher mortality on weekends, especially absence of weekend checklists and lower number of ancillary protocols available.
- Organizational features, especially number of protocols, may become more relevant as length of stay increases.
- Due to multiple correlations and the large number of exploratory models, these results should be interpreted with caution and within a context of low baseline nuse:bed ratio.

Introduction

Higher mortality for patients admitted during the weekends has been repeatedly reported in studies carried out in both wards (1,2) and intensive care units (ICU) (3,4). The so-called "weekend effect" is often ascribed to the imbalance of organizational and staffing features available on weekdays, which either do not occur or are suboptimal during the weekends (5). This notion has driven several health care policies, especially in England where junior doctors' contracts were changed on the assumption that increased weekend working would mitigate the weekend effect (6). This was followed by a great deal of discussion on the veracity of a weekend effect due to uncertainties on the reliability of disease coding on admission during weekends (6,7) and biases related to different profiles of illness severity and comorbidities in weekend admitted patients (8,9).

If the weekend effect is a real phenomenon amongst ICU admissions, it could be mediated by several organizational factors including staffing features such as full-time intensivist coverage and nurse staff levels (10) and use of other ancillary tools designed to sustain the continuity of care such as checklists and number of institutional protocols available(11). However, the association between these organizational characteristics and the weekend effect in ICUs were not thoroughly evaluated. We have used a large national prospectively-collected database to examine the hypothesis that the weekend effect would only be manifest in settings in which sub-optimal organization, staffing or clinical practices could impact on continuity of care.

Methods

Population: This was a *post hoc* analysis of a large cohort study in critically ill patients admitted in 78 Brazilian ICUs during 2013 from January 1st until December 31st (The ORCHESTRA Study) (11). All critically ill patients in the database were elected. From the initial database of 59,693 patients, we excluded 79 patients with missing admission date/hour, leaving 59,614 patients for analysis. In case of readmissions during the study period, we considered only the first ICU admission.

Exposure definitions: We defined weekend admission as any admission to the ICU occurring between Friday 7 pm and Monday 7 am.

Outcome definition: Hospital mortality.

Organizational factors: We considered several organizational factors in the analysis including the use of checklists (structured evaluations using a digital or printed instrument with multiple components focused on prevention of common ICU complications and adherence to best practices) during weekends, the implementation of protocols in the ICU (among a pre-defined set of ten protocols aiming at the adherence to best practices and prevention of acquired complications for frequent conditions in the ICU; see Supplementary File for details), the presence of full-time intensivist coverage 24/7 in the ICU, presence of a low nurse/bed ratio and ICU type. Full-time intensivist coverage was defined as the presence of a board-certified intensivist in the ICU 24 hours a day, 7 days a week. A low nurse/bed ratio was defined as a mean nurse/bed ≤ 0.20 inside the ICU (that is, the mean nurse/bed ratio considering all shifts in the ICU was lower or equal to 0.20). This 0.20 cutoff was established after inspecting the univariate association between nurse/bed ratio and hospital mortality in a generalized additive model (sFigure 1; see Electronic Supplementary Material – ESM – for details). For checklists, dummy coding

was used to represent units with checklists 7 days a week versus those without weekend checklists (that is, units that had checklists on weekdays only or did not apply checklists at all).

Patient factors: We estimated organ failures and the severity of illness using the Sequential Organ Failure Assessment (SOFA) score (12) and the Simplified Acute Physiology Score (SAPS) 3 (13). The Charlson Comorbidity Index was calculated as previously reported (14). Baseline performance status was defined according to the impairment degree as absent/minor, moderate and severe corresponding to performance classes of Eastern Cooperative Oncology Group (ECOG) of 0-1, 2 or 3-4, respectively as previously described (15). Hospital length of stay before ICU admission was collected and stratified in tertiles for the analysis.

Missing values: No outcome was missing. Baseline performance status was missing in 3,476 patients. Multiple imputation using random forest was used to impute missing values for this variable, as previously described (15). There were no other missing values in the variables included in the analysis.

Statistical Analysis: We used a mixed multivariate logistic regression to assess the independent association between each predictor and hospital mortality at the patient level. The admission ICU was added as a random effect (random intercept) in the model while all the other variables were added as fixed effect. Continuous variables were scaled and centered before entering the mixed model. The following variables were included in the main model: age, SOFA score, Charlson Comorbidity Index, performance status impairment, admission type (medical, elective surgery, non-elective surgery), length-of-stay (LOS) before ICU admission stratified in tertiles, use of checklists during the weekends, presence of full-time intensivist coverage, low baseline nurse/bed ratio, ICU

type (medical/surgical or other) and weekend admission. No stepwise selection was performed. Type of funding (public versus private) was not added to the model due to large colinearity with most organizational features.

Subgroup analyses: We defined that sensitivity analysis for the following subgroups would be performed: admission type; quartiles of baseline SAPS 3 score, patients admitted due to sepsis, patients admitted on mechanical ventilation, ICUs with or without decrease in nurse/bed ratio during weekends (regardless of baseline values), ICUs stratified per presence of full-time intensivist coverage, ICUs with or without checklist during the weekends, and according to number of ancillary protocols in the ICU (above or below the median values of protocols per ICU). We repeated the subgroups analyses of organizational features (decrease in nurse staff, absence of full-time intensivist coverage, absence of checklist, and number of ancillary protocols) after stratifying our sample according to scheduled surgical versus non-scheduled ICU admissions (both emergency surgery and clinical) (16). For the number of ancillary protocols, we split the samples in patients admitted to units with less or at least eight protocols, since this value split the number of included intensive care units in half. Scheduled surgery admissions are defined as any admission after a surgical procedure which was scheduled at least 24 hours before its start and for which an ICU bed was requested before the procedure started.

Propensity score analysis: We performed a propensity score 1:1 analysis pairing patients per their predicted probability of weekend admission based solely on the patients' factors. The probability of weekend admission was obtained by creating a logistic regression with the following variable included as predictors: age, SOFA score, SAPS 3 score, Charlson Comorbidity Index, degree of performance status impairment, LOS before ICU admission and admission type. Patients were matched using the nearest neighbor

method considering the logit as the distance method. Maximum distance allowed was 0.40. At each matching, the unit with the closest logit still unmatched was used. After checking the balance of the propensity-matched groups, we compared hospital mortality for propensity-matched patients using chi-squared test.

Effects of organizational features in changes in weekend versus weekday admission mortality: One additional approach to scrutinize the impact of organizational features in weekend admission mortality was applied by performing a linear regression at the ICU level considering the change in mortality (weekend minus weekday mortality for the ICU) as dependent variable and both SAPS 3 and organizational features as predictors. The organizational features selected were the same used for splitting subgroups in multivariate mixed model. After linear regression, we assessed the relative importance of each predictor using the LMG method.

Time effect of the association between organizational features and outcome in patients admitted during weekends: The time dependent effects of organizational factors in patients admitted to the ICU on weekends was assessed through an approach based on multiple sequential random forest models at the patient level from the day of admission (day 0) until 7 days after with hospital mortality as outcome of interest. The first regression included all patients admitted on weekends; the second regression included all patients except those who died in the first day, the third regression included all patients except those who died in the first 2 days, and so on until the first 7 days. All models included SAPS 3 score as predictor as well as organizational features (presence/absence of weekend checklists, low nurse/bed ratio, number of protocols and presence/absence of full-time intensivist coverage), Relative importance was assessed at each model based on mean decrease of Gini value and displayed as percentage over time.

All analyses were performed in R-project version 3.4.2 (17) with packages ggplot2, lme4, dplyr, tidyr, relimpo and gridextra. A p value below 0.05 was considered significant. This report follows the STROBE guideline(18) (shown in Supplementary File).

The Brazilian National Ethics Committee (CAAE: 19687113.8.1001.5249) approved the study. Need for informed consent was waived.

Results

Patients and ICU features:

Out of 59,693 patients admitted to the participating ICUs during the study period, 59,614 (99.9%) had available ICU admission date and hours and were selected for analysis. Main ICU and hospital characteristics are depicted in sTable 1 (see ESM). Most ICUs were private (sTable 1). A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) were admitted on weekends. The number of admissions decreased at weekends especially due to a decrease in elective surgeries but also due to a decrease in medical admissions (Figure 1). A comparison between patients admitted at weekend versus weekdays is shown in Table 1 and in sFigure 2. Patients admitted on weekends were more severely ill (higher SOFA and SAPS 3 scores) and more frequently admitted due to medical reasons than patients admitted during weekdays (Table 1). When compared to patients admitted during weekdays, a slightly lower percentage of weekend admissions occurred in ICUs with a low nurse/bed ratio (49.8% versus 48.6%, respectively; p = 0.007) and in units with fewer than eight protocols (46.9% versus 45.4%, respectively; p = 0.001) as shown in sFigure 2.

Table 1 – Comparisons between weekend and weekday admissions

	Weekday	Weekend	p
Number of Patients	41,894	17,720	-
Age (mean (SD))	61.99 (19.08)	63.10 (19.81)	<0.001
Male (n (%))	20,932 (50.0)	8,795 (49.6)	0.466
SAPS 3 (points) (mean (SD))	42.10 (14.94)	45.17 (14.71)	<0.001
SOFA score (points) (mean (SD))	2.31 (3.01)	2.49 (3.15)	<0.001
CCI (points) (mean (SD))	1.42 (1.87)	1.46 (1.91)	0.007
Performance status Impairment (n (%))			<0.001
Absent/Minor	32,107 (76.6)	13,079 (73.8)	
Moderate	7,165 (17.1)	3,288 (18.6)	
Severe	2,622 (6.3)	1,353 (7.6)	
Hospital LOS before ICU admission (median [IQR])	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	<0.001
Admission type (n (%))			<0.001
Medical	26,088 (62.3)	13,716 (77.4)	
Surgical (elective)	13,638 (32.6)	2,999 (16.9)	
Surgical (urgent)	2,168 (5.2)	1,005 (5.7)	
Admission Source (n (%))			<0.001
Operating Room	13,710 (32.7)	3,589 (20.3)	
Emergency	20,498 (48.9)	10,813 (61.0)	
Ward	2,925 (7.0)	1,530 (8.6)	
Home-care	147 (0.4)	70 (0.4)	
Other	168 (0.4)	63 (0.4)	
Other unit	793 (1.9)	310 (1.7)	
Hemodynamic Room	1,845 (4.4)	284 (1.6)	

Other hospital	1,495 (3.6)	907 (5.1)	
Step down unit	313 (0.7)	154 (0.9)	
Sepsis (n (%))	7,272 (17.4)	3,834 (21.6)	<0.001
Mechanical Ventilation on ICU Admission (n (%))	6,453 (15.4)	2,590 (14.7)	0.016
Mechanical Ventilation during ICU stay (n (%))	7,739 (19.1)	3,192 (18.7)	0.341
Vasopressors on ICU admission (n (%))	5,371 (12.9)	2,260 (12.8)	0.856
Vasopressors during ICU stay (n (%))	5,938 (14.6)	2,585 (15.2)	0.102
Renal replacement therapy on ICU admission (n (%))	1,074 (2.6)	597 (3.4)	<0.001
Renal replacement therapy during ICU stay (n (%))	1,922 (4.7)	1,034 (6.1)	<0.001
ICU LOS (median [IQR])	2.00 [1.00, 4.00]	2.00 [1.00, 5.00]	<0.001
Hospital LOS (median [IQR])	6.00 [2.00, 14.00]	7.00 [3.00, 16.00]	<0.001
ICU mortality (n (%))	3,790 (9.0)	1,918 (10.8)	<0.001
Hospital Mortality (n (%))	5,691 (13.6)	2,863 (16.2)	<0.001

Legend: SD=standard deviation; SAPS=Simplified Acute Physiology Score; SOFA=Sequential Organ Failure Score; CCI=Charlson Comorbidity Index; LOS=length of stay; ICU=intensive care unit; IQR=25%-75% interquartile range

Univariate analysis:

The overall ICU and hospital mortality rates were 9.5% and 14.4%. While hospital mortality for medical admissions per admission week day slightly fluctuated over the week, higher mortality was seen for elective surgical patients admitted on Sunday (Figure 2). For

non-elective surgeries, large fluctuations were seen with a peak mortality for those admitted on Tuesday (Figure 2). In univariate analysis, hospital mortality was significantly higher for patients admitted at weekends (16.2 versus 13.6%, OR 1.22, 95% CI 1.17-1.29; p<0.001).

Mixed model logistic regression:

After adjusting for relevant patient-level and ICU-level characteristics in the multivariable analysis, weekend admission was no longer associated with increased hospital mortality (OR 1.05, 95% CI 0.99-1.11; p = 0.095; full model reported in sTable 2; mixed effects shown on sFigure 3; center effect was markedly present). We present the results of the effect of weekend admission on hospital mortality in the several prespecified subgroups in Figure 3 and in sTables 3-19. A "weekend effect" was apparent for elective surgical admissions (OR 1.34; 95% CI 1.10-1.64; p=0.004; Figure 3 and sTable 4) and in patients admitted to ICUs without checklists during the weekends (OR 1.08; 95% CI 1.00-1.17; p=0.045; Figure 3 and sTable 17). We did not find a statistically significant association between other organizational characteristics (nurse/bed ratio, presence of full-time intensivist coverage or the number of protocols) and increased mortality in patients admitted during the weekends.

Scheduled Surgical versus Unscheduled ICU admissions:

We repeated the analyses separately for scheduled surgical admissions and unscheduled admissions (42,977 and 16,637 admission, respectively). Results are shown on Figure 4 and in sTables 20-37 of the ESM. A "weekend effect" was observed in scheduled surgical admissions. However, weekend effect was only present on scheduled surgical admissions when there was a decrease in weekend nurse/bed ratio (OR 1.40; 95% CI 1.09-1.79, p = 0.008), no weekend checklists (OR 1.41; 95% CI 1.09-1.83, p = 0.009) or a lower

number of protocols (OR 1.42; 95%CI 1.06-1.89, p = 0.018) (Figure 4). There was no "weekend effect" in unscheduled admissions.

Propensity score results:

Out of the study population, 35,440 patients (17,720 weekend admissions and 17,720 weekdays admissions) were matched in the propensity score analysis. All patients admitted on weekend could be paired. The distribution of variables in matched patients stratified per weekend effect is shown in supplementary Figure 4. Mortality was 15.5% for patients admitted on weekdays and 16.1% for those admitted during weekends (p=0.112).

Change in weekend-weekday mortality regression:

After linear regression using the change of weekend to weekday mortality as dependent variable, only SAPS 3 score and low number of protocols (fewer than 8 protocols) were associated with positive increases in mortality in weekends at the ICU level (both p<0.001). There was a trend for presence of weekend checklists and lower changes in weekend-weekday mortality (p=0.08). The model R2 was 74.03%, with SAPS 3 being the most important predictor (66% of all variance), followed by low number of protocols (29%) and presence/absence of weekend checklists (3%, which was not statistically significant).

Time effect association of organizational features and outcome:

The relative contribution of SAPS 3 to hospital mortality decreased in the first 7 days after ICU admission, while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. The relative contribution of other organizational features remained stable (Figure 5).

Discussion

In the present study, we provide evidence that, after proper consideration of illness severity, patient´s background features and reason for admissions, the "weekend effect" is a minor phenomenon that is probably not relevant in the scenario of several Brazilian ICUs. A residual "weekend effect", however, might be present for scheduled surgical admissions and/or when some organizational factors that are associated with disrupted continuity of care and adherence to best practices are present.

Although previous studies suggested an increase in mortality in patients admitted during the weekend(4), the "weekend effect" concept has been recently challenged (6). Criticism of reports suggesting the presence of weekend effect identified three major pitfalls in analysis: (i) studies were performed using administrative databases and might suffer with inconsistent coding; (ii) comorbidities may have not been properly considered and (iii) Illness severity might not be adequately accounted for. Black(6) cited three studies in which, after correction of these issues, the "weekend effect" was no longer significant.

In the present analysis, we intended to overcome the limitations summarized by Black(6). We based our analysis on a quality improvement administrative database that does not only consider International Classification of Diseases (ICD) coding for diagnosis, but it also includes major predefined medical diagnosis (11). This database includes robust prospective clinical data collected at the bedside and not only administrative and/or procedures notes. We also considered the presence of comorbidities and baseline health status by not only adjusting for Charlson Comorbidity Index but also to performance status impairment (14,15). Finally, severity of illness admission was assessed using well validated and widely accepted scores of severity of illness and organ failure (12,19,20). Our work does not corroborate with the hypothesis that the "weekend effect" is a universal feature in

the ICUs. This is highlighted by both the main mixed regression model and by the propensity score analysis performed. In fact, when only unscheduled admissions were considered, no evidence of weekend effect was found regardless of the presence/absence of organizational features in the ICU; this is in accordance with recent reports the of absence of the weekend on unplanned ICU admissions (21). We could find evidence of a weekend effect only in secondary subgroup analyses, suggesting that it might be restricted to scenarios when there is a break in continuity of care during weekends, specifically the absence of patient-centered checklists (11,16), or for schedule admissions.

The case for worse outcomes for elective surgical admissions on weekends is complex, with both ICU and hospital features being able to explain, at least partly, this association (22,23). Differences in surgical care on weekends may play an important role. For example, early recognition and treatment of surgical complications may be delayed on weekends and even the adopted surgical procedure may be different for similar scenarios during weekends (24,25). In this way, checklists may aid at prompt recognition of complications (both clinical (26) and surgical (27)) and improve adherence to daily goals of care (28). Higher nurse staffing may also aid at reducing postoperative complications(10). In our analysis, there was no statistically significant weekend effect in scheduled surgical admissions in units that did not have a decrease in nurse/bed ratio on weekends or that applied checklists on weekends, thereby corroborating to this concept.

Interestingly, several factors potentially related to worse care on weekends did not reach statistical significance in the whole studied population. Despite the rationale for increased mortality when there is a decrease in nurse/bed ratio during weekend (29) or when there is an absence of full-time intensivist coverage (30), we did not find evidence of weekend effect in both scenarios when all admissions types were considered. It is

conceivable that well-structured ICUs with weekend checklists and protocols would be less susceptible to the variation in care driven by the decrease in staff during weekends, thereby mitigating the effect of the latter on mortality. This was only apparent for scheduled surgical admissions in our analysis. However, when we evaluated changes in mortality in weekends versus weekday at the ICU level using a linear model, a low number of protocols was the stronger organizational predictor of increase in mortality on weekends. It should be acknowledged that multiple interactions between organizational features could be expected and that some of the absence of statistically significant findings could be due to Simpson´s Paradox.

For patients admitted on weekends, we found that the length-of-stay ICU could modulate the association between organizational features and outcome, as shown in Figure 5. As expected, illness severity as measured by SAPS 3 score was the most important factor associated with mortality, but its relative contribution decreased during the first seven days while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. This suggests that the main determinant of mortality is a global individual marker of illness severity (as expected) and that the more a patient stays in the ICU, the higher the association between number of protocols and outcome. Interestingly, protocols were also the only variable associated with reduced change in mortality during weekends in the ICU-level linear model. Future studies that assess organizational features and outcome in the ICU should also consider that organizational features may be more important for patients with prolonged ICU length-of-stay.

Our analysis has several constrains. First, the large number of secondary analyses and models built could increase type 1 error due to overtesting. Additionally, the large sample size may also facilitate observing statistical significant results that may not be

clinically relevant. Therefore, our results and specially our subgroup analyses should be considered exploratory and interpreted in the context of multiple models where some groups had small number of patients. It is important to highlight, however, that trends were constant during all analysis performed. We nevertheless advice caution when interpreting our results, specially the effects size reported. Second, albeit the large number of ICUs involved, our results refer to a selected sample of units from a single country and caution is needed when generalizing to other settings. Third, most patients were mostly admitted to private units and had a medium-low illness severity, thereby resulting in a low average mortality. However, no weekend effect was demonstrated in the subgroup analysis per the severity of illness and in septic or mechanically ventilated patients. Fourth, the low nurse/bed ratio reported is common in Brazil and are in accordance with local regulations that estipulate up to 10 beds per nurse in the ICUs but limits its generalization to different European and North American settings. Fifth, we were unable to assess interactions between the several organizational features. Frequently several organizational features occur together and may have synergistic (or even antagonist) effects that should be properly explored in the future. Sixth, we only assessed ICU organizational factors; structure, organizational and staffing patterns at the emergency departments and wards may also play an important role in determining hospital outcome. Finally, we did not assess other relevant outcomes such as readmissions and longer follow-up mortality and multiple imputation was used to correct for an important patient variable (performance status).

Conclusion

After considering an appropriate disease coding and accounting for comorbidities, illness severity and ICU organization characteristics, we did not observe worse outcomes in critically ill patients admitted during weekends. Nonetheless, a "weekend effect" might still occur in scheduled surgical admissions, especially in ICUs with a decrease in nurse/bed ratio and absence of checklists during the weekends as well as in ICUs with a low number of protocols. The ICU length-of-stay potentially modulates the association between organizational features and outcomes in critically ill patients.

Declarations

List of abbreviations:

CI – Confidence Interval

ECOG - Eastern Cooperative Oncology Group

ESM – Electronic Supplementary Material

ICU – Intensive Care Unit

LOS – Length of Stay

OR – Odds ratio

SAPS - Simplified Acute Physiology Score

SOFA – Sequential Organ Failure

Ethical approval: This study was locally approved in all participating intensive care units. Consent form was waived due to the retrospective nature of the analysis.

Consent for publication: Not applicable.

Availability of data: Data is not publically available due to local ethical restrictions.

Competing interest: Dr. Soares and Dr. Salluh are founders and equity shareholders of Epimed Solutions®, which commercializes the Epimed Monitor System®, a cloud-based software for ICU management and benchmarking. The other authors declare that they have no conflict of interest.

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Authors´ Contributions: Manuscript conception: FGZ, TCL, TDC, FAB, JIS, MS. Statistical analyses: FGZ, TCL, FAB, TDC, JIS, MS. Data collection: MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC. Wrote the manuscript: FGZ, TCL, TDC, FAB, JIS, MS. Approved the final version: FGZ, TCL, TDC, FAB, JIS, MS, MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC.

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Figure Legends

Figure 1 – (A) Number of patients admitted to the ICU at each day of the week; (B) Distribution of admission types at each week day.

Figure 2 – Mortality at each day of the week stratified by admission type.

Figure 3 – Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality in the whole population (upper line) and in selected subgroups (see main text for details).

Figure 4 - Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality stratified in unscheduled (left) and scheduled surgical (right) admissions. Further subgroup analyses according to presence/absence of organizational factors are presented

Figure 5 – Relative contribution of illness severity (SAPS 3) and organizational factors in sequential daily random forest models. The relative contribution was defined as the percentage of mean decrease in Gini statistics at each model. Note how the relative importance of illness severity decreases during the first seven days and how the importance of number of protocols increases.

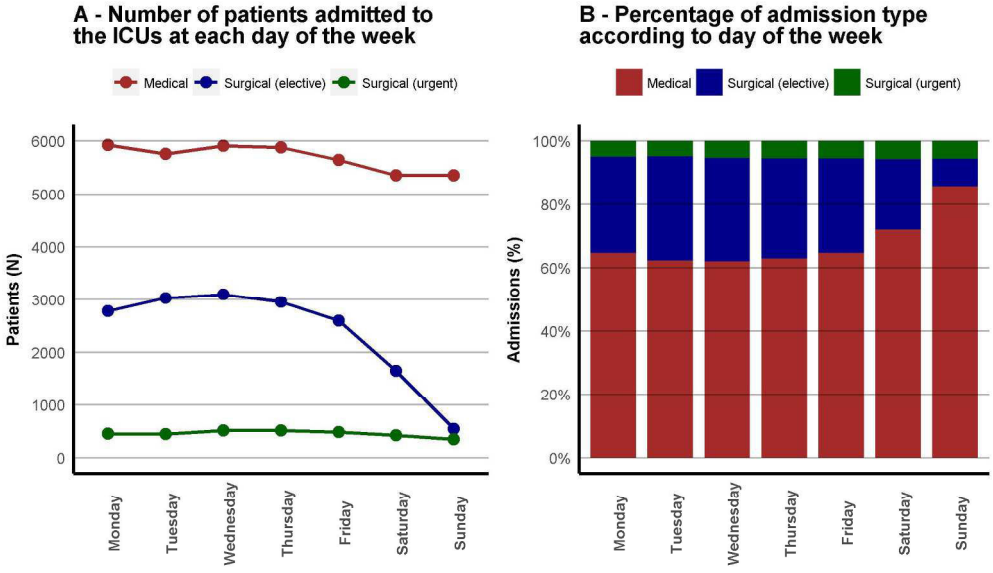

Figure 1

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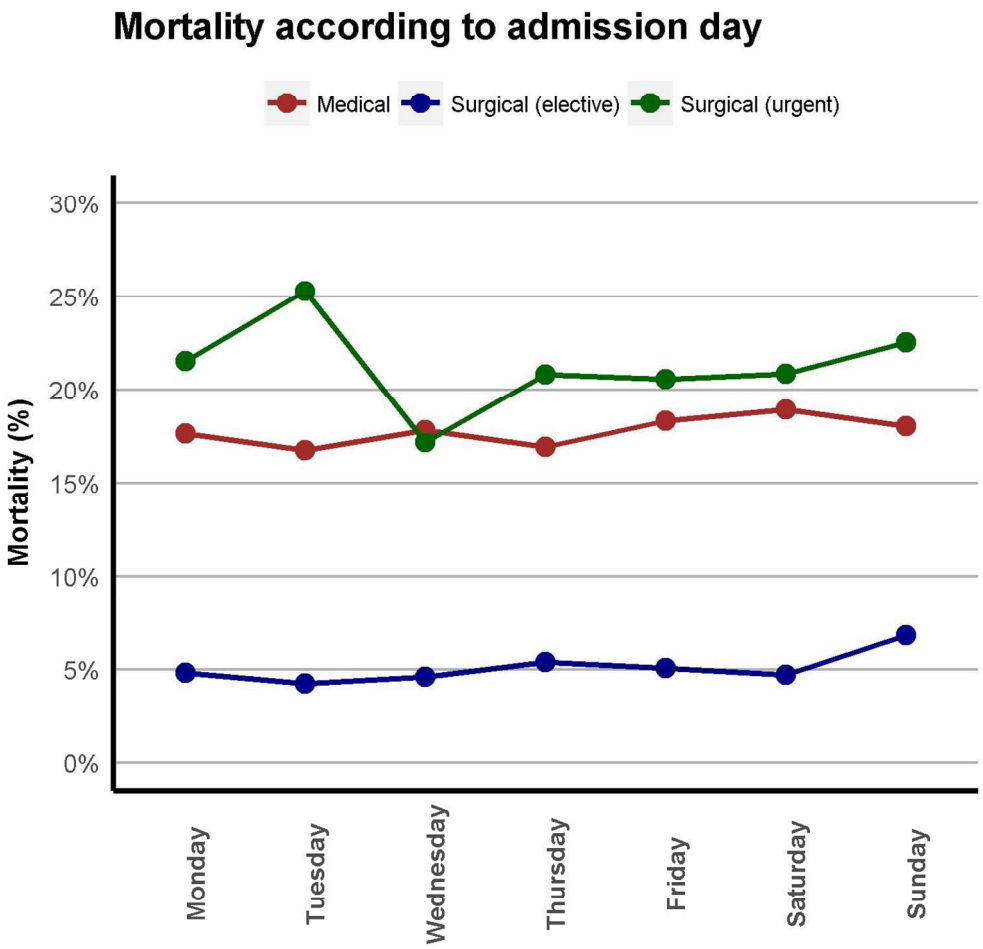

Figure 2

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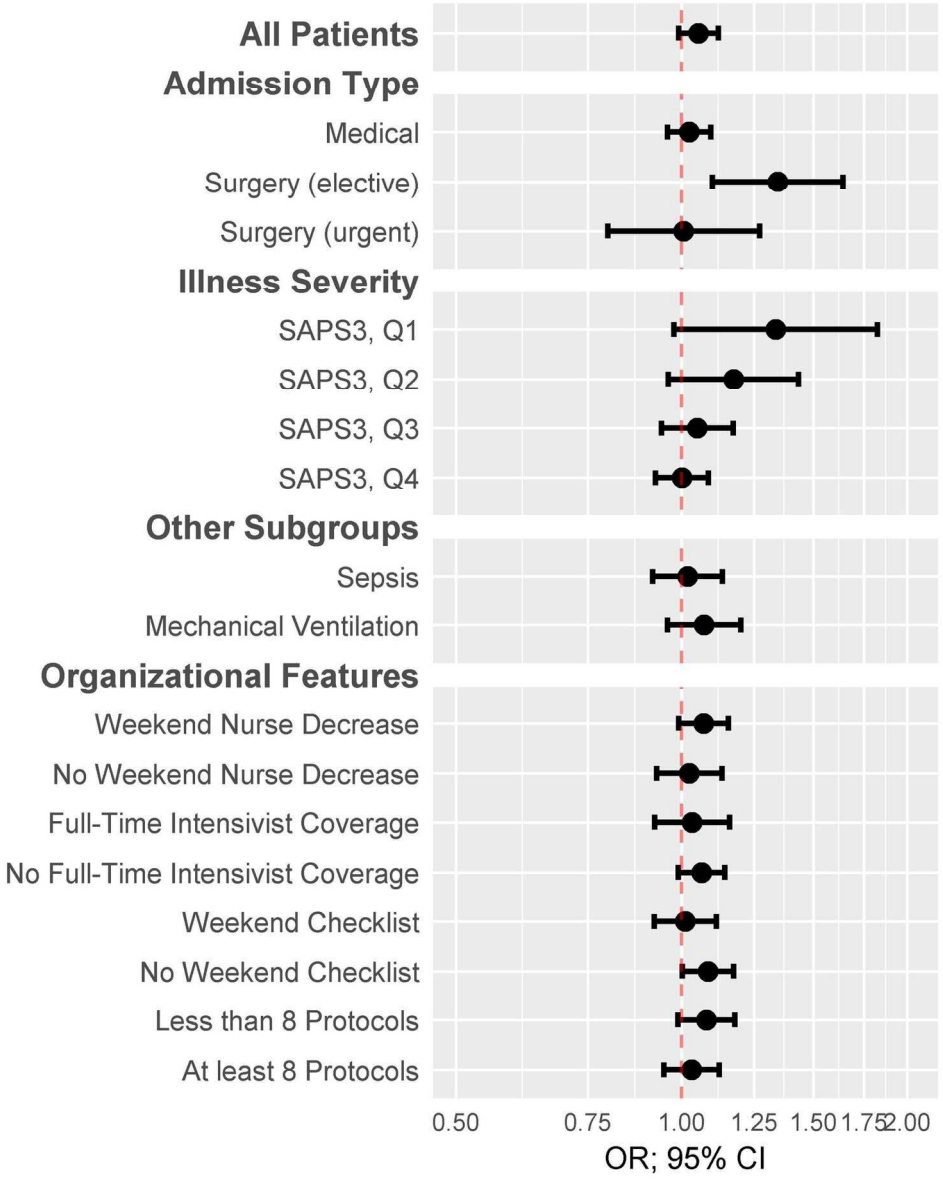

Figure 3

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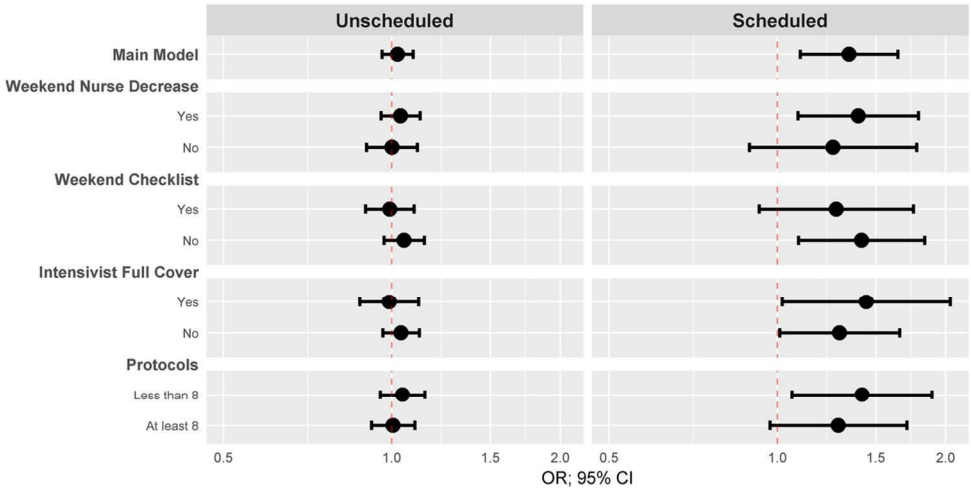

Figure 4

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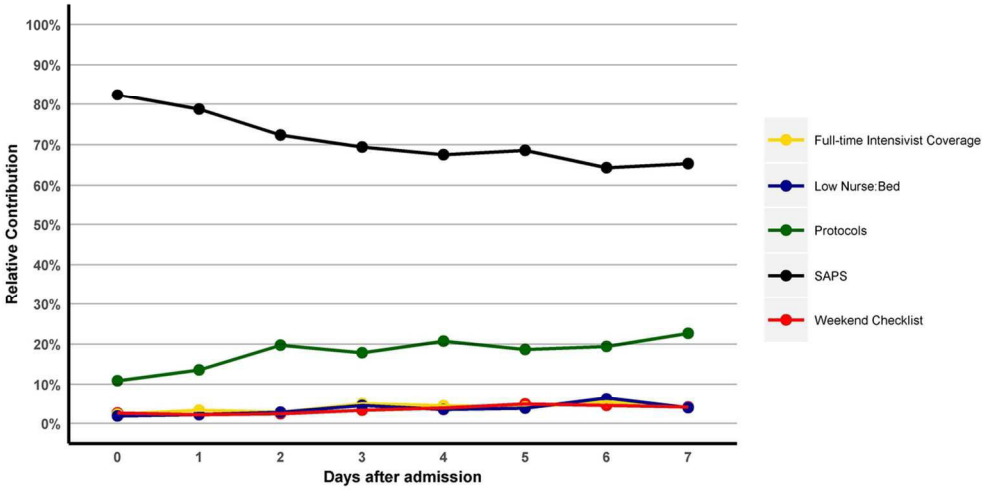

Figure 5

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The Effects of Weekend Admission on the Mortality of Patients Admitted to Intensive Care Units: The Role of Organizational Factors

ELECTRONIC SUPPLEMENTARY FILE

ICU and Hospital Features

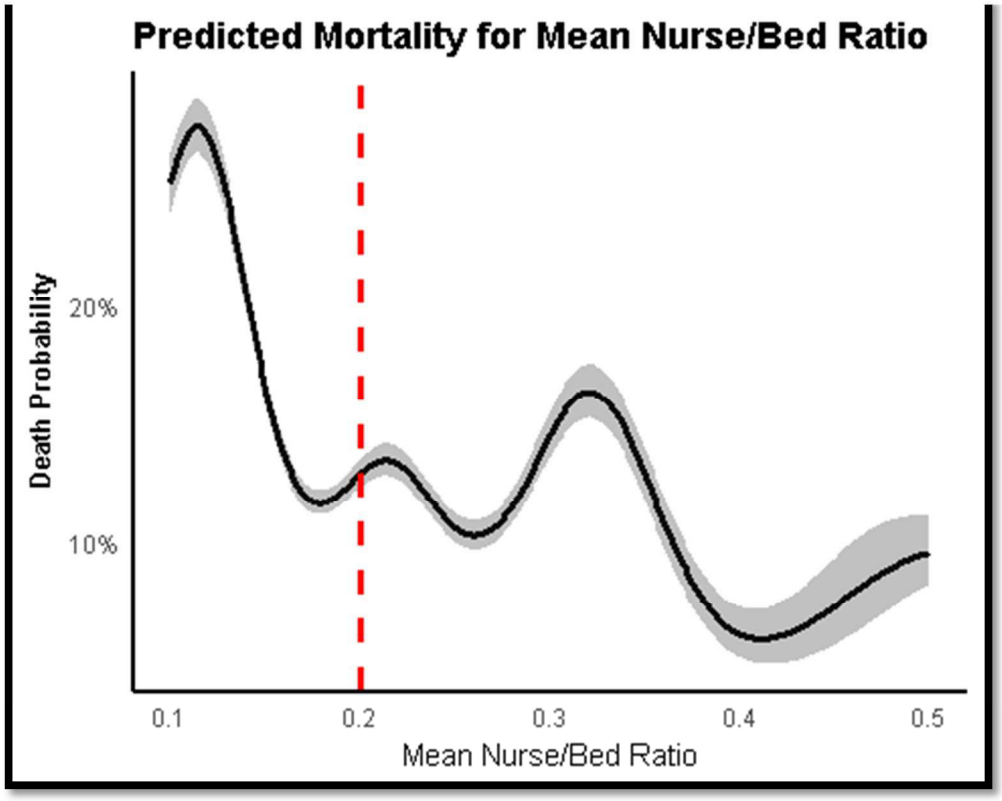
Supplementary Table 1: ICU Features

Number of Units	78
Bed per unit, mean (SD)	17.53 (11.38)
Private hospital, n (%)	67 (85.9)
Accreditation	
None	24 (30.8)
National	30 (38.5)
International	24 (30.8)
Weekend checklists, n (%)	36 (46.2)
Full-time Intensivist Coverage, n(%)	16 (20.5)
Nurse/Bed ratio < 0.2	41 (52.6)
Protocols, mean (SD)	6.96 (2.88)
Medical/Surgical Unit, n (%)	62 (79.5)

Univariate Analysis

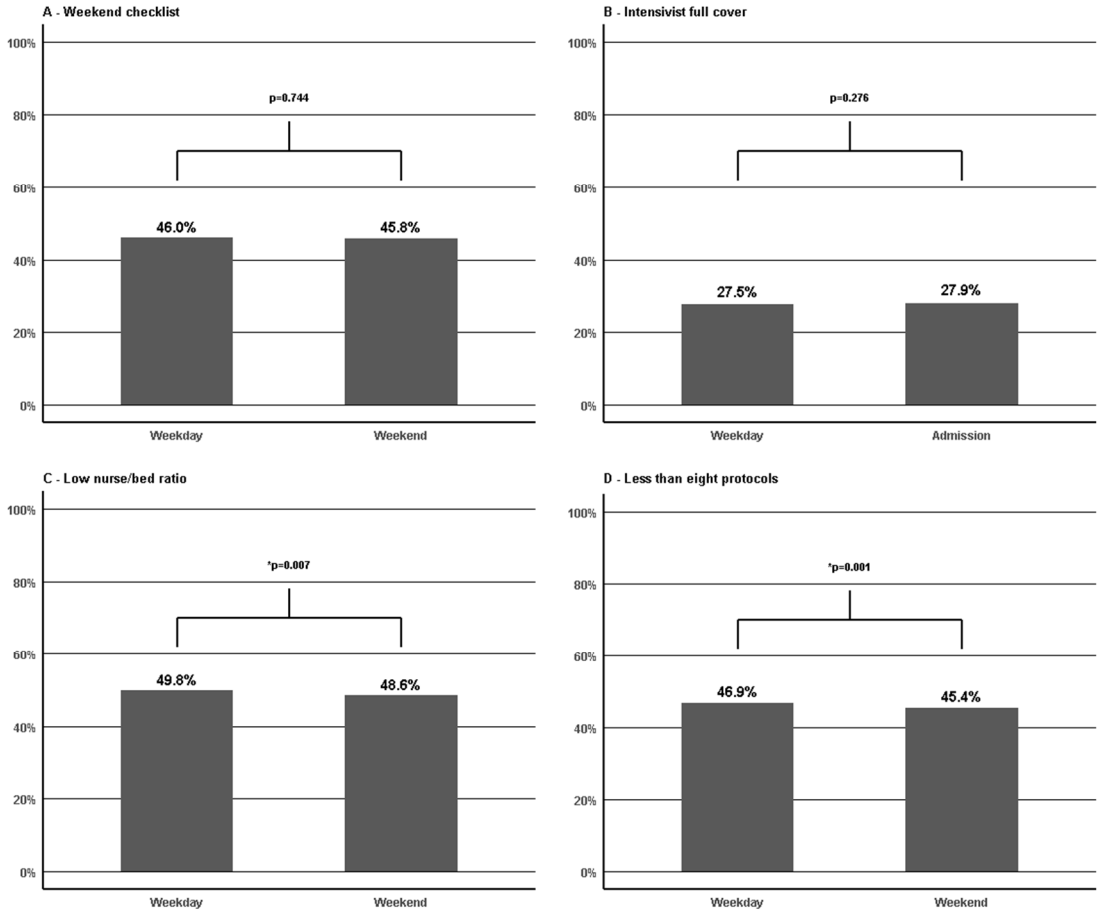
Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

The association between nurse/bed ratio and hospital mortality was assessed using a generalized additive model using the mgcv package. The 0.2 cutoff was chosen by inspecting the plot of predicted probabilities and hospital mortality (red dashed line in the plot).



Percentage of admissions to unit with specific organizational feature

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B - Intensivist fullcover; C - Low nurse/bed ratio; D - Less than eight protocols



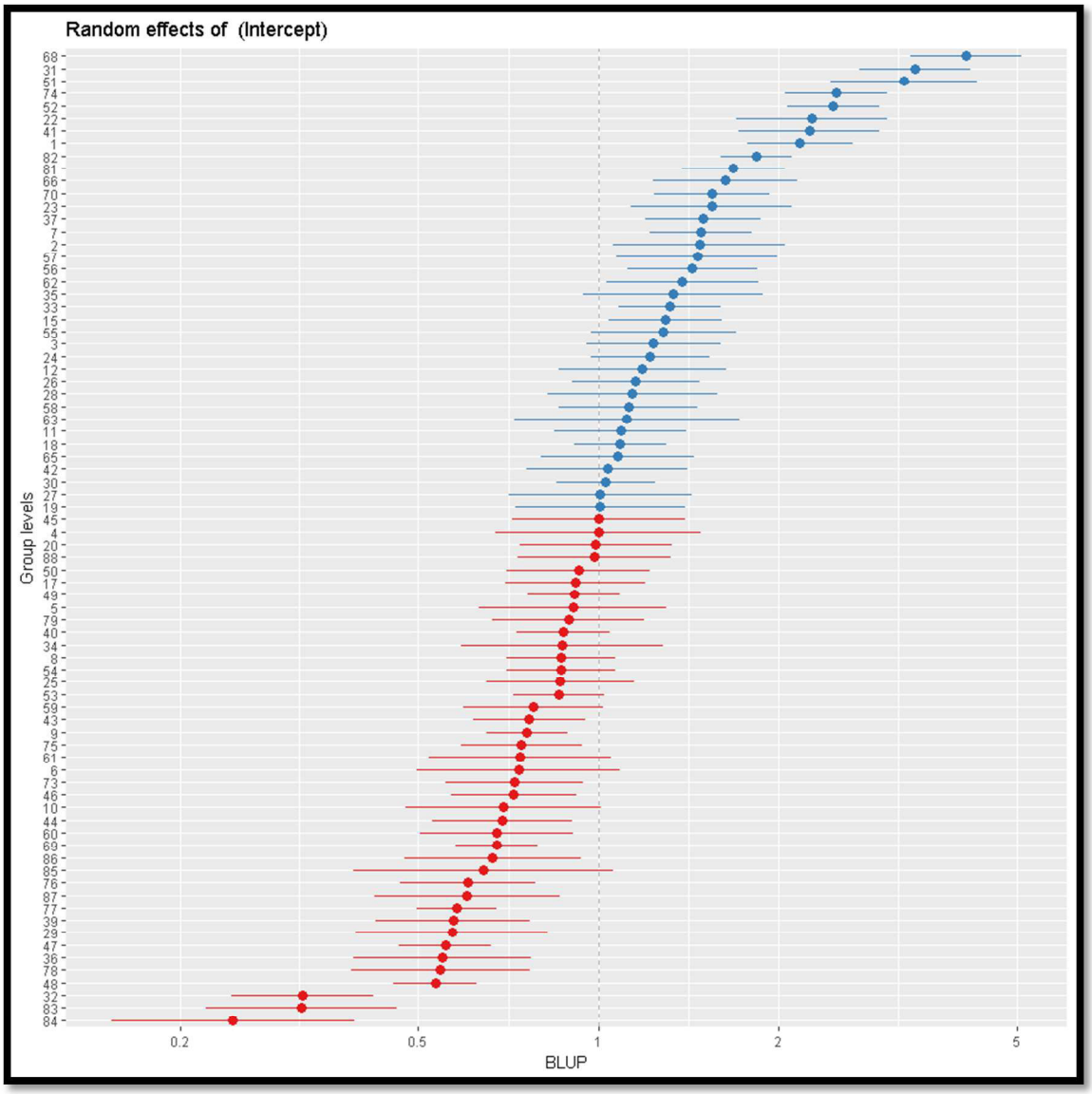
Models Results

Synthax: Mortality ~ Age + SOFA + Charlson Comorbidity Index + Performance Status Impairment + LOS before ICU admission (tertile) + Admission Type + Checklist on Weekends + Full-time Intensivist Coverage + Nurse/Bed lower than 0.2 + Number of Protocols + Medical/Surgical Unit + ICU (random intercept).

Note: Continuous variables were scaled and centered to reduce non-convergence issues; marked with an * through document.

Supplementary Table 2: Results for main model

	OR	CI	p
Age*	1.60	1.55-1.66	<0.001
SOFA*	2.50	2.43-2.57	<0.001
CCI*	1.44	1.41-1.48	<0.001
Moderate Impairment	1.32	1.22-1.42	<0.001
Severe Impairment	2.04	1.86-2.24	<0.001
LOS 1 day	1.17	1.07-1.27	<0.001
LOS >= 2 days	2.44	2.26-2.62	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.76	0.67-0.86	<0.001
Weekend Checklist	0.97	0.74-1.26	0.814
Full-time Intensivist Coverage	0.98	0.72-1.33	0.887
Nurse/Bed <0.2	1.32	1.03-1.7	0.027
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.45	1.06-1.98	0.018
Weekend Admission	1.05	0.99-1.12	0.095



Supplementary Figure 3: Plot of Random Effects

Subgroups

Supplementary Table 3: Medical Patients

	OR	CI	p
Age*	1.56	1.50-1.62	<0.001
SOFA*	2.49	2.42-2.58	<0.001
CCI*	1.46	1.42-1.51	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	1.94	1.76-2.15	<0.001
LOS 1 day	1.14	1.04-1.26	0.008
LOS >= 2 days	2.54	2.34-2.76	<0.001
Weekend Checklist	0.96	0.74-1.24	0.742
Full-time Intensivist Coverage	1.04	0.77-1.41	0.802
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.41	1.04-1.91	0.028
Weekend Admission	1.02	0.96-1.09	0.498

Supplementary Table 4: Elective Surgical Patients

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121

Weekend Admission	1.34	1.1-1.64	0.004

Supplementary Table 5: Urgent Surgical Patients

	OR	CI	p
Age*	1.97	1.73-2.24	<0.001
SOFA*	2.51	2.27-2.77	<0.001
CCI*	1.38	1.23-1.54	<0.001
Moderate Impairment	1.10	0.82-1.48	0.526
Severe Impairment	2.34	1.50-3.65	<0.001
LOS 1 day	0.98	0.73-1.31	0.891
LOS >= 2 days	1.43	1.10-1.85	0.008
Weekend Checklist	0.88	0.53-1.47	0.635
Full-time Intensivist Coverage	0.86	0.50-1.49	0.596
Nurse/Bed <0.2	1.30	0.81-2.11	0.279
Protocols	0.87	0.80-0.95	0.002
surgicalu/Surgical Unit	1.07	0.56-2.05	0.837
Weekend Admission	1.01	0.8-1.27	0.956

Supplementary Table 6: SAPS Quartile 1(5-34)

	OR	CI	p
Age*	1.72	1.43-2.06	<0.001
SOFA*	2.35	1.96-2.82	<0.001
CCI*	1.18	0.96-1.46	0.108
Moderate Impairment	2.11	1.41-3.15	<0.001
Severe Impairment	3.68	1.83-7.39	<0.001
LOS 1 day	1.13	0.77-1.66	0.518
LOS >= 2 days	2.70	1.90-3.83	<0.001
Surgical (elective)	0.37	0.25-0.55	<0.001
Surgical (urgent)	0.86	0.46-1.63	0.655
Weekend Checklist	0.93	0.57-1.52	0.778
Full-time Intensivist Coverage	1.06	0.63-1.77	0.827

Nurse/Bed <0.2	1.07	0.67-1.68	0.786
Protocols	0.83	0.76-0.90	<0.001
Medical/Surgical Unit	1.40	0.78-2.52	0.257
Weekend Admission	1.34	0.98-1.82	0.070

Supplementary Table 7: SAPS Quartile 2 (34-42)

	OR	CI	p
Age*	1.38	1.22-1.57	<0.001
SOFA*	2.08	1.84-2.36	<0.001
CCI*	1.47	1.33-1.62	<0.001
Moderate Impairment	1.34	1.04-1.73	0.022
Severe Impairment	2.75	1.87-4.06	<0.001
LOS 1 day	1.32	1.02-1.71	0.035
LOS >= 2 days	2.62	2.04-3.36	<0.001
Surgical (elective)	0.55	0.41-0.72	<0.001
Surgical (urgent)	0.70	0.47-1.04	0.079
Weekend Checklist	0.94	0.62-1.42	0.766
Full-time Intensivist Coverage	0.83	0.52-1.32	0.422
Nurse/Bed <0.2	1.38	0.94-2.02	0.104
Protocols	0.91	0.84-0.98	0.009
Medical/Surgical Unit	1.81	1.10-2.97	0.020
Weekend Admission	1.17	0.96-1.43	0.117

Supplementary Table 8: SAPS Quartile 3 (42-53)

	OR	CI	p
Age*	1.23	1.15-1.32	<0.001
SOFA*	1.98	1.85-2.13	<0.001
CCI*	1.32	1.25-1.39	<0.001
Moderate Impairment	1.44	1.26-1.65	<0.001
Severe Impairment	2.44	2.05-2.90	<0.001
LOS 1 day	1.18	1.02-1.38	0.030
LOS >= 2 days	2.39	2.07-2.77	<0.001
Surgical (elective)	0.52	0.42-0.63	<0.001

Surgical (urgent)	0.74	0.59-0.93	0.011
Weekend Checklist	1.06	0.81-1.40	0.651
Full-time Intensivist Coverage	0.98	0.71-1.35	0.902
Nurse/Bed <0.2	1.30	1.00-1.68	0.047
Protocols	0.93	0.89-0.98	0.007
Medical/Surgical Unit	1.40	1.01-1.94	0.041
Weekend Admission	1.05	0.94-1.17	0.393

Supplementary Table 9: SAPS Quartile 4 (53-132)

	OR	CI	p
Age*	1.15	1.09-1.21	<0.001
SOFA*	1.92	1.85-2.00	<0.001
CCI*	1.26	1.22-1.30	<0.001
Moderate Impairment	1.18	1.07-1.30	0.001
Severe Impairment	1.66	1.47-1.86	<0.001
LOS 1 day	1.07	0.95-1.20	0.283
LOS >= 2 days	1.91	1.74-2.10	<0.001
Surgical (elective)	0.42	0.33-0.52	<0.001
Surgical (urgent)	0.99	0.84-1.17	0.931
Weekend Checklist	0.92	0.72-1.17	0.488
Full-time Intensivist Coverage	0.92	0.70-1.22	0.567
Nurse/Bed <0.2	1.35	1.08-1.70	0.009
Protocols	0.94	0.90-0.98	0.005
Medical/Surgical Unit	1.33	1.00-1.78	0.053
Weekend Admission	1.00	0.92-1.09	0.979

Supplementary Table 10: Patients admitted due to sepsis

	OR	CI	p
Age*	1.51	1.42-1.60	<0.001
SOFA*	2.19	2.08-2.30	<0.001
CCI*	1.42	1.35-1.49	<0.001
Moderate Impairment	1.31	1.15-1.50	<0.001

Severe Impairment	1.55	1.34-1.80	<0.001
LOS 1 day	1.08	0.92-1.25	0.353
LOS >= 2 days	2.18	1.91-2.50	<0.001
Weekend Checklist	0.90	0.69-1.19	0.460
Full-time Intensivist Coverage	0.95	0.69-1.30	0.755
Nurse/Bed <0.2	1.49	1.15-1.92	0.002
Protocols	0.92	0.88-0.97	0.001
Medical/Surgical Unit	1.24	0.87-1.78	0.232
Weekend Admission	1.02	0.91-1.13	0.737

Supplementary Table 11: Patients that required mechanical ventilation on day 1

	OR	CI	p
Age*	1.61	1.52-1.71	<0.001
SOFA*	1.74	1.66-1.83	<0.001
CCI*	1.30	1.24-1.37	<0.001
Moderate Impairment	1.18	1.02-1.35	0.022
Severe Impairment	1.03	0.87-1.21	0.769
LOS 1 day	1.01	0.87-1.18	0.878
LOS >= 2 days	1.64	1.45-1.86	<0.001
Surgical (elective)	0.17	0.15-0.20	<0.001
Surgical (urgent)	0.59	0.50-0.69	<0.001
Weekend Checklist	0.99	0.72-1.36	0.959
Full-time Intensivist Coverage	0.91	0.64-1.29	0.590
Nurse/Bed <0.2	1.42	1.06-1.90	0.018
Protocols	0.96	0.91-1.01	0.133
Medical/Surgical Unit	1.12	0.76-1.66	0.553
Weekend Admission	1.07	0.96-1.2	0.228

Supplementary Table 12: ICUs with nurse decrease on weekends

	OR	CI	p
Age*	1.52	1.45-1.59	<0.001
SOFA*	2.50	2.41-2.59	<0.001

CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.31	1.2-1.44	<0.001
Severe Impairment	1.88	1.67-2.12	<0.001
LOS 1 day	1.17	1.05-1.30	0.004
LOS >= 2 days	2.46	2.25-2.69	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.73	0.63-0.85	<0.001
Weekend Checklist	1.14	0.85-1.52	0.391
Full-time Intensivist Coverage	0.92	0.65-1.30	0.629
Nurse/Bed <0.2	1.31	0.99-1.73	0.056
Protocols	0.92	0.87-0.98	0.007
Medical/Surgical Unit	1.17	0.80-1.73	0.421
Weekend Admission	1.07	0.99-1.15	0.085

Supplementary Table 13: ICUs with no nurse decrease on weekend

	OR	CI	p
Age*	1.76	1.66-1.86	<0.001
SOFA*	2.50	2.38-2.62	<0.001
CCI*	1.45	1.39-1.52	<0.001
Moderate Impairment	1.34	1.18-1.51	<0.001
Severe Impairment	2.37	2.03-2.76	<0.001
LOS 1 day	1.17	1.02-1.34	0.025
LOS >= 2 days	2.39	2.11-2.71	<0.001
Surgical (elective)	0.24	0.21-0.28	<0.001
Surgical (urgent)	0.81	0.66-0.99	0.040
Weekend Checklist	0.74	0.45-1.20	0.222
Full-time Intensivist Coverage	1.08	0.62-1.88	0.783
Nurse/Bed <0.2	1.50	0.93-2.42	0.094
Protocols	0.94	0.87-1.01	0.085
Medical/Surgical Unit	1.97	1.18-3.27	0.009
Weekend Admission	1.02	0.93-1.13	0.642

Supplementary Table 14: ICUs with intensivist fullcover

	OR	CI	p
Age*	1.63	1.53-1.74	<0.001
SOFA*	2.21	2.09-2.33	<0.001
CCI*	1.33	1.26-1.40	<0.001
Moderate Impairment	1.35	1.16-1.57	<0.001
Severe Impairment	2.12	1.73-2.59	<0.001
LOS 1 day	1.03	0.87-1.23	0.695
LOS >= 2 days	2.40	2.10-2.75	<0.001
Surgical (elective)	0.21	0.17-0.25	<0.001
Surgical (urgent)	0.65	0.51-0.82	<0.001
Weekend Checklist	1.27	0.65-2.48	0.493
Nurse/Bed <0.2	1.49	0.77-2.87	0.240
Protocols	0.90	0.81-0.98	0.022
Medical/Surgical Unit	1.13	0.49-2.64	0.773
Weekend Admission	1.03	0.92-1.16	0.584

Supplementary Table 15: ICUs without intensivist fullcover

	OR	CI	p
Age*	1.60	1.54-1.67	<0.001
SOFA*	2.62	2.53-2.71	<0.001
CCI*	1.49	1.44-1.53	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	2.02	1.82-2.25	<0.001
LOS 1 day	1.21	1.10-1.34	<0.001
LOS >= 2 days	2.42	2.22-2.64	<0.001
Surgical (elective)	0.26	0.23-0.29	<0.001
Surgical (urgent)	0.80	0.70-0.93	0.002
Weekend Checklist	0.91	0.69-1.22	0.535
Nurse/Bed <0.2	1.33	1.02-1.74	0.034
Protocols	0.95	0.90-1.00	0.057
Medical/Surgical Unit	1.47	1.06-2.03	0.020
Weekend Admission	1.06	0.99-1.14	0.094

Supplementary Table 16: ICUs with checklists

	OR	CI	p
Age*	1.69	1.60-1.79	<0.001
SOFA*	2.56	2.44-2.68	<0.001
CCI*	1.45	1.40-1.51	<0.001
Moderate Impairment	1.41	1.25-1.58	<0.001
Severe Impairment	2.30	2.00-2.64	<0.001
LOS 1 day	1.23	1.08-1.41	0.003
LOS >= 2 days	2.57	2.29-2.89	<0.001
Surgical (elective)	0.28	0.24-0.32	<0.001
Surgical (urgent)	0.70	0.57-0.86	0.001
Full-time Intensivist Coverage	1.16	0.71-1.91	0.554
Nurse/Bed <0.2	1.18	0.85-1.64	0.314
Protocols	0.97	0.91-1.04	0.44
Medical/Surgical Unit	1.56	1.04-2.34	0.031
Weekend Admission	1.01	0.92-1.11	0.816

Supplementary Table 17: ICUs without checklist

	OR	CI	p
Age*	1.55	1.49-1.63	<0.001
SOFA*	2.46	2.37-2.55	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.25	1.14-1.38	<0.001
Severe Impairment	1.84	1.62-2.09	<0.001
LOS 1 day	1.13	1.01-1.26	0.034
LOS >= 2 days	2.35	2.15-2.58	<0.001
Surgical (elective)	0.22	0.20-0.25	<0.001
Surgical (urgent)	0.78	0.67-0.90	0.001
Full-time Intensivist Coverage	0.91	0.61-1.35	0.627
Nurse/Bed <0.2	1.53	1.04-2.25	0.032
Protocols	0.91	0.86-0.97	0.003
Medical/Surgical Unit	1.53	0.94-2.49	0.086
Weekend Admission	1.08	1.00-1.17	0.045

Supplementary Table 18: ICUs with less than 8 protocols

	OR	CI	p
Age*	1.67	1.59-1.75	<0.001
SOFA*	2.48	2.38-2.58	<0.001
CCI*	1.42	1.37-1.48	<0.001
Moderate Impairment	1.36	1.22-1.51	<0.001
Severe Impairment	2.25	1.94-2.60	<0.001
LOS 1 day	1.20	1.06-1.35	0.005
LOS >= 2 days	2.11	1.90-2.34	<0.001
Surgical (elective)	0.26	0.23-0.30	<0.001
Surgical (urgent)	0.84	0.71-0.99	0.042
Weekend Checklist	0.76	0.51-1.12	0.168
Full-time Intensivist Coverage	1.06	0.68-1.67	0.790
Nurse/Bed <0.2	1.68	1.13-2.51	0.011
Medical/Surgical Unit	2.17	1.23-3.82	0.007
Weekend Admission	1.08	0.99-1.18	0.088

Supplementary Table 19: ICUs with at least 8 protocols

	OR	CI	p
Age*	1.54	1.46-1.62	<0.001
SOFA*	2.51	2.42-2.61	<0.001
CCI*	1.46	1.41-1.51	<0.001
Moderate Impairment	1.29	1.17-1.43	<0.001
Severe Impairment	1.93	1.70-2.18	<0.001
LOS 1 day	1.13	1.01-1.27	0.035
LOS >= 2 days	2.78	2.52-3.07	<0.001
Surgical (elective)	0.22	0.19-0.25	<0.001
Surgical (urgent)	0.68	0.57-0.80	<0.001
Weekend Checklist	0.99	0.75-1.30	0.930
Full-time Intensivist Coverage	0.80	0.55-1.15	0.231

Nurse/Bed <0.2	1.15	0.88-1.49	0.307
Medical/Surgical Unit	1.17	0.87-1.57	0.298
Weekend Admission	1.03	0.95-1.12	0.474

Analysis on Unscheduled Admissions

Supplementary Table 20: Main model

	OR	CI	p
Age*	1.59	1.53-1.65	<0.001
SOFA*	2.49	2.42-2.57	<0.001
CCI*	1.46	1.42-1.5	<0.001
Moderate Impairment	1.30	1.20-1.41	<0.001
Severe Impairment	1.96	1.78-2.17	<0.001
LOS 1 day	1.12	1.02-1.23	0.013
LOS >= 2 days	2.35	2.18-2.55	<0.001
Weekend Checklist	0.95	0.73-1.23	0.685
Full-time Intensivist Coverage	1.03	0.76-1.40	0.850
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.002
Medical/Surgical Unit	1.42	1.04-1.92	0.026
Weekend Admission	1.02	0.96-1.09	0.473

Supplementary Table 21: Nurse decrease on weekends

	OR	CI	p
Age*	1.50	1.43-1.57	<0.001
SOFA*	2.49	2.40-2.58	<0.001
CCI*	1.46	1.40-1.51	<0.001
Moderate Impairment	1.30	1.18-1.44	<0.001
Severe Impairment	1.86	1.64-2.11	<0.001
LOS 1 day	1.11	0.99-1.25	0.076
LOS >= 2 days	2.39	2.17-2.63	<0.001
Weekend Checklist	1.09	0.82-1.46	0.55
Full-time Intensivist Coverage	0.96	0.68-1.36	0.824
Nurse/Bed <0.2	1.37	1.04-1.81	0.026
Protocols	0.92	0.87-0.97	0.005
Medical/Surgical Unit	1.13	0.77-1.67	0.535

Weekend Admission	1.04	0.96-1.12	0.38

Supplementary Table 22: No nurse decrease on weekends

	OR	CI	p
Age*	1.74	1.64-1.85	<0.001
SOFA*	2.49	2.37-2.62	<0.001
CCI*	1.47	1.41-1.54	<0.001
Moderate Impairment	1.31	1.14-1.49	<0.001
Severe Impairment	2.18	1.85-2.55	<0.001
LOS 1 day	1.15	0.99-1.33	0.067
LOS >= 2 days	2.27	1.98-2.60	<0.001
Weekend Checklist	0.74	0.46-1.18	0.206
Full-time Intensivist Coverage	1.17	0.68-1.99	0.571
Nurse/Bed <0.2	1.51	0.95-2.38	0.080
Protocols	0.94	0.87-1.01	0.075
Medical/Surgical Unit	1.95	1.19-3.19	0.008
Weekend Admission	1.00	0.90-1.11	0.995

Supplementary Table 23: Weekend Checklist

	OR	CI	p
Age*	1.66	1.56-1.76	<0.001
SOFA*	2.54	2.42-2.67	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.38	1.23-1.56	<0.001
Severe Impairment	2.28	1.98-2.63	<0.001
LOS 1 day	1.16	1.00-1.34	0.048
LOS >= 2 days	2.48	2.19-2.81	<0.001
Full-time Intensivist Coverage	1.22	0.73-2.02	0.450
Nurse/Bed <0.2	1.25	0.90-1.76	0.187
Protocols	0.98	0.91-1.05	0.502
Medical/Surgical Unit	1.48	0.97-2.24	0.066

Weekend Admission	0.99	0.90-1.10	0.860

Supplementary Table 24: No weekend Checklist

	OR	CI	p
Age*	1.54	1.47-1.62	<0.001
SOFA*	2.46	2.36-2.55	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.24	1.12-1.38	<0.001
Severe Impairment	1.72	1.50-1.97	<0.001
LOS 1 day	1.10	0.98-1.24	0.117
LOS >= 2 days	2.27	2.05-2.51	<0.001
Full-time Intensivist Coverage	0.97	0.66-1.43	0.873
Nurse/Bed <0.2	1.55	1.06-2.25	0.022
Protocols	0.91	0.86-0.97	0.002
Medical/Surgical Unit	1.53	0.96-2.45	0.076
Weekend Admission	1.05	0.97-1.14	0.233

Supplementary Table 25: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.62	1.51-1.73	<0.001
SOFA*	2.21	2.09-2.34	<0.001
CCI*	1.36	1.29-1.44	<0.001
Moderate Impairment	1.29	1.10-1.53	0.002
Severe Impairment	1.98	1.61-2.44	<0.001
LOS 1 day	1.00	0.83-1.21	0.984
LOS >= 2 days	2.30	1.98-2.66	<0.001
Weekend Checklist	1.20	0.65-2.24	0.562
Nurse/Bed <0.2	1.55	0.84-2.85	0.163
Protocols	0.89	0.82-0.98	0.012
Medical/Surgical Unit	1.11	0.50-2.46	0.791

Weekend Admission	0.99	0.88-1.12	0.856

Supplementary Table 26: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.58	1.51-1.65	<0.001
SOFA*	2.60	2.51-2.70	<0.001
CCI*	1.50	1.45-1.55	<0.001
Moderate Impairment	1.30	1.19-1.43	<0.001
Severe Impairment	1.96	1.76-2.19	<0.001
LOS 1 day	1.16	1.05-1.29	0.005
LOS >= 2 days	2.36	2.15-2.59	<0.001
Weekend Checklist	0.89	0.67-1.19	0.437
Nurse/Bed <0.2	1.36	1.04-1.78	0.025
Protocols	0.95	0.90-1.00	0.065
Medical/Surgical Unit	1.43	1.04-1.98	0.030
Weekend Admission	1.04	0.96-1.12	0.326

Supplementary Table 27: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.67	1.58-1.76	<0.001
SOFA*	2.49	2.38-2.60	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.37	1.22-1.54	<0.001
Severe Impairment	2.15	1.85-2.50	<0.001
LOS 1 day	1.13	0.99-1.30	0.071
LOS >= 2 days	2.05	1.82-2.30	<0.001
Weekend Checklist	0.75	0.51-1.09	0.133
Full-time Intensivist Coverage	1.14	0.73-1.76	0.566

Nurse/Bed <0.2	1.72	1.17-2.54	0.006
Medical/Surgical Unit	2.08	1.20-3.61	0.009
Weekend Admission	1.04	0.95-1.14	0.349

Supplementary Table 28: At least 8 protocols in ICU

	OR	CI	p
Age*	1.51	1.43-1.59	<0.001
SOFA*	2.49	2.39-2.60	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.26	1.13-1.41	<0.001
Severe Impairment	1.87	1.64-2.13	<0.001
LOS 1 day	1.11	0.98-1.26	0.097
LOS >= 2 days	2.64	2.37-2.94	<0.001
Weekend Checklist	0.96	0.72-1.26	0.757
Full-time Intensivist Coverage	0.84	0.58-1.22	0.352
Nurse/Bed <0.2	1.19	0.91-1.55	0.203
Medical/Surgical Unit	1.14	0.84-1.55	0.389
Weekend Admission	1.01	0.92-1.10	0.912

Analysis on Scheduled Admissions

Supplementary Table 29: Main model

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.10-1.64	0.004

Supplementary Table 30: Nurse decrease on weekends

	OR	CI	p
Age*	1.72	1.50-1.96	<0.001
SOFA*	2.44	2.20-2.70	<0.001
CCI*	1.40	1.27-1.53	<0.001
Moderate Impairment	1.40	1.08-1.83	0.012
Severe Impairment	2.62	1.63-4.21	<0.001
LOS 1 day	1.41	1.05-1.89	0.023
LOS >= 2 days	2.60	2.01-3.36	<0.001
Weekend Checklist	1.33	0.81-2.19	0.255
Full-time Intensivist Coverage	0.75	0.43-1.31	0.303
Nurse/Bed <0.2	1.07	0.67-1.73	0.769
Protocols	0.88	0.79-0.97	0.013
Medical/Surgical Unit	1.24	0.61-2.53	0.556
Weekend Admission	1.40	1.09-1.79	0.008

Supplementary Table 31: No nurse decrease on weekends

	OR	CI	p
Age*	2.01	1.67-2.41	<0.001
SOFA*	2.44	2.13-2.8	<0.001
CCI*	1.37	1.22-1.54	<0.001
Moderate Impairment	1.68	1.18-2.39	0.004
Severe Impairment	5.90	3.61-9.63	<0.001
LOS 1 day	1.25	0.83-1.87	0.282
LOS >= 2 days	2.46	1.70-3.55	<0.001
Weekend Checklist	1.00	0.48-2.09	0.996
Full-time Intensivist Coverage	0.93	0.44-1.93	0.836
Nurse/Bed <0.2	1.92	0.95-3.89	0.069
Protocols	0.87	0.78-0.97	0.012
Medical/Surgical Unit	1.70	0.86-3.36	0.127
Weekend Admission	1.26	0.89-1.78	0.193

Supplementary Table 32: Weekend Checklist

	OR	CI	p
Age*	2.03	1.70-2.44	<0.001
SOFA*	2.56	2.23-2.93	<0.001
CCI*	1.55	1.38-1.74	<0.001
Moderate Impairment	1.59	1.15-2.20	0.005
Severe Impairment	2.86	1.69-4.82	<0.001
LOS 1 day	1.69	1.15-2.46	0.007
LOS >= 2 days	2.85	2.04-3.98	<0.001
Full-time Intensivist Coverage	0.91	0.43-1.92	0.800
Nurse/Bed <0.2	1.27	0.70-2.28	0.432
Protocols	0.90	0.78-1.04	0.145
Medical/Surgical Unit	1.76	0.84-3.71	0.135

Weekend Admission	1.27	0.93-1.75	0.134

Supplementary Table 33: No weekend Checklist

	OR	CI	p
Age*	1.68	1.47-1.92	<0.001
SOFA*	2.37	2.14-2.62	<0.001
CCI*	1.32	1.20-1.44	<0.001
Moderate Impairment	1.36	1.03-1.79	0.033
Severe Impairment	4.86	3.11-7.60	<0.001
LOS 1 day	1.16	0.85-1.58	0.347
LOS >= 2 days	2.33	1.77-3.06	<0.001
Full-time Intensivist Coverage	0.78	0.44-1.38	0.399
Nurse/Bed <0.2	1.30	0.73-2.29	0.373
Protocols	0.87	0.79-0.95	0.002
Medical/Surgical Unit	1.38	0.70-2.73	0.357
Weekend Admission	1.41	1.09-1.83	0.009

Supplementary Table 34: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.90	1.55-2.33	<0.001
SOFA*	2.05	1.77-2.37	<0.001
CCI*	1.24	1.08-1.43	0.002
Moderate Impairment	1.77	1.20-2.61	0.004
Severe Impairment	5.71	2.75-11.88	<0.001
LOS 1 day	0.95	0.62-1.46	0.825
LOS >= 2 days	2.06	1.41-3.01	<0.001
Weekend Checklist	1.39	0.53-3.63	0.502
Nurse/Bed <0.2	1.03	0.38-2.77	0.951
Protocols	0.84	0.72-0.97	0.018

Medical/Surgical Unit	1.12	0.32-3.89	0.856
Weekend Admission	1.44	1.02-2.04	0.038

Supplementary Table 35: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.79	1.58-2.03	<0.001
SOFA*	2.65	2.40-2.93	<0.001
CCI*	1.46	1.34-1.59	<0.001
Moderate Impairment	1.40	1.08-1.80	0.010
Severe Impairment	3.38	2.30-4.96	<0.001
LOS 1 day	1.57	1.17-2.09	0.002
LOS >= 2 days	2.82	2.19-3.63	<0.001
Weekend Checklist	1.17	0.73-1.88	0.513
Nurse/Bed <0.2	1.34	0.86-2.09	0.190
Protocols	0.88	0.81-0.97	0.007
Medical/Surgical Unit	1.50	0.90-2.53	0.123
Weekend Admission	1.29	1.01-1.66	0.042

Supplementary Table 36: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.70	1.49-1.95	<0.001
SOFA*	2.42	2.16-2.70	<0.001
CCI*	1.32	1.19-1.47	<0.001
Moderate Impairment	1.30	0.97-1.74	0.079
Severe Impairment	3.91	2.36-6.49	<0.001
LOS 1 day	1.50	1.09-2.08	0.014
LOS >= 2 days	2.16	1.61-2.90	<0.001
Weekend Checklist	0.84	0.46-1.52	0.565

Full-time Intensivist Coverage	0.96	0.51-1.79	0.892
Nurse/Bed <0.2	1.63	0.90-2.94	0.106
Medical/Surgical Unit	2.17	0.98-4.82	0.056
Weekend Admission	1.42	1.06-1.89	0.018

Supplementary Table 37: At least 8 protocols in ICU

	OR	CI	p
Age*	1.94	1.63-2.32	<0.001
SOFA*	2.51	2.23-2.83	<0.001
CCI*	1.46	1.32-1.61	<0.001
Moderate Impairment	1.65	1.22-2.25	0.001
Severe Impairment	3.60	2.28-5.68	<0.001
LOS 1 day	1.18	0.82-1.69	0.372
LOS >= 2 days	2.96	2.19-4.00	<0.001
Weekend Checklist	1.12	0.68-1.83	0.664
Full-time Intensivist Coverage	0.54	0.28-1.03	0.062
Nurse/Bed <0.2	1.02	0.62-1.69	0.925
Medical/Surgical Unit	1.18	0.67-2.07	0.567
Weekend Admission	1.29	0.97-1.70	0.081

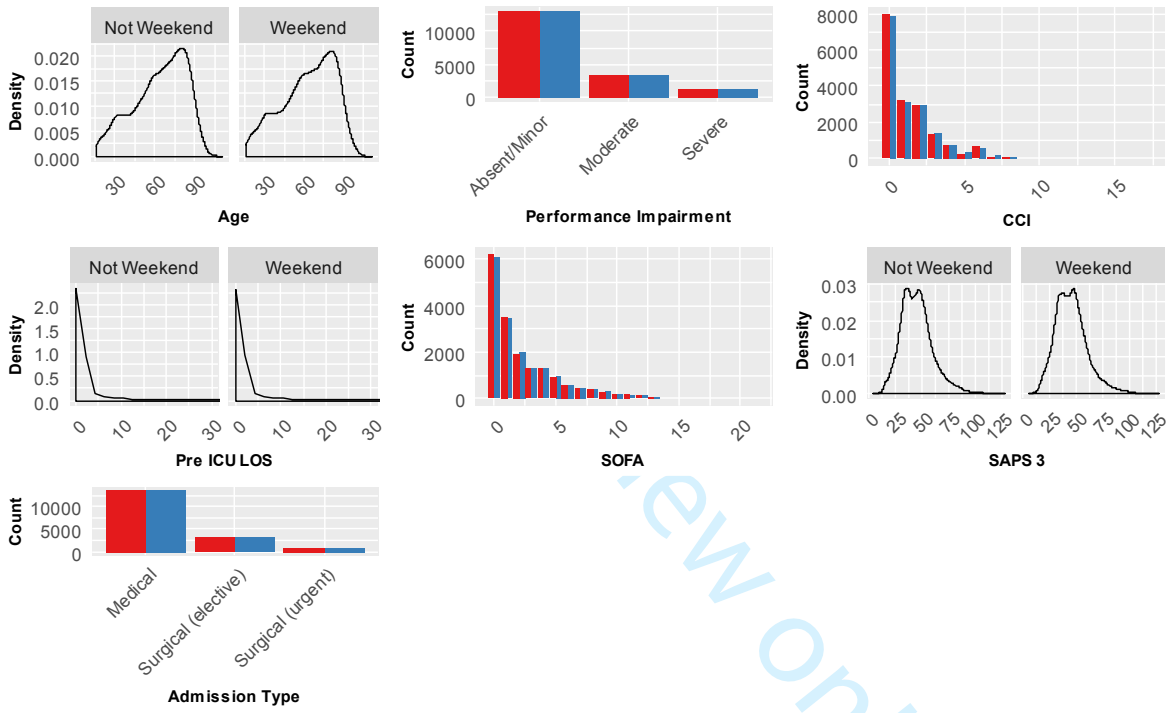
Propensity Score Analysis

Method: 1:1 patient matching controlling for age, CCI, admission type, performance status impairment, LOS before ICU admission, SOFA, SAPS3 and admission type

Results: 35,440 patients (17,720 in each arm) were matched. Mortality was 15.5% for patients admitted on weekdays and 16.1% for patients admitted on weekends (p=0.112)

Matching: Matching was adequate. Figure below shows density plot and barplots for the variables included in the propensity score

Supplementary Figure 4: Variable comparison after propensity score matching



List of Protocols Inquired to Participating ICUs:

Only protocols fully implemented for at least 6 months were considered. If the participating unit reported that protocol was in place, the careprovider responsible for the protocol was also obligatorily reported.

1. Sepsis (i.e. according to the current recommendations of the Surviving Sepsis Campaign)
2. Sedation (i.e. daily interruption or protocolized sedation in ventilated patients)
3. Cerebrovascular accident (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive thrombolysis)
4. Acute coronary syndromes (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive reperfusion therapies or interventions)
5. Liberation from the mechanical ventilation (i.e. care provider-driven spontaneous breathing trials)
6. Lung protective ventilation (i.e. ventilation with low tidal volumes in patients with acute lung injury/ARDS)
7. Therapeutic hypothermia in patients who experienced cardiac arrest
8. Catheter-associated bloodstream infection prevention (i.e. implementation of checklists during insertion and maintenance of vascular catheters)
9. Ventilator-associated pneumonia (VAP) prevention (i.e. implementation of daily checklists to best practices to prevent VAP in ventilated patients)
10. Early mobilization in ventilated patients (i.e protocolized early exercise and mobilization including physical and occupational therapy during periods of daily interruption of sedation in ventilated patients)

STROBE Checklist

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7, first paragraph
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, first paragraph
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, first paragraph
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5, third paragrapg
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 7
Study size	10	Explain how the study size was arrived at	NA

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9, specific subtopic on this
		(*c*) Explain how missing data were addressed	Page 8, specific topic
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Page 7.
		(*e*) Describe any sensitivity analyses	Only subgroup analyses were performed.

Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12, first patagraph
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	All patients in dataset were eligible
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Figures 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Described in methods. Only performance status missing
		(c) *Cohort study*—Summarise follow-up time (eg, average and total	NA

		amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Mortality reported on Table 1.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 15 and 16
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 17, first paragraph
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pages 19 and 20.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 19.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 19.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	First page.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and

Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

STROBE Checklist

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Methods			
Study design	4	Present key elements of study design early in the paper	7, first paragraph
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, first paragraph
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, first paragraph
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5, third paragrapg
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 7
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9, specific subtopic on this

		(*c*) Explain how missing data were addressed	Page 8, specific topic
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Page 7.
		(*e*) Describe any sensitivity analyses	Only subgroup analyses were performed.
Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12, first patagraph
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	All patients in dataset were eligible
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Figures 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Described in methods. Only performance status missing
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Mortality reported on Table 1.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 15 and 16
Discussion			

Key results	18	Summarise key results with reference to study objectives	Page 17, first paragraph
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pages 19 and 20.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 19.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 19.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	First page.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

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The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

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Abstract

Introduction: Higher mortality for patients admitted to the intensive care unit during the weekends in intensive care units (ICUs) has been occasionally reported with mixed results that could be related to organizational factors. We assessed whether ICU organizational and staffing patterns are related to the association between weekend admission and worse outcomes in critically ill patients.

Methods: We included 59,614 patients (78 ICUs) admitted to the ICUs participating of the ORCHESTRA study. Weekend admission was defined as admission from Friday 7pm until Monday 7am. We assessed the association between weekend admission with hospital mortality using a mixed logistic regression model controlling for both patient-level (illness severity, age, comorbidities, performance status and admission type) and ICU-level confounders (decrease in nurse/bed ratio on weekend, full-time intensivist coverage, use of checklists on weekends and number of institutional protocols). Secondary analyses were performed for scheduled surgical admissions.

Results: A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) on weekends. In univariate analysis, weekend admitted patients had higher ICU (10.9% vs. 9.0%, p<0.001) and hospital (16.5% vs. 13.5%, p<0.001) mortality. After adjusting for confounders, weekend admission was not associated with higher hospital mortality (OR 1.05, 95% CI 0.99-1.12, p=0.095). However, a “weekend effect” was still observed in scheduled surgical admissions, as well as in ICUs not following checklists during the weekends. For unscheduled admissions, no “weekend effect” was observed regardless of ICU´s characteristics. For scheduled surgical admissions, a “weekend effect” was present only in ICUs with a reduction in the nurse/bed ratio during weekends, without weekend checklists and with a low number of implemented protocols.

Conclusions: Institutional factors, such as decreased nurse to patient ratio, absence of checklists, and fewer standardized protocols may increase ICU mortality on weekends

Strengths and Limitations:

- After controlling for patient and center-level confounder, a "weekend effect" was not observed in Brazilian ICUs
- Secondary exploratory analyses suggested that some organizational factors could explain the observed higher mortality on weekends, especially absence of weekend checklists and lower number of ancillary protocols available.
- Organizational features, especially number of protocols, may become more relevant as length of stay increases.
- Due to multiple correlations and the large number of exploratory models, these results should be interpreted with caution and within a context of low baseline nuse:bed ratio.

Introduction

Higher mortality for patients admitted during the weekends has been repeatedly reported in studies carried out in both wards (1,2) and intensive care units (ICU) (3,4). The so-called "weekend effect" is often ascribed to the imbalance of organizational and staffing features available on weekdays, which either do not occur or are suboptimal during the weekends (5). This notion has driven several health care policies, especially in England where junior doctors' contracts were changed on the assumption that increased weekend working would mitigate the weekend effect (6). This was followed by a great deal of discussion on the veracity of a weekend effect due to uncertainties on the reliability of disease coding on admission during weekends (6,7) and biases related to different profiles of illness severity and comorbidities in weekend admitted patients (8,9).

If the weekend effect is a real phenomenon amongst ICU admissions, it could be mediated by several organizational factors including staffing features such as full-time intensivist coverage and nurse staff levels (10) and use of other ancillary tools designed to sustain the continuity of care such as checklists and number of institutional protocols available(11). However, the association between these organizational characteristics and the weekend effect in ICUs were not thoroughly evaluated. We have used a large national prospectively-collected database to examine the hypothesis that the weekend effect would only be manifest in settings in which sub-optimal organization; staffing or clinical practices could impact on continuity of care.

Methods

Population: This was a *post hoc* analysis of a large cohort study in critically ill patients admitted in 78 Brazilian ICUs during 2013 from January 1st until December 31st (The ORCHESTRA Study) (11). All critically ill patients in the database were selected. From the initial database of 59,693 patients, we excluded 79 patients with missing admission date/hour, leaving 59,614 patients for analysis. In case of readmissions during the study period, we considered only the first ICU admission.

Exposure definitions: We defined weekend admission as any admission to the ICU occurring between Friday 7 pm and Monday 7 am.

Outcome definition: Hospital mortality.

Organizational factors: We considered several organizational factors in the analysis including the use of checklists (structured evaluations using a digital or printed instrument with multiple components focused on prevention of common ICU complications and adherence to best practices) during weekends, the implementation of protocols in the ICU (among a pre-defined set of ten protocols aiming at the adherence to best practices and prevention of acquired complications for frequent conditions in the ICU; see Supplementary File for details), the presence of full-time intensivist coverage 24/7 in the ICU, presence of a low nurse/bed ratio and ICU type. Full-time intensivist coverage was defined as the presence of a board-certified intensivist in the ICU 24 hours a day, 7 days a week. A low nurse/bed ratio was defined as a mean nurse/bed ≤ 0.20 inside the ICU (that is, the mean nurse/bed ratio considering all shifts in the ICU was lower or equal to 0.20). This 0.20 cutoff was established after inspecting the univariate association between nurse/bed ratio and in-hospital mortality in a generalized additive model (sFigure 1; see Electronic Supplementary Material – ESM – for details). For checklists, dummy coding

was used to represent units with checklists 7 days a week versus those without weekend checklists (that is, units that had checklists on weekdays only or did not apply checklists at all).

Patient factors: We estimated organ failure and the severity of illness using the Sequential Organ Failure Assessment (SOFA) score (12) and the Simplified Acute Physiology Score (SAPS) 3 (13). The Charlson Comorbidity Index was calculated as previously reported (14). Baseline performance status was defined according to the impairment degree as absent/minor, moderate and severe corresponding to performance classes of Eastern Cooperative Oncology Group (ECOG) of 0-1, 2 or 3-4, respectively as previously described (15). Hospital length of stay before ICU admission was collected and stratified in tertiles for the analysis.

Missing values: No outcome was missing. Baseline performance status was missing in 3,476 patients. Multiple imputation using random forest models was used to impute missing values for this variable, as previously described (15). There were no other missing values in the variables included in the analysis.

Statistical Analysis: We used a mixed multivariate logistic regression to assess the independent association between each predictor and hospital mortality at the patient level. The ICU where the patient was admitted was added as a random effect (random intercept) in the model while all the other variables were added as fixed effect. Continuous variables were scaled and centered before entering the mixed model. Entry criteria for entering variables at the patient-level in the logistic regression were based on significance level ($P<0.1$) or those variables known to be related to prognosis (age, SOFA score, Charlson Comorbidity Index, performance status impairment). The following variables were included in the main model: age, SOFA score, Charlson Comorbidity Index, performance

status impairment, admission type (medical, elective surgery, non-elective surgery), length-of-stay (LOS) before ICU admission stratified in tertiles, use of checklists during the weekends, presence of full-time intensivist coverage, low baseline nurse/bed ratio, ICU type (medical/surgical or other) and weekend admission. No stepwise selection was performed. Type of funding (public versus private) was not added to the model due to large colinearity with most organizational features.

Subgroup analyses: We defined that sensitivity analysis for the following subgroups would be performed: admission type; quartiles of baseline SAPS 3 score, patients admitted due to sepsis, patients admitted on mechanical ventilation, ICUs with or without decrease in nurse/bed ratio during weekends (regardless of baseline values), ICUs stratified per presence of full-time intensivist coverage, ICUs with or without checklist during the weekends, and according to number of ancillary protocols in the ICU (above or below the median values of protocols per ICU). We repeated the subgroup analyses of organizational features (decrease in nurse staff, absence of full-time intensivist coverage, absence of checklist, and number of ancillary protocols) after stratifying our sample according to scheduled surgical versus non-scheduled ICU admissions (both emergency surgery and clinical) (16). For the number of ancillary protocols, we split the samples in patients admitted to units with less or at least eight protocols, since this value split the number of included intensive care units in half. Scheduled surgery admissions are defined as any admission after a surgical procedure which was scheduled at least 24 hours before its start and for which an ICU bed was requested before the procedure started.

Propensity score analysis: We performed a propensity score 1:1 analysis pairing patients per their predicted probability of weekend admission based solely on the patients' factors. The probability of weekend admission was obtained by creating a logistic

regression with the following variable included as predictors: age, SOFA score, SAPS 3 score, Charlson Comorbidity Index, degree of performance status impairment, LOS before ICU admission and admission type. Patients were matched using the nearest neighbor method considering the logit as the distance method. Maximum distance allowed was 0.40. At each matching, the unit with the closest logit still unmatched was used. After checking the balance of the propensity-matched groups, we compared hospital mortality for propensity-matched patients using chi-squared test.

Effects of organizational changes during weekends in weekend versus-weekday mortality: One additional approach to scrutinize the impact of organizational features in weekend admission mortality was applied by performing a linear regression at the ICU level considering the change in mortality (weekend minus weekday mortality for the ICU) as dependent variable and both SAPS 3 and organizational features as predictors. The organizational features selected were the same used for splitting subgroups in multivariate mixed model. After linear regression, we assessed the relative importance of each predictor using the method suggested by Lindeman, Merenda, and Gold (LMG).

Temporal association between organizational features and outcome in patients admitted during weekends: The time dependent effects of organizational factors in patients admitted to the ICU on weekends was assessed through an approach based on multiple sequential random forest models at the patient level from the day of admission (day 0) until 7 days after with hospital mortality as outcome of interest. The first regression included all patients admitted on weekends; the second regression included all patients except those who died in the first day, the third regression included all patients except those who died in the first 2 days, and so on until the first 7 days. All models included SAPS 3 score as predictor as well as organizational features (presence/absence of weekend checklists, low nurse/bed ratio,

number of protocols and presence/absence of full-time intensivist coverage), Relative importance was assessed at each model based on mean decrease of Gini value and displayed as percentage over time.

All analyses were performed in R-project version 3.4.2 (17) with packages ggplot2, lme4, dplyr, tidyr, relimpo and gridextra. A p value below 0.05 was considered significant. This report follows the STROBE guideline(18) (shown in Supplementary File).

The Brazilian National Ethics Committee (CAAE: 19687113.8.1001.5249) approved the study. Need for informed consent was waived.

Results

Patients and ICU features:

Out of 59,693 patients admitted to the participating ICUs during the study period, 59,614 (99.9%) had available ICU admission date and hours and were selected for analysis. Main ICU and hospital characteristics are depicted in sTable 1 (see ESM). Most ICUs were private (sTable 1). A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) were admitted on weekends. The number of admissions decreased at weekends especially due to a decrease in elective surgeries but also due to a decrease in medical admissions (Figure 1). A comparison between patients admitted at weekend versus weekdays is shown in Table 1 and in sFigure 2. Patients admitted on weekends were more severely ill (higher SOFA and SAPS 3 scores) and more frequently admitted due to medical reasons than patients admitted during weekdays (Table 1). When compared to patients admitted during weekdays, a slightly lower percentage of weekend admissions occurred in ICUs with a low nurse/bed ratio (49.8% versus 48.6%, respectively; p = 0.007) and in units with fewer than eight protocols (46.9% versus 45.4%, respectively; p = 0.001) as shown in sFigure 2.

Table 1 – Comparisons between weekend and weekday admissions

	Weekday	Weekend	p
Number of Patients	41,894	17,720	-
Age (mean (SD))	61.99 (19.08)	63.10 (19.81)	<0.001
Male (n (%))	20,932 (50.0)	8,795 (49.6)	0.466
SAPS 3 (points) (mean (SD))	42.10 (14.94)	45.17 (14.71)	<0.001
SOFA score (points) (mean (SD))	2.31 (3.01)	2.49 (3.15)	<0.001
CCI (points) (mean (SD))	1.42 (1.87)	1.46 (1.91)	0.007
Performance status Impairment (n (%))			<0.001
Absent/Minor	32,107 (76.6)	13,079 (73.8)	
Moderate	7,165 (17.1)	3,288 (18.6)	
Severe	2,622 (6.3)	1,353 (7.6)	
Hospital LOS before ICU admission (median [IQR])	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	<0.001
Admission type (n (%))			<0.001
Medical	26,088 (62.3)	13,716 (77.4)	
Surgical (elective)	13,638 (32.6)	2,999 (16.9)	
Surgical (urgent)	2,168 (5.2)	1,005 (5.7)	
Admission Source (n (%))			<0.001
Operating Room	13,710 (32.7)	3,589 (20.3)	
Emergency	20,498 (48.9)	10,813 (61.0)	
Ward	2,925 (7.0)	1,530 (8.6)	
Home-care	147 (0.4)	70 (0.4)	
Other	168 (0.4)	63 (0.4)	
Other unit	793 (1.9)	310 (1.7)	
Hemodynamic Room	1,845 (4.4)	284 (1.6)	

Other hospital	1,495 (3.6)	907 (5.1)	
Step down unit	313 (0.7)	154 (0.9)	
Sepsis (n (%))	7,272 (17.4)	3,834 (21.6)	<0.001
Mechanical Ventilation on ICU Admission (n (%))	6,453 (15.4)	2,590 (14.7)	0.016
Mechanical Ventilation during ICU stay (n (%))	7,739 (19.1)	3,192 (18.7)	0.341
Vasopressors on ICU admission (n (%))	5,371 (12.9)	2,260 (12.8)	0.856
Vasopressors during ICU stay (n (%))	5,938 (14.6)	2,585 (15.2)	0.102
Renal replacement therapy on ICU admission (n (%))	1,074 (2.6)	597 (3.4)	<0.001
Renal replacement therapy during ICU stay (n (%))	1,922 (4.7)	1,034 (6.1)	<0.001
ICU LOS (median [IQR])	2.00 [1.00, 4.00]	2.00 [1.00, 5.00]	<0.001
Hospital LOS (median [IQR])	6.00 [2.00, 14.00]	7.00 [3.00, 16.00]	<0.001
ICU mortality (n (%))	3,790 (9.0)	1,918 (10.8)	<0.001
Hospital Mortality (n (%))	5,691 (13.6)	2,863 (16.2)	<0.001

Legend: SD=standard deviation; SAPS=Simplified Acute Physiology Score; SOFA=Sequential Organ Failure Score; CCI=Charlson Comorbidity Index; LOS=length of stay; ICU=intensive care unit; IQR=25%-75% interquartile range

Univariate analysis:

The overall ICU and hospital mortality rates were 9.5% and 14.4%. While hospital mortality for medical admissions per admission week day slightly fluctuated over the week, higher mortality was seen for elective surgical patients admitted on Sunday (Figure 2). For

non-elective surgeries, large fluctuations were seen with a peak mortality for those admitted on Tuesday (Figure 2). In univariate analysis, hospital mortality was significantly higher for patients admitted at weekends (16.2 versus 13.6%, OR 1.22, 95% CI 1.17-1.29; p<0.001).

Mixed model logistic regression:

After adjusting for relevant patient-level and ICU-level characteristics in the multivariate analysis, weekend admission was no longer associated with increased hospital mortality (OR 1.05, 95% CI 0.99-1.11; p = 0.095; full model reported in sTable 2; mixed effects shown on sFigure 3; center effect was markedly present). We present the results of the effect of weekend admission on hospital mortality in the several prespecified subgroups in Figure 3 and in sTables 3-19. A "weekend effect" was apparent for elective surgical admissions (OR 1.34; 95% CI 1.10-1.64; p=0.004; Figure 3 and sTable 4) and in patients admitted to ICUs without checklists during the weekends (OR 1.08; 95% CI 1.00-1.17; p=0.045; Figure 3 and sTable 17). We did not find a statistically significant association between other organizational characteristics (nurse/bed ratio, presence of full-time intensivist coverage or the number of protocols) and increased mortality in patients admitted during the weekends.

Scheduled Surgical versus Unscheduled ICU admissions:

We repeated the analyses separately for scheduled surgical admissions and unscheduled admissions (42,977 and 16,637 admission, respectively). Results are shown on Figure 4 and in sTables 20-37 of the ESM. A "weekend effect" was observed in scheduled surgical admissions. However, weekend effect was only present on scheduled surgical admissions when there was a decrease in weekend nurse/bed ratio (OR 1.40; 95% CI 1.09-1.79, p = 0.008), no weekend checklists (OR 1.41; 95% CI 1.09-1.83, p = 0.009) or a lower

number of protocols (OR 1.42; 95%CI 1.06-1.89, p = 0.018) (Figure 4). There was no "weekend effect" in unscheduled admissions.

Propensity score results:

Out of the study population, 35,440 patients (17,720 weekend admissions and 17,720 weekdays admissions) were matched in the propensity score analysis. All patients admitted on weekend could be paired. The distribution of variables in matched patients stratified per weekend effect is shown in sFigure 4. Mortality was 15.5% for patients admitted on weekdays and 16.1% for those admitted during weekends (p=0.112).

Change in weekend-weekday mortality regression:

After linear regression using the change of weekend to weekday mortality as dependent variable, only SAPS 3 score and low number of protocols (fewer than 8 protocols) were associated with increases in mortality in weekends at the ICU level (both p<0.001). There was a trend for presence of weekend checklists and lower changes in weekend-weekday mortality (p=0.08). The model R2 was 74.03%, with SAPS 3 being the most important predictor (66% of all variance), followed by low number of protocols (29%) and presence/absence of weekend checklists (3%, which was not statistically significant).

Temporal association of organizational features and outcome:

The relative contribution of SAPS 3 to hospital mortality decreased in the first 7 days after ICU admission, while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. The relative contribution of other organizational features remained stable (Figure 5).

Discussion

In the present study, we provide evidence that, after proper consideration of illness severity, patient´s background features and reason for admissions, the "weekend effect" is a minor phenomenon that is probably not relevant in the scenario of several Brazilian ICUs. A residual "weekend effect", however, might be present for scheduled surgical admissions and/or when some organizational factors that are associated with disrupted continuity of care and adherence to best practices are present. The weekend effect was therefore seen primarily in hospitals with suboptimal care processes. Whether this is because of the care processes themselves, or a reflection of other hospital characteristics (eg. quality of surgeons, general ward care, available resources), cannot be definitively determined.

Although previous studies suggested an increase in mortality in patients admitted during the weekend(4), the "weekend effect" concept has been recently challenged (6). Criticism of reports suggesting the presence of weekend effect identified three major pitfalls in analysis: (i) studies were performed using administrative databases and might suffer with inconsistent coding; (ii) comorbidities may have not been properly considered and (iii) Illness severity might not be adequately accounted for. Black(6) cited three studies in which, after correction of these issues, the "weekend effect" was no longer significant.

In the present analysis, we intended to overcome the limitations summarized by Black(6). We based our analysis on a quality improvement administrative database that does not only consider International Classification of Diseases (ICD) coding for diagnosis, but it also includes major predefined medical diagnosis (11). This database includes robust prospective clinical data collected at the bedside and not only administrative and/or procedures notes. We also considered the presence of comorbidities and baseline health status by not only adjusting for Charlson Comorbidity Index but also to performance status

impairment (14,15). Finally, severity of illness admission was assessed using well validated and widely accepted scores of severity of illness and organ failure (12,19,20). Our work does not corroborate with the hypothesis that the "weekend effect" is a universal feature in the ICUs. This is highlighted by both the main mixed regression model and by the propensity score analysis performed. In fact, when only unscheduled admissions were considered, no evidence of weekend effect was found regardless of the presence/absence of organizational features in the ICU; this is in accordance with recent reports the of absence of the weekend on unplanned ICU admissions (21). We could find evidence of a weekend effect only in secondary subgroup analyses, suggesting that it might be restricted to scenarios when there is a break in continuity of care during weekends, specifically the absence of patient-centered checklists (11,16), or for schedule admissions.

The case for worse outcomes for elective surgical admissions on weekends is complex, with both ICU and hospital features being able to explain, at least partly, this association (22,23). Differences in surgical care on weekends may play an important role. For example, early recognition and treatment of surgical complications may be delayed on weekends and even the adopted surgical procedure may be different for similar scenarios during weekends (24,25). In this way, checklists may aid at prompt recognition of complications (both clinical (26) and surgical (27)) and improve adherence to daily goals of care (28). Higher nurse staffing may also aid at reducing postoperative complications(10). In our analysis, there was no statistically significant weekend effect in scheduled surgical admissions in units that did not have a decrease in nurse/bed ratio on weekends or that applied checklists on weekends, thereby corroborating to this concept.

Interestingly, several factors potentially related to worse care on weekends did not reach statistical significance in the whole studied population. Despite the rationale for

increased mortality when there is a decrease in nurse/bed ratio during weekend (29) or when there is an absence of full-time intensivist coverage (30), we did not find evidence of weekend effect in both scenarios when all admissions types were considered. It is conceivable that well-structured ICUs with weekend checklists and protocols would be less susceptible to the variation in care driven by the decrease in staff during weekends, thereby mitigating the effect of the latter on mortality. This was only apparent for scheduled surgical admissions in our analysis. However, when we evaluated changes in mortality in weekends versus weekday at the ICU level using a linear model, a low number of protocols was the stronger organizational predictor of increase in mortality on weekends. It should be acknowledged that multiple interactions between organizational features could be expected and that some of the absence of statistically significant findings could be due to Simpson´s Paradox.

For patients admitted on weekends, we found that the length-of-stay ICU could modulate the association between organizational features and outcome, as shown in Figure 5. As expected, illness severity as measured by SAPS 3 score was the most important factor associated with mortality, but its relative contribution decreased during the first seven days while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. This suggests that the main determinant of mortality is a global individual marker of illness severity (as expected) and that the more a patient stays in the ICU, the higher the association between number of protocols and outcome. Interestingly, protocols were also the only variable associated with reduced change in mortality during weekends in the ICU-level linear model. Future studies that assess organizational features and outcome in the ICU should also consider that organizational features may be more important for patients with prolonged ICU length-of-stay.

Our analysis has several constraints. First, the large number of secondary analyses and models built could increase type 1 error due to overtesting. Additionally, the large sample size may also facilitate observing statistical significant results that may not be clinically relevant. Therefore, our results and especially our subgroup analyses should be considered exploratory and interpreted in the context of multiple models where some groups had small number of patients. It is important to highlight, however, that trends were constant during all analysis performed. We nevertheless advice caution when interpreting our results, specially the effects size reported. Second, albeit the large number of ICUs involved, our results refer to a selected sample of units from a single country and caution is needed when generalizing to other settings. Third, most patients were mostly admitted to private units and had a medium-low illness severity, thereby resulting in a low average mortality. However, no weekend effect was demonstrated in the subgroup analysis per the severity of illness and in septic or mechanically ventilated patients. Fourth, the low nurse/bed ratio reported is common in Brazil and are in accordance with local regulations that estipulate up to 10 beds per nurse in the ICUs but limits its generalization to different European and North American settings. Fifth, we were unable to assess interactions between the several organizational features. Frequently several organizational features occur together and may have synergistic (or even antagonist) effects that should be properly explored in the future. Sixth, we only assessed ICU organizational factors; structure, organizational and staffing patterns at the emergency departments and wards may also play an important role in determining hospital outcome. Finally, we did not assess other relevant outcomes such as readmissions and longer follow-up mortality and multiple imputation was used to correct for an important patient variable (performance status).

Conclusion

After considering an appropriate disease coding and accounting for comorbidities, illness severity and ICU organization characteristics, we did not observe worse outcomes in critically ill patients admitted during weekends. Nonetheless, a "weekend effect" might still occur in scheduled surgical admissions, especially in ICUs with a decrease in nurse/bed ratio and absence of checklists during the weekends as well as in ICUs with a low number of protocols. The ICU length-of-stay potentially modulates the association between organizational features and outcomes in critically ill patients.

Declarations

List of abbreviations:

CI – Confidence Interval

ECOG - Eastern Cooperative Oncology Group

ESM – Electronic Supplementary Material

ICU – Intensive Care Unit

LOS – Length of Stay

OR – Odds ratio

SAPS - Simplified Acute Physiology Score

SOFA – Sequential Organ Failure

Ethical approval: This study was locally approved in all participating intensive care units. Consent form was waived due to the retrospective nature of the analysis.

Consent for publication: Not applicable.

Availability of data: Data is not publicly available due to local ethical restrictions.

Competing interest: Dr. Soares and Dr. Salluh are founders and equity shareholders of Epimed Solutions®, which commercializes the Epimed Monitor System®, a cloud-based software for ICU management and benchmarking. The other authors declare that they have no conflict of interest.

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Authors´ Contributions: Manuscript conception: FGZ, TCL, TDC, FAB, JIS, MS. Statistical analyses: FGZ, TCL, FAB, TDC, JIS, MS. Data collection: MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC. Wrote the manuscript: FGZ, TCL, TDC, FAB, JIS, MS. Approved the final version: FGZ, TCL, TDC, FAB, JIS, MS, MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC.

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Figure Legends

Figure 1 – (A) Number of patients admitted to the ICU at each day of the week; (B) Distribution of admission types at each week day.

Figure 2 – Mortality at each day of the week stratified by admission type.

Figure 3 – Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality in the whole population (upper line) and in selected subgroups (see main text for details).

Figure 4 - Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality stratified in unscheduled (left) and scheduled surgical (right) admissions. Further subgroup analyses according to presence/absence of organizational factors are presented

Figure 5 – Relative contribution of illness severity (SAPS 3) and organizational factors in sequential daily random forest models. The relative contribution was defined as the percentage of mean decrease in Gini statistics at each model. Note how the relative importance of illness severity decreases during the first seven days and how the importance of number of protocols increases.

Supplementary Figure Legends:

Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B – Full-time intensivist coverage; C - Low nurse/bed ratio; D - Less than eight protocols

Supplementary Figure 3 - Plot of Random Effects

Supplementary Figure 4 - Variable comparison after propensity score matching

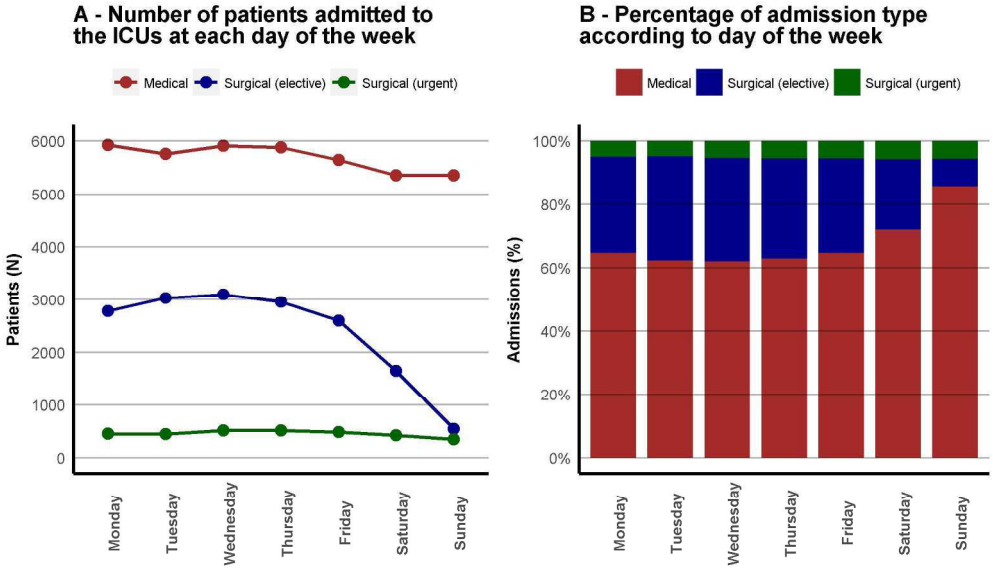

Figure 1

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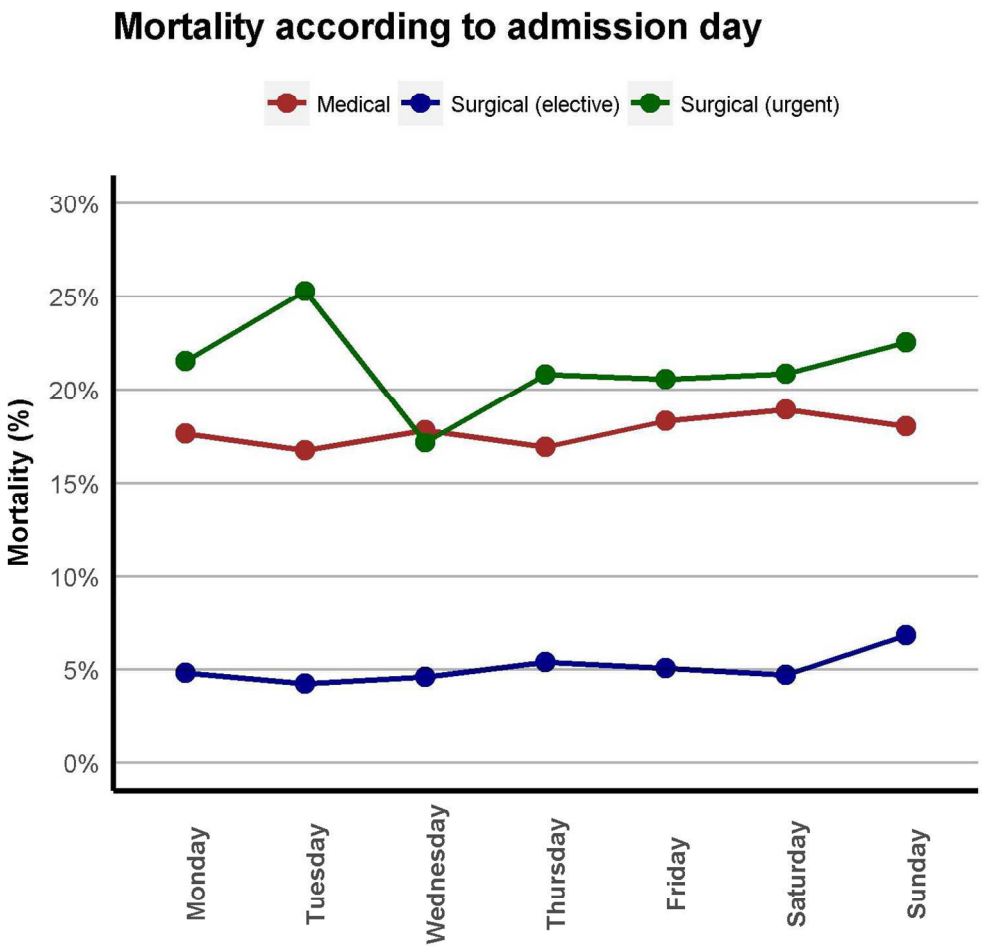

Figure 2

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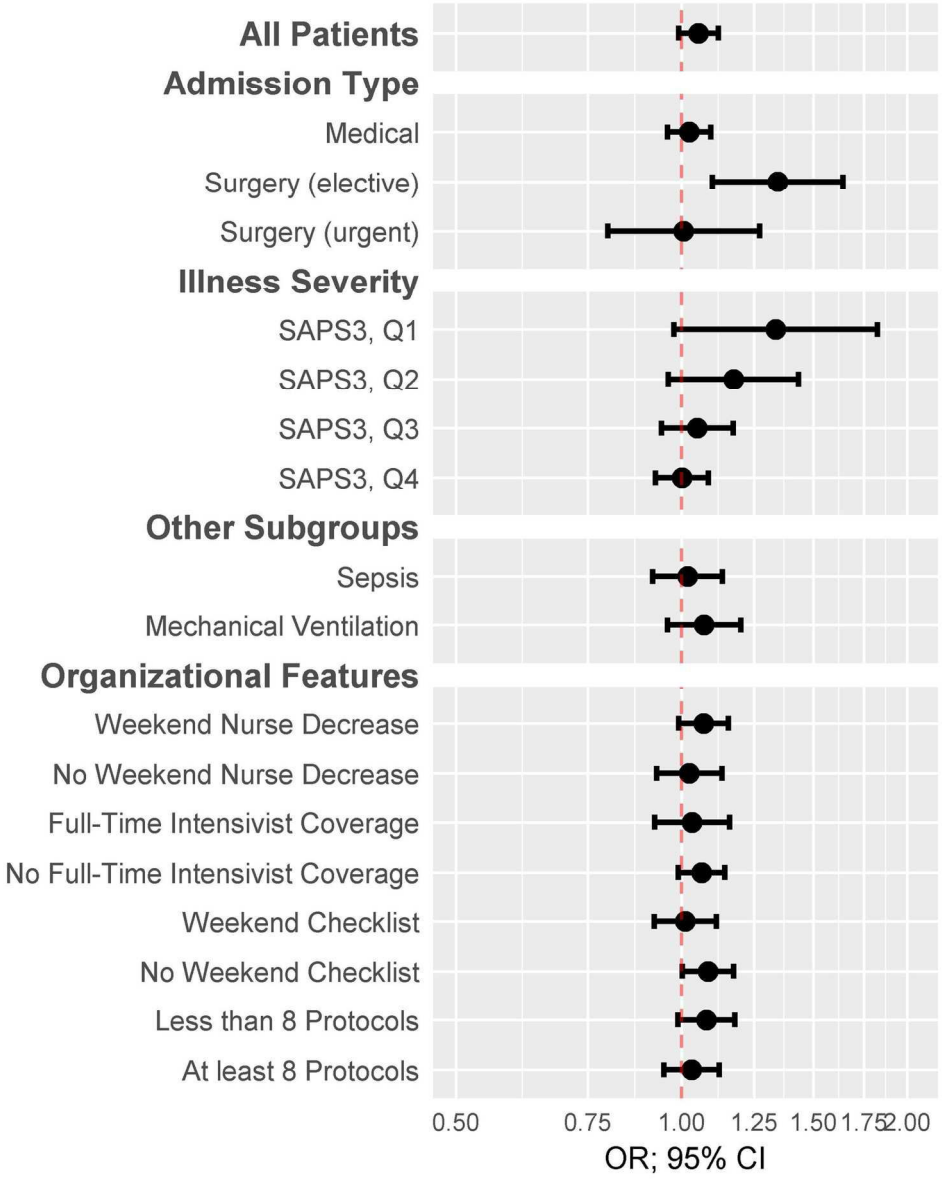

Figure 3

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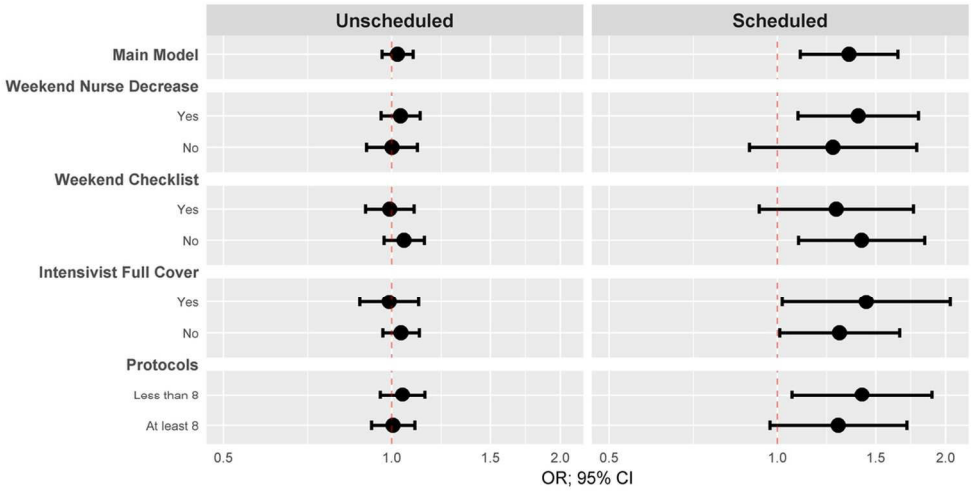

Figure 4

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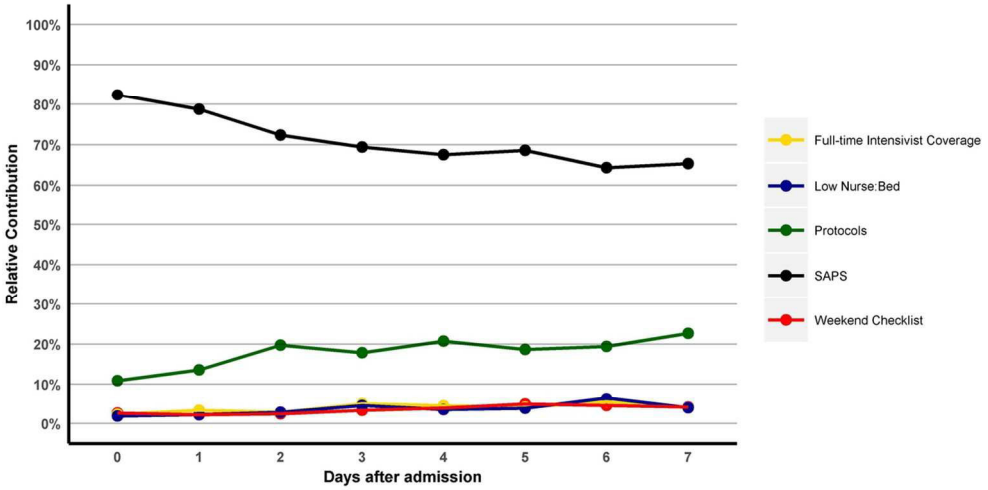

Figure 5

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The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

ELECTRONIC SUPPLEMENTARY FILE

ICU and Hospital Features

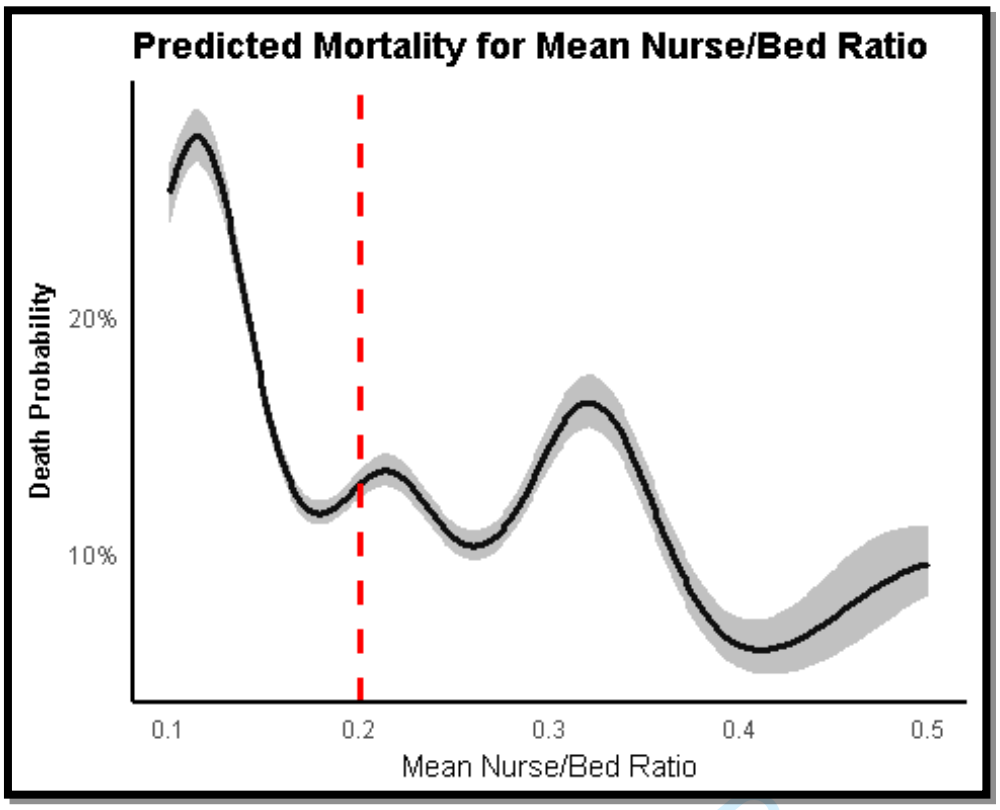
Supplementary Table 1: ICU Features

Number of Units	78
Bed per unit, mean (SD)	17.53 (11.38)
Private hospital, n (%)	67 (85.9)
Accreditation	
None	24 (30.8)
National	30 (38.5)
International	24 (30.8)
Weekend checklists, n (%)	36 (46.2)
Full-time Intensivist Coverage, n(%)	16 (20.5)
Nurse/Bed ratio < 0.2	41 (52.6)
Protocols, mean (SD)	6.96 (2.88)
Medical/Surgical Unit, n (%)	62 (79.5)

Univariate Analysis

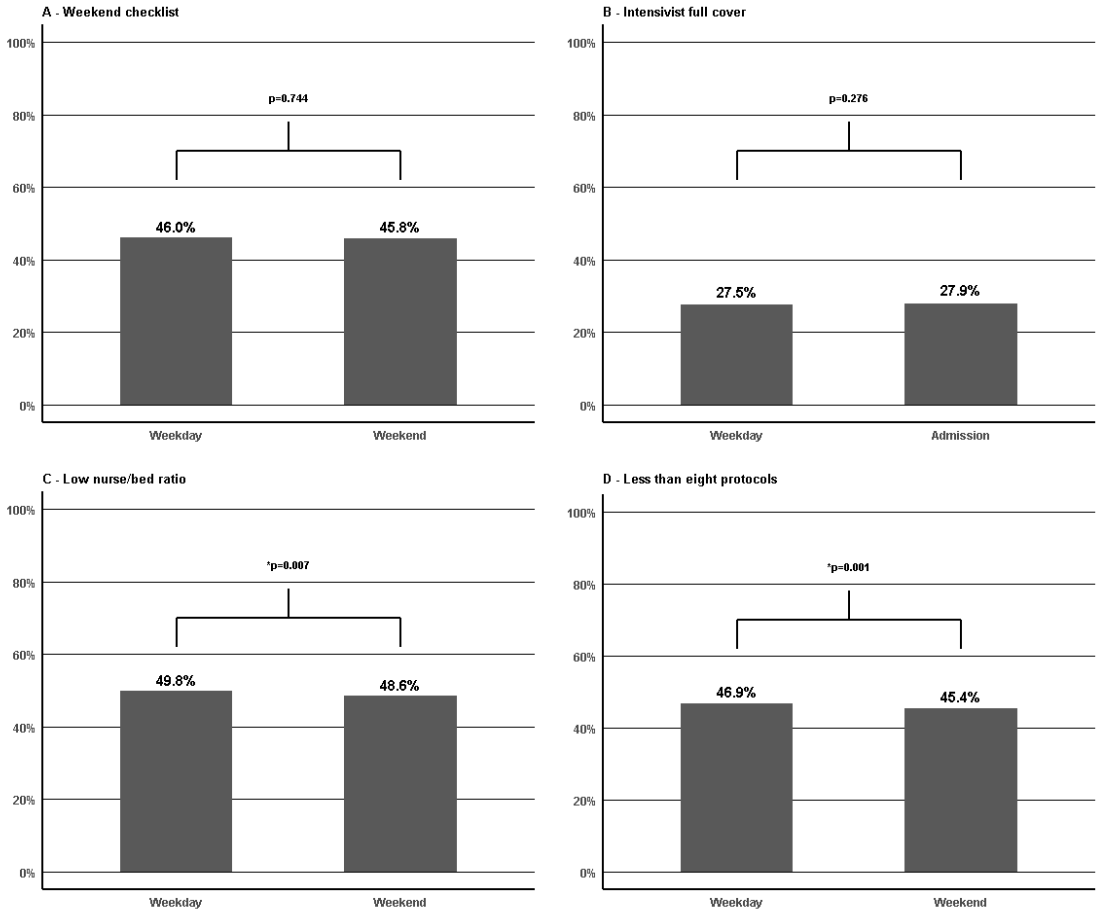
Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

The association between nurse/bed ratio and hospital mortality was assessed using a generalized additive model using the mgcv package. The 0.2 cutoff was chosen by inspecting the plot of predicted probabilities and hospital mortality (red dashed line in the plot).



Percentage of admissions to unit with specific organizational feature

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B - Intensivist fullcover; C - Low nurse/bed ratio; D - Less than eight protocols



Models Results

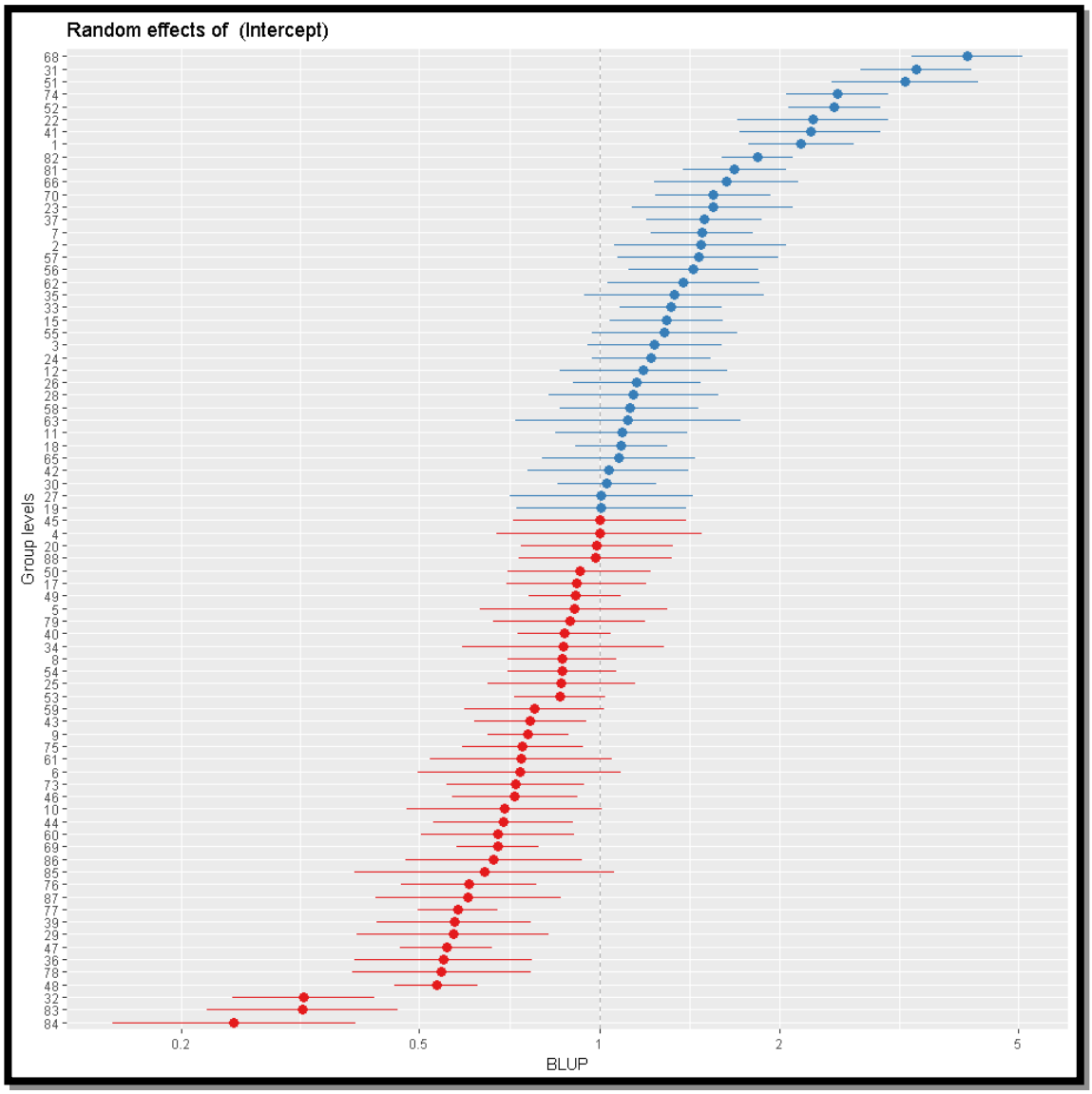
Synthax: Mortality ~ Age + SOFA + Charlson Comorbidity Index + Performance Status Impairment + LOS before ICU admission (tertile) + Admission Type + Checklist on Weekends + Full-time Intensivist Coverage + Nurse/Bed lower than 0.2 + Number of Protocols + Medical/Surgical Unit + ICU (random intercept).

Note: Continuous variables were scaled and centered to reduce non-convergence issues; marked with an * through document.

Supplementary Table 2: Results for main model

	OR	CI	p
Age*	1.60	1.55-1.66	<0.001
SOFA*	2.50	2.43-2.57	<0.001
CCI*	1.44	1.41-1.48	<0.001
Moderate Impairment	1.32	1.22-1.42	<0.001
Severe Impairment	2.04	1.86-2.24	<0.001
LOS 1 day	1.17	1.07-1.27	<0.001
LOS >= 2 days	2.44	2.26-2.62	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.76	0.67-0.86	<0.001
Weekend Checklist	0.97	0.74-1.26	0.814
Full-time Intensivist Coverage	0.98	0.72-1.33	0.887
Nurse/Bed <0.2	1.32	1.03-1.7	0.027
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.45	1.06-1.98	0.018
Weekend Admission	1.05	0.99-1.12	0.095

Supplementary Figure 3: Plot of Random Effects



Subgroups

Supplementary Table 3: Medical Patients

	OR	CI	p
Age*	1.56	1.50-1.62	<0.001
SOFA*	2.49	2.42-2.58	<0.001
CCI*	1.46	1.42-1.51	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	1.94	1.76-2.15	<0.001
LOS 1 day	1.14	1.04-1.26	0.008
LOS >= 2 days	2.54	2.34-2.76	<0.001
Weekend Checklist	0.96	0.74-1.24	0.742
Full-time Intensivist Coverage	1.04	0.77-1.41	0.802
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.41	1.04-1.91	0.028
Weekend Admission	1.02	0.96-1.09	0.498

Supplementary Table 4: Elective Surgical Patients

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.1-1.64	0.004

Supplementary Table 5: Urgent Surgical Patients

	OR	CI	p
Age*	1.97	1.73-2.24	<0.001
SOFA*	2.51	2.27-2.77	<0.001
CCI*	1.38	1.23-1.54	<0.001
Moderate Impairment	1.10	0.82-1.48	0.526
Severe Impairment	2.34	1.50-3.65	<0.001
LOS 1 day	0.98	0.73-1.31	0.891
LOS >= 2 days	1.43	1.10-1.85	0.008
Weekend Checklist	0.88	0.53-1.47	0.635
Full-time Intensivist Coverage	0.86	0.50-1.49	0.596
Nurse/Bed <0.2	1.30	0.81-2.11	0.279
Protocols	0.87	0.80-0.95	0.002
surgicalu/Surgical Unit	1.07	0.56-2.05	0.837
Weekend Admission	1.01	0.8-1.27	0.956

Supplementary Table 6: SAPS Quartile 1(5-34)

	OR	CI	p
Age*	1.72	1.43-2.06	<0.001
SOFA*	2.35	1.96-2.82	<0.001
CCI*	1.18	0.96-1.46	0.108
Moderate Impairment	2.11	1.41-3.15	<0.001
Severe Impairment	3.68	1.83-7.39	<0.001
LOS 1 day	1.13	0.77-1.66	0.518
LOS >= 2 days	2.70	1.90-3.83	<0.001
Surgical (elective)	0.37	0.25-0.55	<0.001
Surgical (urgent)	0.86	0.46-1.63	0.655
Weekend Checklist	0.93	0.57-1.52	0.778
Full-time Intensivist Coverage	1.06	0.63-1.77	0.827
Nurse/Bed <0.2	1.07	0.67-1.68	0.786
Protocols	0.83	0.76-0.90	<0.001
Medical/Surgical Unit	1.40	0.78-2.52	0.257
Weekend Admission	1.34	0.98-1.82	0.070

Supplementary Table 7: SAPS Quartile 2 (34-42)

	OR	CI	p
Age*	1.38	1.22-1.57	<0.001
SOFA*	2.08	1.84-2.36	<0.001
CCI*	1.47	1.33-1.62	<0.001
Moderate Impairment	1.34	1.04-1.73	0.022
Severe Impairment	2.75	1.87-4.06	<0.001
LOS 1 day	1.32	1.02-1.71	0.035
LOS >= 2 days	2.62	2.04-3.36	<0.001
Surgical (elective)	0.55	0.41-0.72	<0.001
Surgical (urgent)	0.70	0.47-1.04	0.079
Weekend Checklist	0.94	0.62-1.42	0.766
Full-time Intensivist Coverage	0.83	0.52-1.32	0.422
Nurse/Bed <0.2	1.38	0.94-2.02	0.104
Protocols	0.91	0.84-0.98	0.009
Medical/Surgical Unit	1.81	1.10-2.97	0.020
Weekend Admission	1.17	0.96-1.43	0.117

Supplementary Table 8: SAPS Quartile 3 (42-53)

	OR	CI	p
Age*	1.23	1.15-1.32	<0.001
SOFA*	1.98	1.85-2.13	<0.001
CCI*	1.32	1.25-1.39	<0.001
Moderate Impairment	1.44	1.26-1.65	<0.001
Severe Impairment	2.44	2.05-2.90	<0.001
LOS 1 day	1.18	1.02-1.38	0.030
LOS >= 2 days	2.39	2.07-2.77	<0.001
Surgical (elective)	0.52	0.42-0.63	<0.001
Surgical (urgent)	0.74	0.59-0.93	0.011
Weekend Checklist	1.06	0.81-1.40	0.651
Full-time Intensivist Coverage	0.98	0.71-1.35	0.902
Nurse/Bed <0.2	1.30	1.00-1.68	0.047
Protocols	0.93	0.89-0.98	0.007

Medical/Surgical Unit	1.40	1.01-1.94	0.041
Weekend Admission	1.05	0.94-1.17	0.393

Supplementary Table 9: SAPS Quartile 4 (53-132)

	OR	CI	p
Age*	1.15	1.09-1.21	<0.001
SOFA*	1.92	1.85-2.00	<0.001
CCI*	1.26	1.22-1.30	<0.001
Moderate Impairment	1.18	1.07-1.30	0.001
Severe Impairment	1.66	1.47-1.86	<0.001
LOS 1 day	1.07	0.95-1.20	0.283
LOS >= 2 days	1.91	1.74-2.10	<0.001
Surgical (elective)	0.42	0.33-0.52	<0.001
Surgical (urgent)	0.99	0.84-1.17	0.931
Weekend Checklist	0.92	0.72-1.17	0.488
Full-time Intensivist Coverage	0.92	0.70-1.22	0.567
Nurse/Bed <0.2	1.35	1.08-1.70	0.009
Protocols	0.94	0.90-0.98	0.005
Medical/Surgical Unit	1.33	1.00-1.78	0.053
Weekend Admission	1.00	0.92-1.09	0.979

Supplementary Table 10: Patients admitted due to sepsis

	OR	CI	p
Age*	1.51	1.42-1.60	<0.001
SOFA*	2.19	2.08-2.30	<0.001
CCI*	1.42	1.35-1.49	<0.001
Moderate Impairment	1.31	1.15-1.50	<0.001
Severe Impairment	1.55	1.34-1.80	<0.001
LOS 1 day	1.08	0.92-1.25	0.353
LOS >= 2 days	2.18	1.91-2.50	<0.001
Weekend Checklist	0.90	0.69-1.19	0.460
Full-time Intensivist Coverage	0.95	0.69-1.30	0.755
Nurse/Bed <0.2	1.49	1.15-1.92	0.002

Protocols	0.92	0.88-0.97	0.001
Medical/Surgical Unit	1.24	0.87-1.78	0.232
Weekend Admission	1.02	0.91-1.13	0.737

Supplementary Table 11: Patients that required mechanical ventilation on day 1

	OR	CI	p
Age*	1.61	1.52-1.71	<0.001
SOFA*	1.74	1.66-1.83	<0.001
CCI*	1.30	1.24-1.37	<0.001
Moderate Impairment	1.18	1.02-1.35	0.022
Severe Impairment	1.03	0.87-1.21	0.769
LOS 1 day	1.01	0.87-1.18	0.878
LOS >= 2 days	1.64	1.45-1.86	<0.001
Surgical (elective)	0.17	0.15-0.20	<0.001
Surgical (urgent)	0.59	0.50-0.69	<0.001
Weekend Checklist	0.99	0.72-1.36	0.959
Full-time Intensivist Coverage	0.91	0.64-1.29	0.590
Nurse/Bed <0.2	1.42	1.06-1.90	0.018
Protocols	0.96	0.91-1.01	0.133
Medical/Surgical Unit	1.12	0.76-1.66	0.553
Weekend Admission	1.07	0.96-1.2	0.228

Supplementary Table 12: ICUs with nurse decrease on weekends

	OR	**CI**	**p**
Age*	1.52	1.45-1.59	<0.001
SOFA*	2.50	2.41-2.59	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.31	1.2-1.44	<0.001
Severe Impairment	1.88	1.67-2.12	<0.001
LOS 1 day	1.17	1.05-1.30	0.004
LOS >= 2 days	2.46	2.25-2.69	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.73	0.63-0.85	<0.001
Weekend Checklist	1.14	0.85-1.52	0.391

Full-time Intensivist Coverage	0.92	0.65-1.30	0.629
Nurse/Bed <0.2	1.31	0.99-1.73	0.056
Protocols	0.92	0.87-0.98	0.007
Medical/Surgical Unit	1.17	0.80-1.73	0.421
Weekend Admission	1.07	0.99-1.15	0.085

Supplementary Table 13: ICUs with no nurse decrease on weekend

	OR	CI	p
Age*	1.76	1.66-1.86	<0.001
SOFA*	2.50	2.38-2.62	<0.001
CCI*	1.45	1.39-1.52	<0.001
Moderate Impairment	1.34	1.18-1.51	<0.001
Severe Impairment	2.37	2.03-2.76	<0.001
LOS 1 day	1.17	1.02-1.34	0.025
LOS >= 2 days	2.39	2.11-2.71	<0.001
Surgical (elective)	0.24	0.21-0.28	<0.001
Surgical (urgent)	0.81	0.66-0.99	0.040
Weekend Checklist	0.74	0.45-1.20	0.222
Full-time Intensivist Coverage	1.08	0.62-1.88	0.783
Nurse/Bed <0.2	1.50	0.93-2.42	0.094
Protocols	0.94	0.87-1.01	0.085
Medical/Surgical Unit	1.97	1.18-3.27	0.009
Weekend Admission	1.02	0.93-1.13	0.642

Supplementary Table 14: ICUs with intensivist fullcover

	OR	CI	p
Age*	1.63	1.53-1.74	<0.001
SOFA*	2.21	2.09-2.33	<0.001
CCI*	1.33	1.26-1.40	<0.001
Moderate Impairment	1.35	1.16-1.57	<0.001
Severe Impairment	2.12	1.73-2.59	<0.001
LOS 1 day	1.03	0.87-1.23	0.695

LOS >= 2 days	2.40	2.10-2.75	<0.001
Surgical (elective)	0.21	0.17-0.25	<0.001
Surgical (urgent)	0.65	0.51-0.82	<0.001
Weekend Checklist	1.27	0.65-2.48	0.493
Nurse/Bed <0.2	1.49	0.77-2.87	0.240
Protocols	0.90	0.81-0.98	0.022
Medical/Surgical Unit	1.13	0.49-2.64	0.773
Weekend Admission	1.03	0.92-1.16	0.584

Supplementary Table 15: ICUs without intensivist fullcover

	OR	CI	p
Age*	1.60	1.54-1.67	<0.001
SOFA*	2.62	2.53-2.71	<0.001
CCI*	1.49	1.44-1.53	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	2.02	1.82-2.25	<0.001
LOS 1 day	1.21	1.10-1.34	<0.001
LOS >= 2 days	2.42	2.22-2.64	<0.001
Surgical (elective)	0.26	0.23-0.29	<0.001
Surgical (urgent)	0.80	0.70-0.93	0.002
Weekend Checklist	0.91	0.69-1.22	0.535
Nurse/Bed <0.2	1.33	1.02-1.74	0.034
Protocols	0.95	0.90-1.00	0.057
Medical/Surgical Unit	1.47	1.06-2.03	0.020
Weekend Admission	1.06	0.99-1.14	0.094

Supplementary Table 16: ICUs with checklists

	OR	CI	p
Age*	1.69	1.60-1.79	<0.001
SOFA*	2.56	2.44-2.68	<0.001
CCI*	1.45	1.40-1.51	<0.001
Moderate Impairment	1.41	1.25-1.58	<0.001
Severe Impairment	2.30	2.00-2.64	<0.001
LOS 1 day	1.23	1.08-1.41	0.003
LOS >= 2 days	2.57	2.29-2.89	<0.001

Surgical (elective)	0.28	0.24-0.32	<0.001
Surgical (urgent)	0.70	0.57-0.86	0.001
Full-time Intensivist Coverage	1.16	0.71-1.91	0.554
Nurse/Bed <0.2	1.18	0.85-1.64	0.314
Protocols	0.97	0.91-1.04	0.44
Medical/Surgical Unit	1.56	1.04-2.34	0.031
Weekend Admission	1.01	0.92-1.11	0.816

Supplementary Table 17: ICUs without checklist

	OR	CI	p
Age*	1.55	1.49-1.63	<0.001
SOFA*	2.46	2.37-2.55	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.25	1.14-1.38	<0.001
Severe Impairment	1.84	1.62-2.09	<0.001
LOS 1 day	1.13	1.01-1.26	0.034
LOS >= 2 days	2.35	2.15-2.58	<0.001
Surgical (elective)	0.22	0.20-0.25	<0.001
Surgical (urgent)	0.78	0.67-0.90	0.001
Full-time Intensivist Coverage	0.91	0.61-1.35	0.627
Nurse/Bed <0.2	1.53	1.04-2.25	0.032
Protocols	0.91	0.86-0.97	0.003
Medical/Surgical Unit	1.53	0.94-2.49	0.086
Weekend Admission	1.08	1.00-1.17	0.045

Supplementary Table 18: ICUs with less than 8 protocols

	OR	CI	p
Age*	1.67	1.59-1.75	<0.001
SOFA*	2.48	2.38-2.58	<0.001
CCI*	1.42	1.37-1.48	<0.001
Moderate Impairment	1.36	1.22-1.51	<0.001
Severe Impairment	2.25	1.94-2.60	<0.001
LOS 1 day	1.20	1.06-1.35	0.005

LOS >= 2 days	2.11	1.90-2.34	<0.001
Surgical (elective)	0.26	0.23-0.30	<0.001
Surgical (urgent)	0.84	0.71-0.99	0.042
Weekend Checklist	0.76	0.51-1.12	0.168
Full-time Intensivist Coverage	1.06	0.68-1.67	0.790
Nurse/Bed <0.2	1.68	1.13-2.51	0.011
Medical/Surgical Unit	2.17	1.23-3.82	0.007
Weekend Admission	1.08	0.99-1.18	0.088

Supplementary Table 19: ICUs with at least 8 protocols

	OR	CI	p
Age*	1.54	1.46-1.62	<0.001
SOFA*	2.51	2.42-2.61	<0.001
CCI*	1.46	1.41-1.51	<0.001
Moderate Impairment	1.29	1.17-1.43	<0.001
Severe Impairment	1.93	1.70-2.18	<0.001
LOS 1 day	1.13	1.01-1.27	0.035
LOS >= 2 days	2.78	2.52-3.07	<0.001
Surgical (elective)	0.22	0.19-0.25	<0.001
Surgical (urgent)	0.68	0.57-0.80	<0.001
Weekend Checklist	0.99	0.75-1.30	0.930
Full-time Intensivist Coverage	0.80	0.55-1.15	0.231
Nurse/Bed <0.2	1.15	0.88-1.49	0.307
Medical/Surgical Unit	1.17	0.87-1.57	0.298
Weekend Admission	1.03	0.95-1.12	0.474

Analysis on Unscheduled Admissions

Supplementary Table 20: Main model

	OR	CI	p
Age*	1.59	1.53-1.65	<0.001
SOFA*	2.49	2.42-2.57	<0.001
CCI*	1.46	1.42-1.5	<0.001
Moderate Impairment	1.30	1.20-1.41	<0.001
Severe Impairment	1.96	1.78-2.17	<0.001
LOS 1 day	1.12	1.02-1.23	0.013
LOS >= 2 days	2.35	2.18-2.55	<0.001
Weekend Checklist	0.95	0.73-1.23	0.685
Full-time Intensivist Coverage	1.03	0.76-1.40	0.850
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.002
Medical/Surgical Unit	1.42	1.04-1.92	0.026
Weekend Admission	1.02	0.96-1.09	0.473

Supplementary Table 21: Nurse decrease on weekends

	OR	CI	p
Age*	1.50	1.43-1.57	<0.001
SOFA*	2.49	2.40-2.58	<0.001
CCI*	1.46	1.40-1.51	<0.001
Moderate Impairment	1.30	1.18-1.44	<0.001
Severe Impairment	1.86	1.64-2.11	<0.001
LOS 1 day	1.11	0.99-1.25	0.076
LOS >= 2 days	2.39	2.17-2.63	<0.001
Weekend Checklist	1.09	0.82-1.46	0.55
Full-time Intensivist Coverage	0.96	0.68-1.36	0.824
Nurse/Bed <0.2	1.37	1.04-1.81	0.026
Protocols	0.92	0.87-0.97	0.005
Medical/Surgical Unit	1.13	0.77-1.67	0.535
Weekend Admission	1.04	0.96-1.12	0.38

Supplementary Table 22: No nurse decrease on weekends

	OR	CI	p
Age*	1.74	1.64-1.85	<0.001
SOFA*	2.49	2.37-2.62	<0.001
CCI*	1.47	1.41-1.54	<0.001
Moderate Impairment	1.31	1.14-1.49	<0.001
Severe Impairment	2.18	1.85-2.55	<0.001
LOS 1 day	1.15	0.99-1.33	0.067
LOS >= 2 days	2.27	1.98-2.60	<0.001
Weekend Checklist	0.74	0.46-1.18	0.206
Full-time Intensivist Coverage	1.17	0.68-1.99	0.571
Nurse/Bed <0.2	1.51	0.95-2.38	0.080
Protocols	0.94	0.87-1.01	0.075
Medical/Surgical Unit	1.95	1.19-3.19	0.008
Weekend Admission	1.00	0.90-1.11	0.995

Supplementary Table 23: Weekend Checklist

	OR	CI	p
Age*	1.66	1.56-1.76	<0.001
SOFA*	2.54	2.42-2.67	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.38	1.23-1.56	<0.001
Severe Impairment	2.28	1.98-2.63	<0.001
LOS 1 day	1.16	1.00-1.34	0.048
LOS >= 2 days	2.48	2.19-2.81	<0.001
Full-time Intensivist Coverage	1.22	0.73-2.02	0.450
Nurse/Bed <0.2	1.25	0.90-1.76	0.187
Protocols	0.98	0.91-1.05	0.502
Medical/Surgical Unit	1.48	0.97-2.24	0.066
Weekend Admission	0.99	0.90-1.10	0.860

Supplementary Table 24: No weekend Checklist

	OR	CI	p

Age*	1.54	1.47-1.62	<0.001
SOFA*	2.46	2.36-2.55	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.24	1.12-1.38	<0.001
Severe Impairment	1.72	1.50-1.97	<0.001
LOS 1 day	1.10	0.98-1.24	0.117
LOS >= 2 days	2.27	2.05-2.51	<0.001
Full-time Intensivist Coverage	0.97	0.66-1.43	0.873
Nurse/Bed <0.2	1.55	1.06-2.25	0.022
Protocols	0.91	0.86-0.97	0.002
Medical/Surgical Unit	1.53	0.96-2.45	0.076
Weekend Admission	1.05	0.97-1.14	0.233

Supplementary Table 25: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.62	1.51-1.73	<0.001
SOFA*	2.21	2.09-2.34	<0.001
CCI*	1.36	1.29-1.44	<0.001
Moderate Impairment	1.29	1.10-1.53	0.002
Severe Impairment	1.98	1.61-2.44	<0.001
LOS 1 day	1.00	0.83-1.21	0.984
LOS >= 2 days	2.30	1.98-2.66	<0.001
Weekend Checklist	1.20	0.65-2.24	0.562
Nurse/Bed <0.2	1.55	0.84-2.85	0.163
Protocols	0.89	0.82-0.98	0.012
Medical/Surgical Unit	1.11	0.50-2.46	0.791
Weekend Admission	0.99	0.88-1.12	0.856

Supplementary Table 26: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.58	1.51-1.65	<0.001
SOFA*	2.60	2.51-2.70	<0.001
CCI*	1.50	1.45-1.55	<0.001
Moderate Impairment	1.30	1.19-1.43	<0.001

Severe Impairment	1.96	1.76-2.19	<0.001
LOS 1 day	1.16	1.05-1.29	0.005
LOS >= 2 days	2.36	2.15-2.59	<0.001
Weekend Checklist	0.89	0.67-1.19	0.437
Nurse/Bed <0.2	1.36	1.04-1.78	0.025
Protocols	0.95	0.90-1.00	0.065
Medical/Surgical Unit	1.43	1.04-1.98	0.030
Weekend Admission	1.04	0.96-1.12	0.326

Supplementary Table 27: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.67	1.58-1.76	<0.001
SOFA*	2.49	2.38-2.60	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.37	1.22-1.54	<0.001
Severe Impairment	2.15	1.85-2.50	<0.001
LOS 1 day	1.13	0.99-1.30	0.071
LOS >= 2 days	2.05	1.82-2.30	<0.001
Weekend Checklist	0.75	0.51-1.09	0.133
Full-time Intensivist Coverage	1.14	0.73-1.76	0.566
Nurse/Bed <0.2	1.72	1.17-2.54	0.006
Medical/Surgical Unit	2.08	1.20-3.61	0.009
Weekend Admission	1.04	0.95-1.14	0.349

Supplementary Table 28: At least 8 protocols in ICU

	OR	CI	p
Age*	1.51	1.43-1.59	<0.001
SOFA*	2.49	2.39-2.60	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.26	1.13-1.41	<0.001
Severe Impairment	1.87	1.64-2.13	<0.001
LOS 1 day	1.11	0.98-1.26	0.097
LOS >= 2 days	2.64	2.37-2.94	<0.001
Weekend Checklist	0.96	0.72-1.26	0.757

Full-time Intensivist Coverage	0.84	0.58-1.22	0.352
Nurse/Bed <0.2	1.19	0.91-1.55	0.203
Medical/Surgical Unit	1.14	0.84-1.55	0.389
Weekend Admission	1.01	0.92-1.10	0.912

Analysis on Scheduled Admissions

Supplementary Table 29: Main model

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.10-1.64	0.004

Supplementary Table 30: Nurse decrease on weekends

	OR	CI	p
Age*	1.72	1.50-1.96	<0.001
SOFA*	2.44	2.20-2.70	<0.001
CCI*	1.40	1.27-1.53	<0.001
Moderate Impairment	1.40	1.08-1.83	0.012
Severe Impairment	2.62	1.63-4.21	<0.001
LOS 1 day	1.41	1.05-1.89	0.023
LOS >= 2 days	2.60	2.01-3.36	<0.001
Weekend Checklist	1.33	0.81-2.19	0.255
Full-time Intensivist	0.75	0.43-1.31	0.303

Coverage			
Nurse/Bed <0.2	1.07	0.67-1.73	0.769
Protocols	0.88	0.79-0.97	0.013
Medical/Surgical Unit	1.24	0.61-2.53	0.556
Weekend Admission	1.40	1.09-1.79	0.008

Supplementary Table 31: No nurse decrease on weekends

	OR	CI	p
Age*	2.01	1.67-2.41	<0.001
SOFA*	2.44	2.13-2.8	<0.001
CCI*	1.37	1.22-1.54	<0.001
Moderate Impairment	1.68	1.18-2.39	0.004
Severe Impairment	5.90	3.61-9.63	<0.001
LOS 1 day	1.25	0.83-1.87	0.282
LOS >= 2 days	2.46	1.70-3.55	<0.001
Weekend Checklist	1.00	0.48-2.09	0.996
Full-time Intensivist Coverage	0.93	0.44-1.93	0.836
Nurse/Bed <0.2	1.92	0.95-3.89	0.069
Protocols	0.87	0.78-0.97	0.012
Medical/Surgical Unit	1.70	0.86-3.36	0.127
Weekend Admission	1.26	0.89-1.78	0.193

Supplementary Table 32: Weekend Checklist

	OR	CI	p
Age*	2.03	1.70-2.44	<0.001
SOFA*	2.56	2.23-2.93	<0.001
CCI*	1.55	1.38-1.74	<0.001
Moderate Impairment	1.59	1.15-2.20	0.005
Severe Impairment	2.86	1.69-4.82	<0.001
LOS 1 day	1.69	1.15-2.46	0.007
LOS >= 2 days	2.85	2.04-3.98	<0.001
Full-time Intensivist Coverage	0.91	0.43-1.92	0.800
Nurse/Bed <0.2	1.27	0.70-2.28	0.432

Protocols	0.90	0.78-1.04	0.145
Medical/Surgical Unit	1.76	0.84-3.71	0.135
Weekend Admission	1.27	0.93-1.75	0.134

Supplementary Table 33: No weekend Checklist

	OR	CI	p
Age*	1.68	1.47-1.92	<0.001
SOFA*	2.37	2.14-2.62	<0.001
CCI*	1.32	1.20-1.44	<0.001
Moderate Impairment	1.36	1.03-1.79	0.033
Severe Impairment	4.86	3.11-7.60	<0.001
LOS 1 day	1.16	0.85-1.58	0.347
LOS >= 2 days	2.33	1.77-3.06	<0.001
Full-time Intensivist Coverage	0.78	0.44-1.38	0.399
Nurse/Bed <0.2	1.30	0.73-2.29	0.373
Protocols	0.87	0.79-0.95	0.002
Medical/Surgical Unit	1.38	0.70-2.73	0.357
Weekend Admission	1.41	1.09-1.83	0.009

Supplementary Table 34: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.90	1.55-2.33	<0.001
SOFA*	2.05	1.77-2.37	<0.001
CCI*	1.24	1.08-1.43	0.002
Moderate Impairment	1.77	1.20-2.61	0.004
Severe Impairment	5.71	2.75-11.88	<0.001
LOS 1 day	0.95	0.62-1.46	0.825
LOS >= 2 days	2.06	1.41-3.01	<0.001
Weekend Checklist	1.39	0.53-3.63	0.502
Nurse/Bed <0.2	1.03	0.38-2.77	0.951
Protocols	0.84	0.72-0.97	0.018
Medical/Surgical Unit	1.12	0.32-3.89	0.856
Weekend Admission	1.44	1.02-2.04	0.038

Supplementary Table 35: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.79	1.58-2.03	<0.001
SOFA*	2.65	2.40-2.93	<0.001
CCI*	1.46	1.34-1.59	<0.001
Moderate Impairment	1.40	1.08-1.80	0.010
Severe Impairment	3.38	2.30-4.96	<0.001
LOS 1 day	1.57	1.17-2.09	0.002
LOS >= 2 days	2.82	2.19-3.63	<0.001
Weekend Checklist	1.17	0.73-1.88	0.513
Nurse/Bed <0.2	1.34	0.86-2.09	0.190
Protocols	0.88	0.81-0.97	0.007
Medical/Surgical Unit	1.50	0.90-2.53	0.123
Weekend Admission	1.29	1.01-1.66	0.042

Supplementary Table 36: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.70	1.49-1.95	<0.001
SOFA*	2.42	2.16-2.70	<0.001
CCI*	1.32	1.19-1.47	<0.001
Moderate Impairment	1.30	0.97-1.74	0.079
Severe Impairment	3.91	2.36-6.49	<0.001
LOS 1 day	1.50	1.09-2.08	0.014
LOS >= 2 days	2.16	1.61-2.90	<0.001
Weekend Checklist	0.84	0.46-1.52	0.565
Full-time Intensivist Coverage	0.96	0.51-1.79	0.892
Nurse/Bed <0.2	1.63	0.90-2.94	0.106
Medical/Surgical Unit	2.17	0.98-4.82	0.056
Weekend Admission	1.42	1.06-1.89	0.018

Supplementary Table 37: At least 8 protocols in ICU

	OR	CI	p
Age*	1.94	1.63-2.32	<0.001
SOFA*	2.51	2.23-2.83	<0.001
CCI*	1.46	1.32-1.61	<0.001

Moderate Impairment	1.65	1.22-2.25	0.001
Severe Impairment	3.60	2.28-5.68	<0.001
LOS 1 day	1.18	0.82-1.69	0.372
LOS >= 2 days	2.96	2.19-4.00	<0.001
Weekend Checklist	1.12	0.68-1.83	0.664
Full-time Intensivist Coverage	0.54	0.28-1.03	0.062
Nurse/Bed <0.2	1.02	0.62-1.69	0.925
Medical/Surgical Unit	1.18	0.67-2.07	0.567
Weekend Admission	1.29	0.97-1.70	0.081

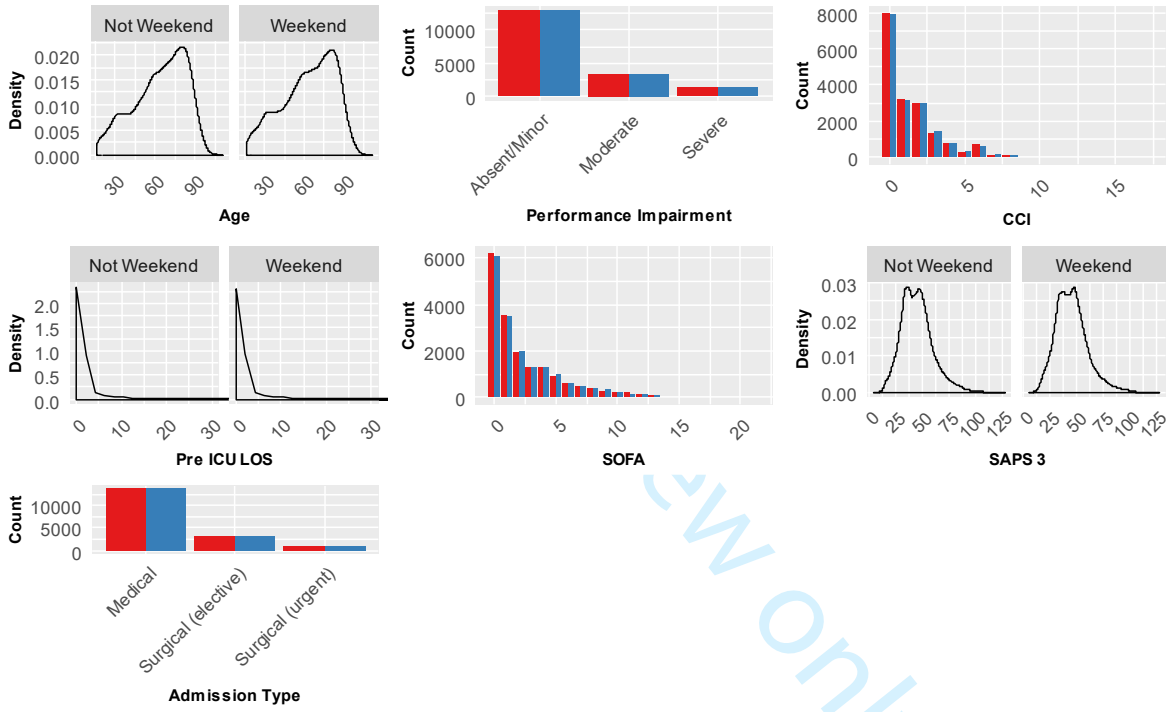
Propensity Score Analysis

Method: 1:1 patient matching controlling for age, CCI, admission type, performance status impairment, LOS before ICU admission, SOFA, SAPS3 and admission type

Results: 35,440 patients (17,720 in each arm) were matched. Mortality was 15.5% for patients admitted on weekdays and 16.1% for patients admitted on weekends (p=0.112)

Matching: Matching was adequate. Figure below shows density plot and barplots for the variables included in the propensity score

Supplementary Figure 4: Variable comparison after propensity score matching



List of Protocols Inquired to Participating ICUs:

Only protocols fully implemented for at least 6 months were considered. If the participating unit reported that protocol was in place, the careprovider responsible for the protocol was also obligatorily reported.

1. Sepsis (i.e. according to the current recommendations of the Surviving Sepsis Campaign)
2. Sedation (i.e. daily interruption or protocolized sedation in ventilated patients)
3. Cerebrovascular accident (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive thrombolysis)
4. Acute coronary syndromes (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive reperfusion therapies or interventions)
5. Liberation from the mechanical ventilation (i.e. care provider-driven spontaneous breathing trials)
6. Lung protective ventilation (i.e. ventilation with low tidal volumes in patients with acute lung injury/ARDS)
7. Therapeutic hypothermia in patients who experienced cardiac arrest
8. Catheter-associated bloodstream infection prevention (i.e. implementation of checklists during insertion and maintenance of vascular catheters)
9. Ventilator-associated pneumonia (VAP) prevention (i.e. implementation of daily checklists to best practices to prevent VAP in ventilated patients)
10. Early mobilization in ventilated patients (i.e protocolized early exercise and mobilization including physical and occupational therapy during periods of daily interruption of sedation in ventilated patients)

STROBE Checklist

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7, first paragraph
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, first paragraph
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, first paragraph
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5, third paragrapg
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 7
Study size	10	Explain how the study size was arrived at	NA

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9, specific subtopic on this
		(*c*) Explain how missing data were addressed	Page 8, specific topic
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Page 7.
		(*e*) Describe any sensitivity analyses	Only subgroup analyses were performed.

Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12, first patagraph
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	All patients in dataset were eligible
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Figures 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Described in methods. Only performance status missing

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Mortality reported on Table 1.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 15 and 16
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 17, first paragraph
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Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 19.
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Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	First page.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and

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The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

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Primary Subject Heading:	Intensive care
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Keywords:	weekend effect, intensive care unit, organizational factors

The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

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Word count: 3843

Data sharing: Data sharing is not available due to local ethics restriction.

Abstract

Introduction: Higher mortality for patients admitted to intensive care units (ICU) during the weekends has been occasionally reported with conflicting results that could be related to organizational factors. We investigated the effects of ICU organizational and staffing patterns on the potential association between weekend admission and outcomes in critically ill patients.

Methods: We included 59,614 patients admitted to 78 ICUs participating during 2013. We defined "weekend admission" as any ICU admission from Friday 7pm until Monday 7am. We assessed the association between weekend admission with hospital mortality using a mixed logistic regression model controlling for both patient-level (illness severity, age, comorbidities, performance status and admission type) and ICU-level confounders (decrease in nurse/bed ratio on weekend, full-time intensivist coverage, use of checklists on weekends and number of institutional protocols). We performed secondary analyses in the subgroup of scheduled surgical admissions.

Results: A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) on weekends. In univariable analysis, weekend admitted patients had higher ICU (10.9% vs. 9.0%, p<0.001) and hospital (16.5% vs. 13.5%, p<0.001) mortality. After adjusting for confounders, weekend admission was not associated with higher hospital mortality (OR 1.05, 95% CI 0.99-1.12, p=0.095). However, a "weekend effect" was still observed in scheduled surgical admissions, as well as in ICUs not using checklists during the weekends. For unscheduled admissions, no "weekend effect" was observed regardless of ICU´s characteristics. For scheduled surgical admissions, a "weekend effect" was present only in ICUs with a low number of implemented protocols and those with a reduction in the nurse/bed ratio and not applying checklists during weekends..

Conclusions: ICU organizational factors, such as decreased nurse to patient ratio, absence of checklists, and fewer standardized protocols may explain in part increases in mortality in patients admitted to the ICU mortality on weekends

Strengths and Limitations:

- Large prospective cohort including several Brazilian ICUs with different organizational features
- Analyses corrected for both relevant patient and center-level confounders
- Large number of models built may have increased type-1 error
- Variable selection for main multivariable may have been arbitrary

Introduction

Higher mortality for patients admitted during the weekends has been repeatedly reported in studies carried out in both wards (1,2) and intensive care units (ICU) (3,4). The so-called "weekend effect" is often ascribed to the imbalance of organizational and staffing features available on weekdays, which either do not occur or are suboptimal during the weekends (5). This notion has driven several health care policies, especially in England where junior doctors' contracts were changed on the assumption that increased weekend working would mitigate the weekend effect (6). This was followed by a great deal of discussion on the veracity of a weekend effect due to uncertainties on the reliability of disease coding on admission during weekends (6,7) and biases related to different profiles of illness severity and comorbidities in weekend admitted patients (8,9).

If the weekend effect is a real phenomenon amongst ICU admissions, it could be mediated by several organizational factors including staffing features such as full-time intensivist coverage and nurse staff levels (10) and use of other ancillary tools designed to sustain the continuity of care such as checklists and number of institutional protocols available(11). However, the association between these organizational characteristics and the weekend effect in ICUs were not thoroughly evaluated. We have used a large national prospectively-collected database to examine the hypothesis that the weekend effect would only be manifest in settings in which sub-optimal organization; staffing or clinical practices could impact on continuity of care.

Methods

Population: This was a *post hoc* analysis of the ORCHESTRA study, a multicenter retrospective cohort study of critical care organization and outcomes in critically ill patients admitted in 78 Brazilian ICUs during 2013 from January 1st until December 31st (11). All patients in the database were selected. From the initial database of 59,693 patients, we excluded 79 patients with missing admission date/hour, leaving 59,614 patients for analysis. In case of readmissions during the study period, we considered only the first ICU admission.

Exposure definitions: We defined weekend admission as any admission to the ICU occurring between Friday 7 pm and Monday 7 am.

Outcome definition: Hospital mortality.

Organizational factors: We considered several organizational factors in the analysis including the use of checklists (structured evaluations using a digital or printed instrument with multiple components focused on prevention of common ICU complications and adherence to best practices) during weekends, the implementation of protocols in the ICU (among a pre-defined set of ten protocols aiming at the adherence to best practices and prevention of acquired complications for frequent conditions in the ICU; see Supplementary File for details), the presence of full-time intensivist coverage 24/7 in the ICU, presence of a low nurse/bed ratio and ICU type. Full-time intensivist coverage was defined as the presence of a board-certified intensivist in the ICU 24 hours a day, 7 days a week. A low nurse/bed ratio was defined as a mean nurse/bed $\leq$ 0.20 inside the ICU (that is, the mean nurse/bed ratio considering all shifts in the ICU was lower or equal to 0.20). This 0.20 cutoff was established after inspecting the univariable association between nurse/bed ratio and in-hospital mortality in a generalized additive model (sFigure 1; see

Electronic Supplementary Material – ESM – for details). For checklists, dummy coding was used to represent units with checklists 7 days a week versus those without weekend checklists (that is, units that had checklists on weekdays only or did not apply checklists at all).

Patient factors: We estimated organ failure and the severity of illness using the Sequential Organ Failure Assessment (SOFA) score (12) and the Simplified Acute Physiology Score (SAPS) 3 (13). The Charlson Comorbidity Index (CCI) was calculated as previously reported (14). Baseline performance status (assessed one week before hospital admission) was defined according to the impairment degree as absent/minor, moderate and severe corresponding to performance classes of Eastern Cooperative Oncology Group (ECOG) of 0-1, 2 or 3-4, respectively as previously described (15). Hospital length of stay (LOS) before ICU admission was collected and stratified in tertiles for the analysis.

Missing values: No outcome was missing. Baseline performance status was missing in 3,476 patients. Multiple imputation using random forest models was used to impute missing values for this variable, as previously described (15). There were no other missing values in the variables included in the analysis.

Statistical Analysis: We used a mixed multivariable logistic regression to assess the independent association between each predictor and hospital mortality at the patient level. The ICU where the patient was admitted was added as a random effect (random intercept) in the model while all the other variables were added as fixed effect. Continuous variables were scaled and centered before entering the mixed model. For patient-level variables, we initially considered those associated with hospital mortality with a p value lower than 0.1 for the multivariable model; from the initial set of variables, the decision to add then to the model was based on clinical relevance. In case of collinearity, the decision to keep the

variable to enter in the multivariable analysis was also based on clinical grounds. For example, both SAPS 3 score and SOFA scores are highly correlated, but the SAPS 3 also includes information on age, reason for admission, organ failures, comorbidities and hospital length-of-stay before ICU admission. In this sense, we have chosen to use SOFA score for the main multivariable models and added age, reason for admission, comorbidities (evaluated using the CCI) and length-of-stay before ICU admission as individual covariates. The following patient-level variables were included in the main model: age, SOFA score, CCI, baseline performance status impairment, admission type (medical, elective surgery, non-elective surgery) and hospital LOS before ICU admission stratified in tertiles. For center-level variables, we have chosen to add variables known from previous studies to be associated with worse ICU (10, 11). These variables included use of checklists during the weekends, presence of full-time intensivist coverage, low baseline nurse/bed ratio and ICU type (medical/surgical or other). Weekend admission was forced in the model. No stepwise selection was performed. Type of funding (public versus private) was not added to the model due to large colinearity with most organizational features.

Subgroup analyses: We defined that sensitivity analysis for the following subgroups would be performed: admission type; quartiles of baseline SAPS 3 score, patients admitted due to sepsis, patients admitted on mechanical ventilation, ICUs with or without decrease in nurse/bed ratio during weekends (regardless of baseline values), ICUs stratified per presence of full-time intensivist coverage, ICUs with or without checklist during the weekends, and according to number of ancillary protocols in the ICU (above or below the median values of protocols per ICU). We repeated the subgroup analyses of organizational features (decrease in nurse staff, absence of full-time intensivist coverage, absence of checklist, and number of ancillary protocols) after stratifying our sample according to

scheduled surgical versus non-scheduled ICU admissions (both emergency surgery and clinical) (16). For the number of ancillary protocols, we split the samples in patients admitted to units with less or at least eight protocols, since this value split the number of included intensive care units in half. Scheduled surgery admissions are defined as any admission after a surgical procedure which was scheduled at least 24 hours before its start and for which an ICU bed was requested before the procedure started.

Propensity score analysis: We performed a propensity score 1:1 analysis pairing patients per their predicted probability of weekend admission based solely on the patients' factors. The probability of weekend admission was obtained by creating a logistic regression with the following variable included as predictors, based on clinical grounds: age, SOFA score, SAPS 3 score, Charlson Comorbidity Index, degree of performance status impairment, hospital LOS before ICU admission and admission type. Patients were matched using the nearest neighbor method considering the logit as the distance method. Maximum distance allowed was 0.40. At each matching, the unit with the closest logit still unmatched was used. After checking the balance of the propensity-matched groups, we compared hospital mortality for propensity-matched patients using chi-squared test.

Effects of organizational changes during weekends in weekend versus-weekday mortality: One additional approach to scrutinize the impact of organizational features in weekend admission mortality was applied by performing a linear regression at the ICU level considering the change in mortality (weekend minus weekday mortality for the ICU) as dependent variable and both SAPS 3 and organizational features as predictors. Due to the relatively small number of ICUs, we have chosen to minimize the number of predictors; in this sense, only SAPS3 score was used to control for patient-centered variables since it encompasses information of reason for admission, age, LOS before admission and

comorbidities. The organizational features selected were the same used for splitting subgroups in multivariable mixed model. After linear regression, we assessed the relative importance of each predictor using the method suggested by Lindeman, Merenda, and Gold (LMG).

Temporal association between organizational features and outcome in patients admitted during weekends: The time dependent effects of organizational factors in patients admitted to the ICU on weekends was assessed through an approach based on multiple sequential random forest models at the patient level from the day of admission (day 0) until 7 days after with hospital mortality as outcome of interest. The first regression included all patients admitted on weekends; the second regression included all patients except those who died in the first day, the third regression included all patients except those who died in the first 2 days, and so on until the first 7 days. Again, for simplicity, we used SAPS 3 score as a single predictor for patient-level confounders. Organizational features (presence/absence of weekend checklists, low nurse/bed ratio, number of protocols and presence/absence of full-time intensivist coverage) were added to the random forest model. Relative importance was assessed at each model based on mean decrease of Gini value and displayed as percentage over time.

All analyses were performed in R-project version 3.4.2 (17) with packages ggplot2, lme4, dplyr, tidyr, relimpo and gridextra. A p value below 0.05 was considered significant. This report follows the STROBE guideline(18) (shown in Supplementary File).

The Brazilian National Ethics Committee (CAAE: 19687113.8.1001.5249) approved the study. Need for informed consent was waived.

Results

Patients and ICU features:

Out of 59,693 patients admitted to the participating ICUs during the study period, 59,614 (99.9%) had available ICU admission date and hours and were selected for analysis. Main ICU and hospital characteristics are depicted in sTable 1 (see ESM). Most ICUs were private (sTable 1). A total of 41,894 patients (70.3%) were admitted on weekdays and 17,720 patients (29.7%) were admitted on weekends. The number of admissions decreased during weekends especially due to a decrease in elective surgeries but also due to a decrease in medical admissions (Figure 1). A comparison between patients admitted at weekend versus weekdays is shown in Table 1 and in sFigure 2. Patients admitted on weekends were more severely ill (with higher SOFA and SAPS 3 scores) and more frequently admitted due to medical reasons than patients admitted during weekdays (Table 1). When compared to patients admitted during weekdays, a slightly lower percentage of weekend admissions occurred in ICUs with a low nurse/bed ratio (49.8% versus 48.6%, respectively; p = 0.007) and/or fewer than eight protocols (46.9% versus 45.4%, respectively; p = 0.001), as shown in sFigure 2.

Table 1 – Comparisons between weekend and weekday admissions

	Weekday	Weekend	p
Number of Patients	41,894	17,720	-
Age (mean (SD))	61.99 (19.08)	63.10 (19.81)	<0.001
Male (n (%))	20,932 (50.0)	8,795 (49.6)	0.466
SAPS 3 (points) (mean (SD))	42.10 (14.94)	45.17 (14.71)	<0.001
SOFA score (points) (mean (SD))	2.31 (3.01)	2.49 (3.15)	<0.001
CCI (points) (mean (SD))	1.42 (1.87)	1.46 (1.91)	0.007
Performance status Impairment (n (%))			<0.001
Absent/Minor	32,107 (76.6)	13,079 (73.8)	
Moderate	7,165 (17.1)	3,288 (18.6)	
Severe	2,622 (6.3)	1,353 (7.6)	
Hospital LOS before ICU admission (median [IQR])	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	<0.001
Admission type (n (%))			<0.001
Medical	26,088 (62.3)	13,716 (77.4)	
Surgical (elective)	13,638 (32.6)	2,999 (16.9)	
Surgical (urgent)	2,168 (5.2)	1,005 (5.7)	
Admission Source (n (%))			<0.001
Operating Room	13,710 (32.7)	3,589 (20.3)	
Emergency	20,498 (48.9)	10,813 (61.0)	
Ward	2,925 (7.0)	1,530 (8.6)	
Home-care	147 (0.4)	70 (0.4)	
Other	168 (0.4)	63 (0.4)	
Other unit	793 (1.9)	310 (1.7)	
Hemodynamic Room	1,845 (4.4)	284 (1.6)	

Other hospital	1,495 (3.6)	907 (5.1)	
Step down unit	313 (0.7)	154 (0.9)	
Sepsis (n (%))	7,272 (17.4)	3,834 (21.6)	<0.001
Mechanical Ventilation on ICU Admission (n (%))	6,453 (15.4)	2,590 (14.7)	0.016
Mechanical Ventilation during ICU stay (n (%))	7,739 (19.1)	3,192 (18.7)	0.341
Vasopressors on ICU admission (n (%))	5,371 (12.9)	2,260 (12.8)	0.856
Vasopressors during ICU stay (n (%))	5,938 (14.6)	2,585 (15.2)	0.102
Renal replacement therapy on ICU admission (n (%))	1,074 (2.6)	597 (3.4)	<0.001
Renal replacement therapy during ICU stay (n (%))	1,922 (4.7)	1,034 (6.1)	<0.001
ICU LOS (median [IQR])	2.00 [1.00, 4.00]	2.00 [1.00, 5.00]	<0.001
Hospital LOS (median [IQR])	6.00 [2.00, 14.00]	7.00 [3.00, 16.00]	<0.001
ICU mortality (n (%))	3,790 (9.0)	1,918 (10.8)	<0.001
Hospital Mortality (n (%))	5,691 (13.6)	2,863 (16.2)	<0.001

Legend: SD=standard deviation; SAPS=Simplified Acute Physiology Score; SOFA=Sequential Organ Failure Score; CCI=Charlson Comorbidity Index; LOS=length of stay; ICU=intensive care unit; IQR=25%-75% interquartile range

Univariable analysis:

The overall ICU and hospital mortality rates were 9.5% and 14.4%. While hospital mortality for medical admissions per week day of ICU admission slightly fluctuated over the week, higher mortality was seen for elective surgical patients admitted on Sunday

(Figure 2). For non-elective surgeries, large fluctuations were observed with a peak mortality for those admitted on Tuesday (Figure 2). In univariable analysis, hospital mortality was significantly higher for patients admitted at weekends (16.2 versus 13.6%, OR 1.22, 95% CI 1.17-1.29; p<0.001).

Mixed model logistic regression:

After adjusting for relevant patient-level and ICU-level characteristics in the multivariable analysis, weekend admission was no longer associated with increased hospital mortality (OR 1.05, 95% CI 0.99-1.11; p = 0.095; full model reported in sTable 2; mixed effects shown on sFigure 3; center effect was markedly present). We present the results of the effect of weekend admission on hospital mortality in the several prespecified subgroups in Figure 3 and in sTables 3-19. A "weekend effect" was apparent for elective surgical admissions (OR 1.34; 95% CI 1.10-1.64; p=0.004; Figure 3 and sTable 4) and in patients admitted to ICUs without checklists during the weekends (OR 1.08; 95% CI 1.00-1.17; p=0.045; Figure 3 and sTable 17). We did not find a statistically significant association between other organizational characteristics (nurse/bed ratio, presence of full-time intensivist coverage or the number of protocols) and increased mortality in patients admitted during the weekends.

Scheduled Surgical versus Unscheduled ICU admissions:

We repeated the analyses separately for scheduled surgical admissions and unscheduled admissions (42,977 and 16,637 admission, respectively). Results are shown on Figure 4 and in sTables 20-37 of the ESM. A "weekend effect" was observed in scheduled surgical admissions. However, weekend effect was only present on scheduled surgical admissions when there was a decrease in weekend nurse/bed ratio (OR 1.40; 95% CI 1.09-1.79, p = 0.008), no weekend checklists (OR 1.41; 95% CI 1.09-1.83, p = 0.009) or a lower

number of protocols (OR 1.42; 95%CI 1.06-1.89, p = 0.018) (Figure 4). There was no "weekend effect" in unscheduled admissions.

Propensity score results:

Out of the study population, 35,440 patients (17,720 weekend admissions and 17,720 weekdays admissions) were matched in the propensity score analysis. All patients admitted on weekend could be paired. The distribution of variables in matched patients stratified per weekend effect is shown in sFigure 4. Mortality was 15.5% for patients admitted on weekdays and 16.1% for those admitted during weekends (p=0.112).

Change in weekend-weekday mortality regression:

After linear regression using the change of weekend to weekday mortality as dependent variable, only SAPS 3 score and low number of protocols (fewer than 8 protocols) were associated with increases in mortality in weekends at the ICU level (both p<0.001). There was a trend for presence of weekend checklists and lower changes in weekend-weekday mortality (p=0.08). The model R2 was 74.03%, with SAPS 3 being the most important predictor (66% of all variance), followed by low number of protocols (29%) and presence/absence of weekend checklists (3%, which was not statistically significant).

Temporal association of organizational features and outcome:

The relative contribution of SAPS 3 to hospital mortality decreased in the first 7 days after ICU admission, while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. The relative contribution of other organizational features remained stable (Figure 5).

Discussion

In the present study, we provide evidence that, after proper consideration patients' characteristics along with those related to ICU organization, the association between admissions during the weekend and patients' outcomes is weak and probably not relevant in the scenario of several Brazilian ICUs. However, a residual "weekend effect" might be present for scheduled surgical patients admitted to ICUs with a disrupted continuity of care and adherence to best practices. The weekend effect was therefore seen primarily in hospitals with suboptimal care processes. Nonetheless, we were not able to definitely determine whether this adverse impact is explained by processes of care themselves, or a reflection of other hospital characteristics (eg. quality of surgeons, general ward care, available resources).

Although previous studies suggested an increase in mortality in patients admitted during the weekend(4), the "weekend effect" concept has been recently challenged (6). Criticism of reports suggesting the presence of weekend effect identified three major pitfalls in analysis: (i) studies were performed using administrative databases and might suffer with inconsistent coding; (ii) comorbidities may have not been properly considered and (iii) Illness severity might not be adequately accounted for. Black(6) cited three studies in which, after correction of these issues, the "weekend effect" was no longer significant.

In the present analysis, we intended to overcome the limitations summarized by Black(6). We based our analysis on a quality improvement administrative database that does not only consider International Classification of Diseases (ICD) coding for diagnosis, but it also includes major predefined medical diagnosis (11). This database includes robust prospective clinical data collected at the bedside and not only administrative and/or procedures notes. We also considered the presence of comorbidities and baseline health

status by not only adjusting for Charlson Comorbidity Index but also to performance status impairment (14,15). Finally, severity of illness admission was assessed using well validated and widely accepted scores of severity of illness and organ failure (12,19,20). Our work does not corroborate with the hypothesis that the "weekend effect" is a universal feature in the ICUs. This was highlighted by both the main mixed regression model and by the propensity score analysis performed. In fact, when only unscheduled admissions were considered, no evidence of weekend effect was found regardless of the presence/absence of organizational features in the ICU; this is in accordance with recent reports the of absence of the weekend on unplanned ICU admissions (21). We could find evidence of a weekend effect only in secondary subgroup analyses, suggesting that it might be restricted to scenarios when there is a break in continuity of care during weekends, specifically the absence of patient-centered checklists (11,16), or for schedule admissions.

The case for worse outcomes in elective surgical admissions on weekends is complex, with both ICU and hospital features being able to explain, at least partly, this association (22,23). Differences in surgical care on weekends may play an important role. For example, early recognition and treatment of surgical complications may be delayed on weekends and even the adopted surgical procedure may be different for similar scenarios during weekends (24,25). In this way, checklists may aid at prompt recognition of complications (both clinical (26) and surgical (27)) and improve adherence to daily goals of care (28). Higher nurse staffing may also aid at reducing postoperative complications(10). In our analysis, there was no statistically significant weekend effect in scheduled surgical admissions in units that did not have a decrease in nurse/bed ratio on weekends or that applied checklists on weekends, thereby corroborating to this concept.

Interestingly, several factors potentially related to worse care on weekends did not reach statistical significance in the whole studied population. Despite the rationale for increased mortality when there is a decrease in nurse/bed ratio during weekend (29) or when there is an absence of full-time intensivist coverage (30), we did not find evidence of weekend effect in both scenarios when all admissions types were considered. It is conceivable that well-structured ICUs with weekend checklists and protocols would be less susceptible to the variation in care driven by the decrease in staff during weekends, thereby mitigating the effect of the latter on mortality. This was only apparent for scheduled surgical admissions in our analysis. However, when we evaluated changes in mortality in weekends versus weekday at the ICU level using a linear model, a low number of protocols was the stronger organizational predictor of increase in mortality on weekends. It should be acknowledged that multiple interactions between organizational features could be expected and that some of the absence of statistically significant findings could be due to Simpson´s Paradox.

For patients admitted on weekends, we found that the length-of-stay ICU could modulate the association between organizational features and outcome, as shown in Figure 5. As expected, illness severity as measured by SAPS 3 score was the most important factor associated with mortality, but its relative contribution decreased during the first seven days while the relative contribution of number of protocols increased. The other organizational features remained reasonably stable. This suggests that the main determinant of mortality is a global individual marker of illness severity (as expected) and that the more a patient stays in the ICU, the higher the association between number of protocols and outcome. Interestingly, protocols were also the only variable associated with reduced change in mortality during weekends in the ICU-level linear model. Future studies that assess

organizational features and outcome in the ICU should also consider that organizational features may be more important for patients with prolonged ICU LOS.

Our analysis has several constraints. First, the large number of secondary analyses and models built could increase type 1 error due to overtesting. Additionally, the large sample size may also facilitate observing statistical significant results that may not be clinically relevant. Therefore, our results and especially our subgroup analyses should be considered exploratory and interpreted in the context of multiple models where some groups had small number of patients. It is important to highlight, however, that trends were constant during all analysis performed. We nevertheless advice caution when interpreting our results, specially the effects size reported. Second, albeit the large number of ICUs involved, our results refer to a selected sample of units from a single country and caution is needed when generalizing to other settings. Third, most patients were mostly admitted to private units and had a medium-low illness severity, thereby resulting in a low average mortality. However, no weekend effect was demonstrated in the subgroup analysis per the severity of illness and in septic or mechanically ventilated patients. Fourth, the low nurse/bed ratio reported is common in Brazil and are in accordance with local regulations that estipulate up to 10 beds per nurse in the ICUs but limits its generalization to different European and North American settings. Fifth, we were unable to assess interactions between the several organizational features. Frequently several organizational features occur together and may have synergistic (or even antagonist) effects that should be properly explored in the future. Sixth, we only assessed ICU organizational factors; structure, organizational and staffing patterns at the emergency departments and wards may also play an important role in determining hospital outcome. Finally, we did not assess other relevant

outcomes such as readmissions and longer follow-up mortality and multiple imputation was used to correct for an important patient variable (performance status).

Conclusion

After considering an appropriate disease coding and accounting for comorbidities, illness severity and ICU organization characteristics, we did not observe worse outcomes in patients admitted to ICUs during weekends. Nonetheless, a "weekend effect" might still occur in scheduled surgical admissions, especially in ICUs with a decrease in nurse/bed ratio and absence of checklists during the weekends as well as in ICUs with a low number of protocols. The ICU LOS potentially modulates the association between organizational features and outcomes in critically ill patients.

Declarations

List of abbreviations:

CI – Confidence Interval

ECOG - Eastern Cooperative Oncology Group

ESM – Electronic Supplementary Material

ICU – Intensive Care Unit

LOS – Length of Stay

OR – Odds ratio

SAPS - Simplified Acute Physiology Score

SOFA – Sequential Organ Failure

Ethical approval: This study was locally approved in all participating intensive care units. Consent form was waived due to the retrospective nature of the analysis.

Consent for publication: Not applicable.

Availability of data: Data is not publicly available due to local ethical restrictions.

Competing interest: Dr. Soares and Dr. Salluh are founders and equity shareholders of Epimed Solutions®, which commercializes the Epimed Monitor System®, a cloud-based software for ICU management and benchmarking. The other authors declare that they have no conflict of interest.

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Authors´ Contributions: Manuscript conception: FGZ, TCL, TDC, FAB, JIS, MS. Statistical analyses: FGZ, TCL, FAB, TDC, JIS, MS. Data collection: MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC. Wrote the manuscript: FGZ, TCL, TDC, FAB, JIS, MS. Approved the final version: FGZ, TCL, TDC, FAB, JIS, MS, MF, HSF, AMJ, JCRV, ACPC, MFK, BFM, FC, JMV, WNV, RC, MMG, MOM, EBC.

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Figure Legends

Figure 1 – (A) Number of patients admitted to the ICU at each day of the week; (B) Distribution of admission types at each week day.

Figure 2 – Mortality at each day of the week stratified by admission type.

Figure 3 – Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality in the whole population (upper line) and in selected subgroups (see main text for details).

Figure 4 - Forest plot for the odds ratio (OR) and 95% confidence interval for the association between weekend admission and hospital mortality stratified in unscheduled (left) and scheduled surgical (right) admissions. Further subgroup analyses according to presence/absence of organizational factors are presented

Figure 5 – Relative contribution of illness severity (SAPS 3) and organizational factors in sequential daily random forest models. The relative contribution was defined as the percentage of mean decrease in Gini statistics at each model. Note how the relative importance of illness severity decreases during the first seven days and how the importance of number of protocols increases.

Supplementary Figure Legends:

Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B – Full-time intensivist coverage; C - Low nurse/bed ratio; D - Less than eight protocols

Supplementary Figure 3 - Plot of Random Effects

Supplementary Figure 4 - Variable comparison after propensity score matching

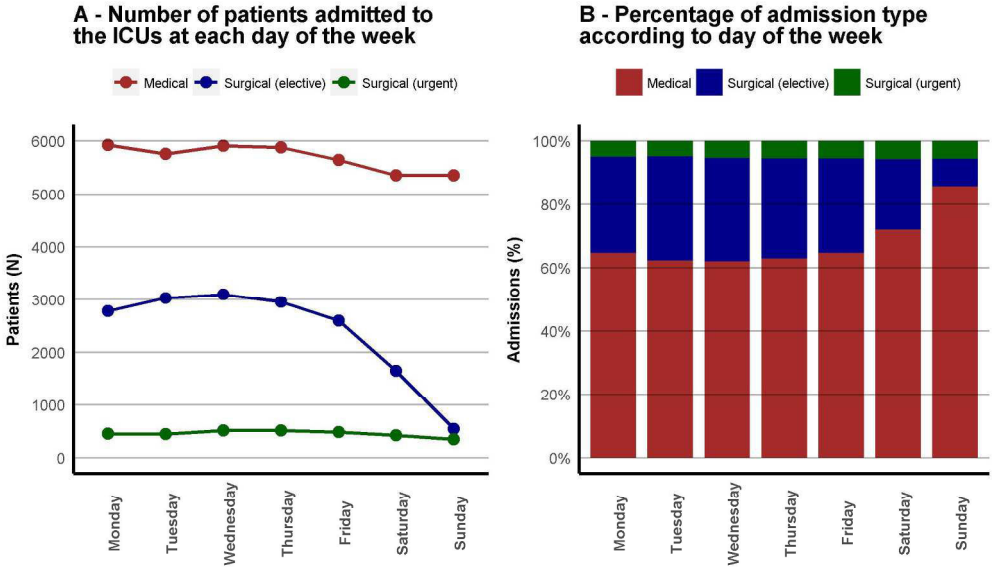

Figure 1

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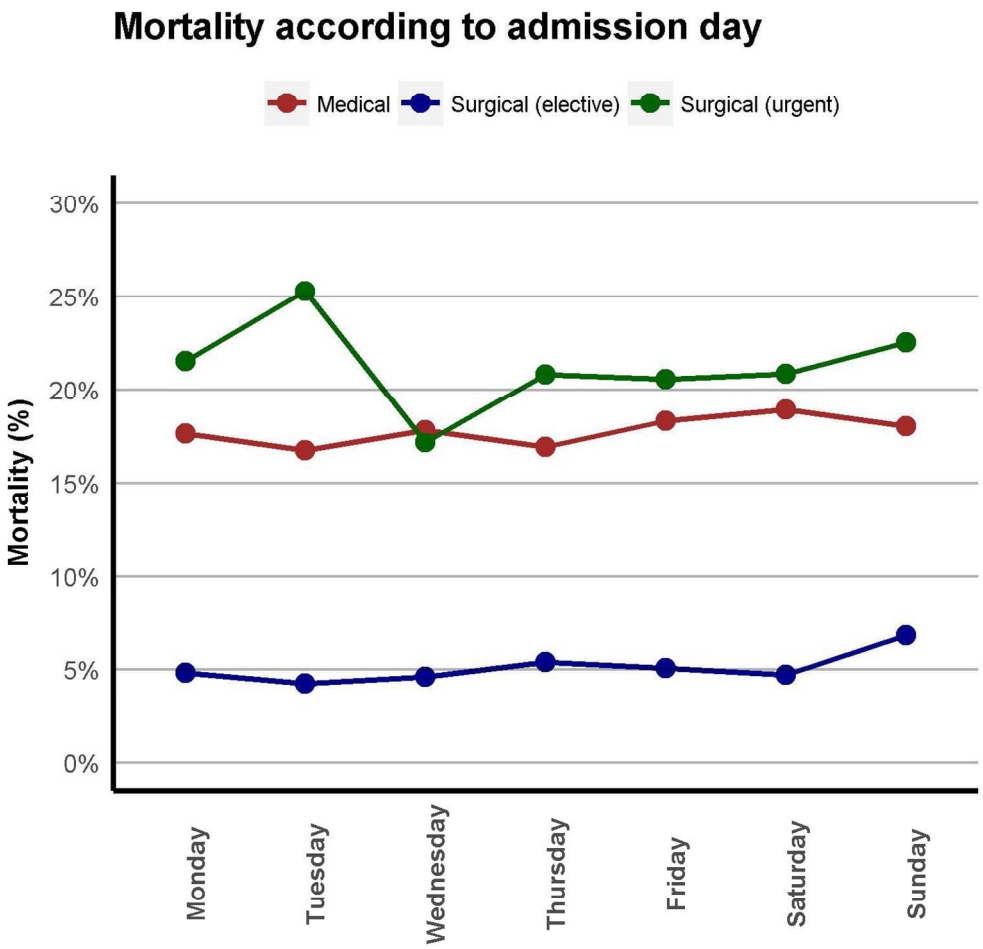


Figure 2

127x127mm (300 x 300 DPI)

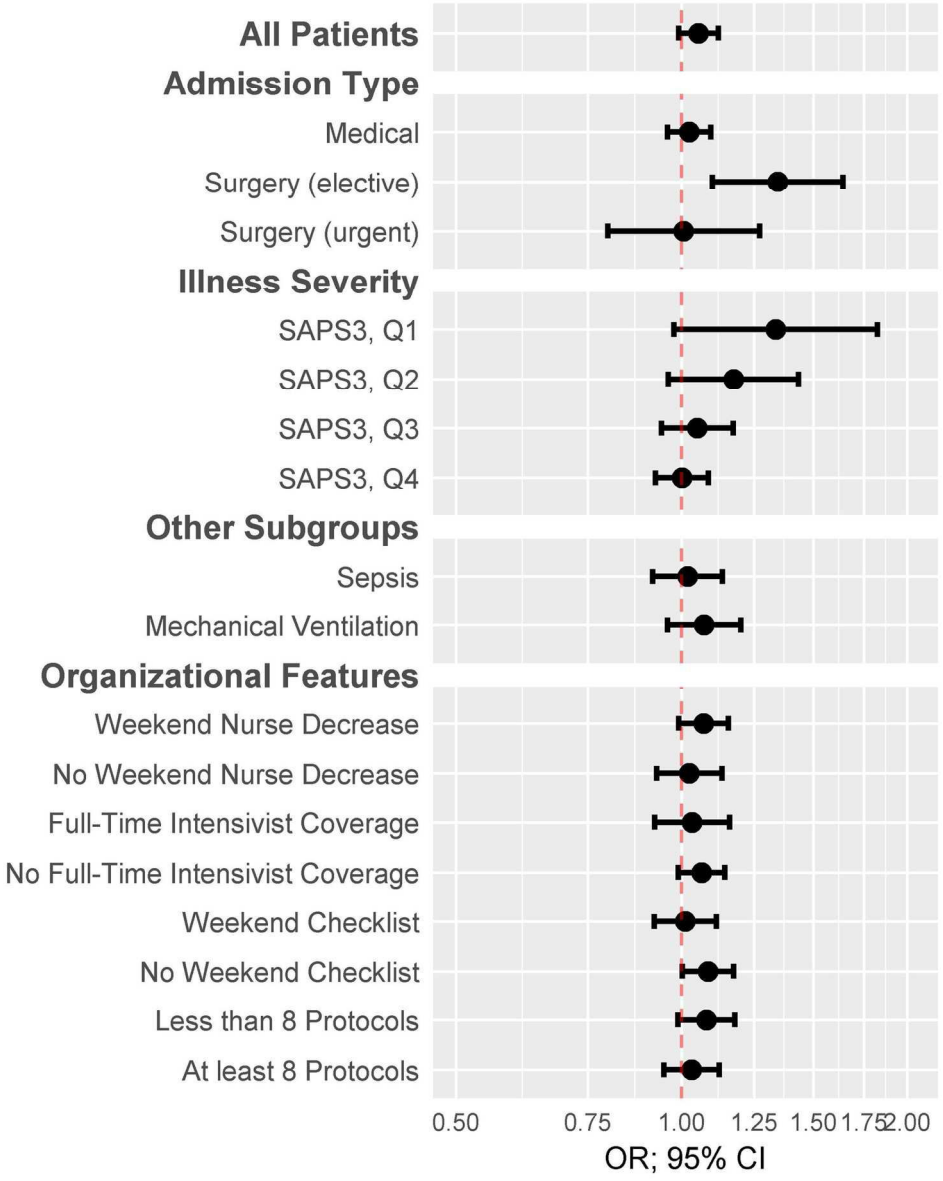


Figure 3

152x182mm (300 x 300 DPI)

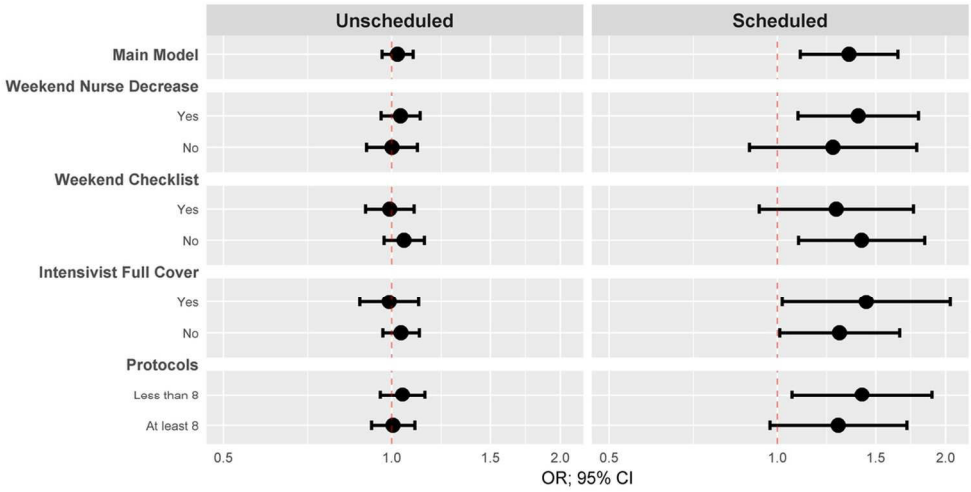


Figure 4

112x56mm (300 x 300 DPI)

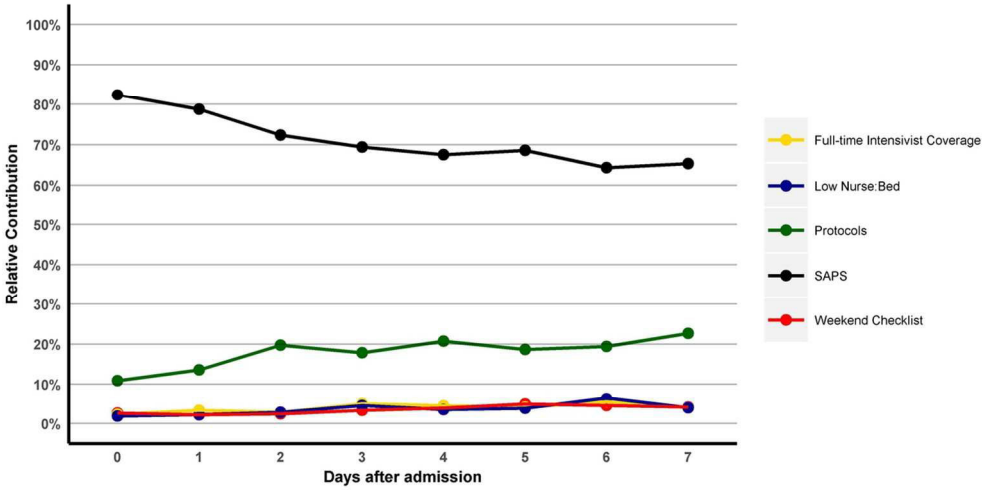


Figure 5

112x56mm (300 x 300 DPI)

The role of organizational factors on the "weekend effect" in critically ill patients in Brazil: A prospective cohort analysis

ELECTRONIC SUPPLEMENTARY FILE

ICU and Hospital Features

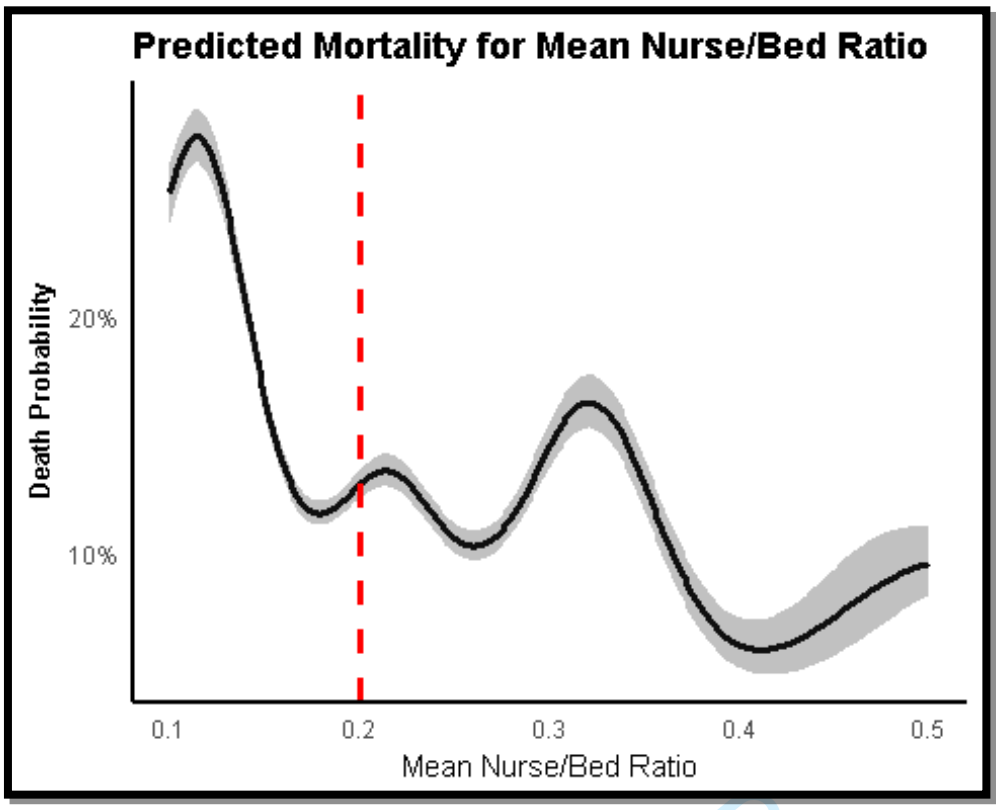
Supplementary Table 1: ICU Features

Number of Units	78
Bed per unit, mean (SD)	17.53 (11.38)
Private hospital, n (%)	67 (85.9)
Accreditation	
None	24 (30.8)
National	30 (38.5)
International	24 (30.8)
Weekend checklists, n (%)	36 (46.2)
Full-time Intensivist Coverage, n(%)	16 (20.5)
Nurse/Bed ratio < 0.2	41 (52.6)
Protocols, mean (SD)	6.96 (2.88)
Medical/Surgical Unit, n (%)	62 (79.5)

Univariate Analysis

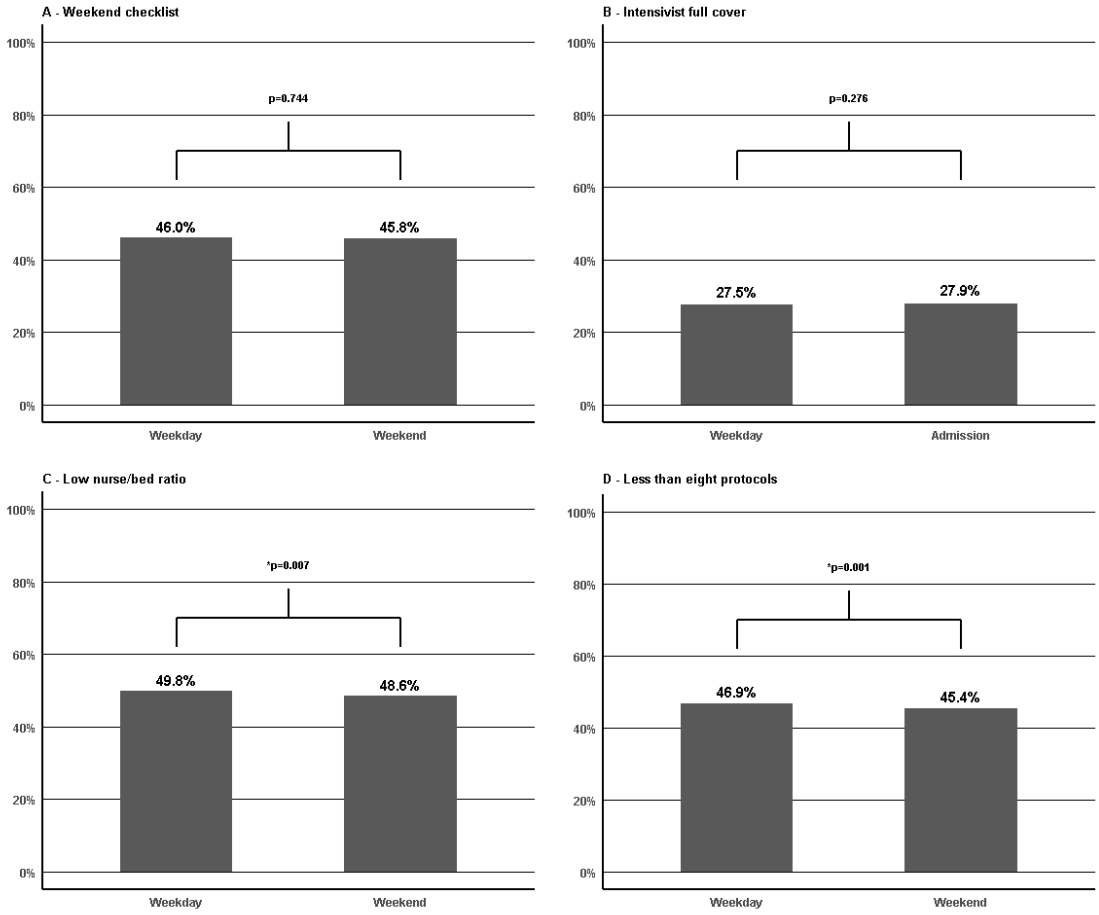
Supplementary Figure 1 - Association between mean nurse/bed ratio and outcome

The association between nurse/bed ratio and hospital mortality was assessed using a generalized additive model using the mgcv package. The 0.2 cutoff was chosen by inspecting the plot of predicted probabilities and hospital mortality (red dashed line in the plot).



Percentage of admissions to unit with specific organizational feature

Supplementary Figure 2 - Percentage of admission to units with: A - Weekend checklist; B - Intensivist fullcover; C - Low nurse/bed ratio; D - Less than eight protocols



Models Results

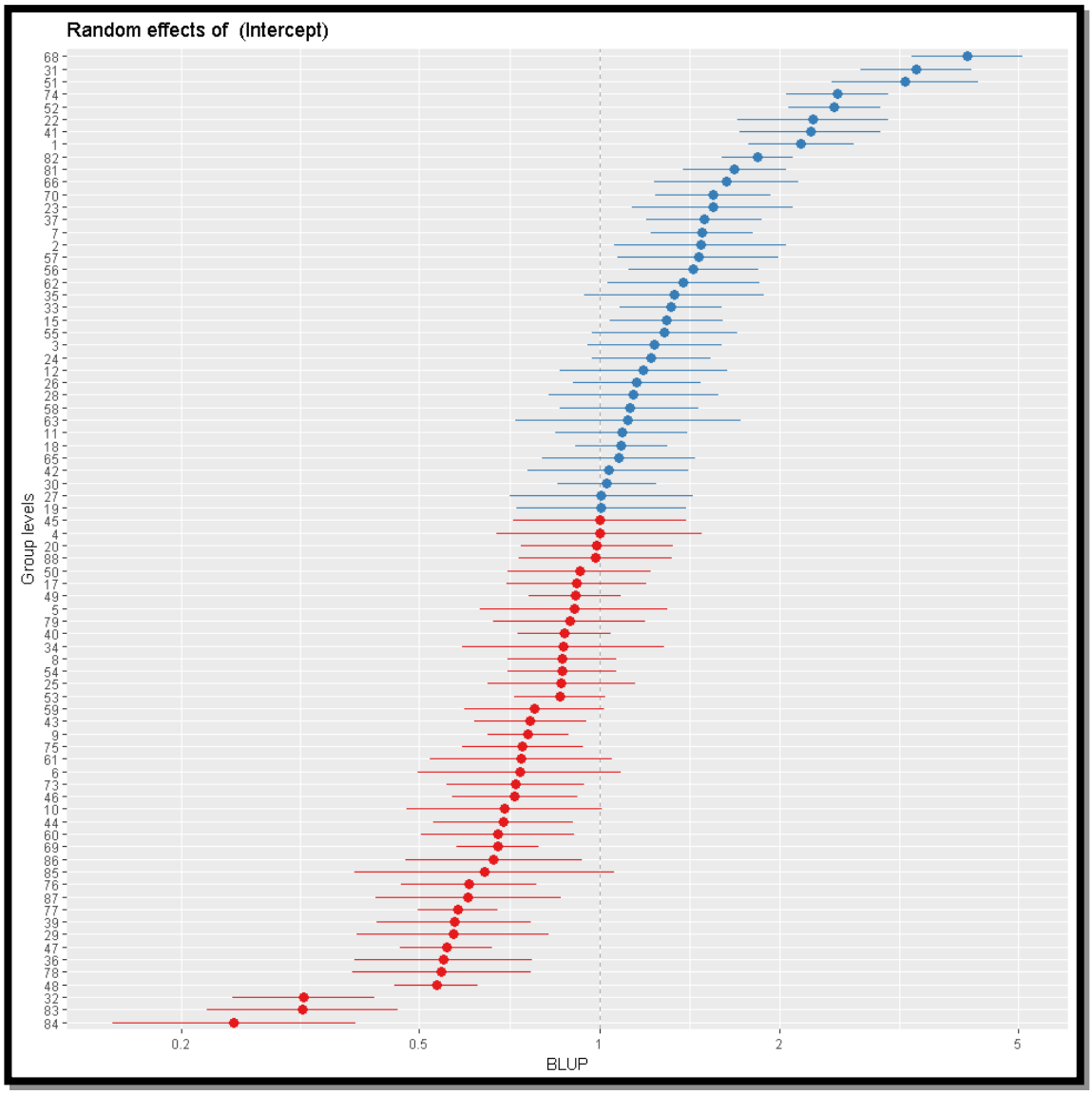
Synthax: Mortality ~ Age + SOFA + Charlson Comorbidity Index + Performance Status Impairment + LOS before ICU admission (tertile) + Admission Type + Checklist on Weekends + Full-time Intensivist Coverage + Nurse/Bed lower than 0.2 + Number of Protocols + Medical/Surgical Unit + ICU (random intercept).

Note: Continuous variables were scaled and centered to reduce non-convergence issues; marked with an * through document.

Supplementary Table 2: Results for main model

	OR	CI	p
Age*	1.60	1.55-1.66	<0.001
SOFA*	2.50	2.43-2.57	<0.001
CCI*	1.44	1.41-1.48	<0.001
Moderate Impairment	1.32	1.22-1.42	<0.001
Severe Impairment	2.04	1.86-2.24	<0.001
LOS 1 day	1.17	1.07-1.27	<0.001
LOS >= 2 days	2.44	2.26-2.62	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.76	0.67-0.86	<0.001
Weekend Checklist	0.97	0.74-1.26	0.814
Full-time Intensivist Coverage	0.98	0.72-1.33	0.887
Nurse/Bed <0.2	1.32	1.03-1.7	0.027
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.45	1.06-1.98	0.018
Weekend Admission	1.05	0.99-1.12	0.095

Supplementary Figure 3: Plot of Random Effects



Subgroups

Supplementary Table 3: Medical Patients

	OR	CI	p
Age*	1.56	1.50-1.62	<0.001
SOFA*	2.49	2.42-2.58	<0.001
CCI*	1.46	1.42-1.51	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	1.94	1.76-2.15	<0.001
LOS 1 day	1.14	1.04-1.26	0.008
LOS >= 2 days	2.54	2.34-2.76	<0.001
Weekend Checklist	0.96	0.74-1.24	0.742
Full-time Intensivist Coverage	1.04	0.77-1.41	0.802
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.003
Medical/Surgical Unit	1.41	1.04-1.91	0.028
Weekend Admission	1.02	0.96-1.09	0.498

Supplementary Table 4: Elective Surgical Patients

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.1-1.64	0.004

Supplementary Table 5: Urgent Surgical Patients

	OR	CI	p
Age*	1.97	1.73-2.24	<0.001
SOFA*	2.51	2.27-2.77	<0.001
CCI*	1.38	1.23-1.54	<0.001
Moderate Impairment	1.10	0.82-1.48	0.526
Severe Impairment	2.34	1.50-3.65	<0.001
LOS 1 day	0.98	0.73-1.31	0.891
LOS >= 2 days	1.43	1.10-1.85	0.008
Weekend Checklist	0.88	0.53-1.47	0.635
Full-time Intensivist Coverage	0.86	0.50-1.49	0.596
Nurse/Bed <0.2	1.30	0.81-2.11	0.279
Protocols	0.87	0.80-0.95	0.002
surgicalu/Surgical Unit	1.07	0.56-2.05	0.837
Weekend Admission	1.01	0.8-1.27	0.956

Supplementary Table 6: SAPS Quartile 1(5-34)

	OR	CI	p
Age*	1.72	1.43-2.06	<0.001
SOFA*	2.35	1.96-2.82	<0.001
CCI*	1.18	0.96-1.46	0.108
Moderate Impairment	2.11	1.41-3.15	<0.001
Severe Impairment	3.68	1.83-7.39	<0.001
LOS 1 day	1.13	0.77-1.66	0.518
LOS >= 2 days	2.70	1.90-3.83	<0.001
Surgical (elective)	0.37	0.25-0.55	<0.001
Surgical (urgent)	0.86	0.46-1.63	0.655
Weekend Checklist	0.93	0.57-1.52	0.778
Full-time Intensivist Coverage	1.06	0.63-1.77	0.827
Nurse/Bed <0.2	1.07	0.67-1.68	0.786
Protocols	0.83	0.76-0.90	<0.001
Medical/Surgical Unit	1.40	0.78-2.52	0.257
Weekend Admission	1.34	0.98-1.82	0.070

Supplementary Table 7: SAPS Quartile 2 (34-42)

	OR	CI	p
Age*	1.38	1.22-1.57	<0.001
SOFA*	2.08	1.84-2.36	<0.001
CCI*	1.47	1.33-1.62	<0.001
Moderate Impairment	1.34	1.04-1.73	0.022
Severe Impairment	2.75	1.87-4.06	<0.001
LOS 1 day	1.32	1.02-1.71	0.035
LOS >= 2 days	2.62	2.04-3.36	<0.001
Surgical (elective)	0.55	0.41-0.72	<0.001
Surgical (urgent)	0.70	0.47-1.04	0.079
Weekend Checklist	0.94	0.62-1.42	0.766
Full-time Intensivist Coverage	0.83	0.52-1.32	0.422
Nurse/Bed <0.2	1.38	0.94-2.02	0.104
Protocols	0.91	0.84-0.98	0.009
Medical/Surgical Unit	1.81	1.10-2.97	0.020
Weekend Admission	1.17	0.96-1.43	0.117

Supplementary Table 8: SAPS Quartile 3 (42-53)

	OR	CI	p
Age*	1.23	1.15-1.32	<0.001
SOFA*	1.98	1.85-2.13	<0.001
CCI*	1.32	1.25-1.39	<0.001
Moderate Impairment	1.44	1.26-1.65	<0.001
Severe Impairment	2.44	2.05-2.90	<0.001
LOS 1 day	1.18	1.02-1.38	0.030
LOS >= 2 days	2.39	2.07-2.77	<0.001
Surgical (elective)	0.52	0.42-0.63	<0.001
Surgical (urgent)	0.74	0.59-0.93	0.011
Weekend Checklist	1.06	0.81-1.40	0.651
Full-time Intensivist Coverage	0.98	0.71-1.35	0.902
Nurse/Bed <0.2	1.30	1.00-1.68	0.047
Protocols	0.93	0.89-0.98	0.007

Medical/Surgical Unit	1.40	1.01-1.94	0.041
Weekend Admission	1.05	0.94-1.17	0.393

Supplementary Table 9: SAPS Quartile 4 (53-132)

	OR	CI	p
Age*	1.15	1.09-1.21	<0.001
SOFA*	1.92	1.85-2.00	<0.001
CCI*	1.26	1.22-1.30	<0.001
Moderate Impairment	1.18	1.07-1.30	0.001
Severe Impairment	1.66	1.47-1.86	<0.001
LOS 1 day	1.07	0.95-1.20	0.283
LOS >= 2 days	1.91	1.74-2.10	<0.001
Surgical (elective)	0.42	0.33-0.52	<0.001
Surgical (urgent)	0.99	0.84-1.17	0.931
Weekend Checklist	0.92	0.72-1.17	0.488
Full-time Intensivist Coverage	0.92	0.70-1.22	0.567
Nurse/Bed <0.2	1.35	1.08-1.70	0.009
Protocols	0.94	0.90-0.98	0.005
Medical/Surgical Unit	1.33	1.00-1.78	0.053
Weekend Admission	1.00	0.92-1.09	0.979

Supplementary Table 10: Patients admitted due to sepsis

	OR	CI	p
Age*	1.51	1.42-1.60	<0.001
SOFA*	2.19	2.08-2.30	<0.001
CCI*	1.42	1.35-1.49	<0.001
Moderate Impairment	1.31	1.15-1.50	<0.001
Severe Impairment	1.55	1.34-1.80	<0.001
LOS 1 day	1.08	0.92-1.25	0.353
LOS >= 2 days	2.18	1.91-2.50	<0.001
Weekend Checklist	0.90	0.69-1.19	0.460
Full-time Intensivist Coverage	0.95	0.69-1.30	0.755
Nurse/Bed <0.2	1.49	1.15-1.92	0.002

Protocols	0.92	0.88-0.97	0.001
Medical/Surgical Unit	1.24	0.87-1.78	0.232
Weekend Admission	1.02	0.91-1.13	0.737

Supplementary Table 11: Patients that required mechanical ventilation on day 1

	OR	CI	p
Age*	1.61	1.52-1.71	<0.001
SOFA*	1.74	1.66-1.83	<0.001
CCI*	1.30	1.24-1.37	<0.001
Moderate Impairment	1.18	1.02-1.35	0.022
Severe Impairment	1.03	0.87-1.21	0.769
LOS 1 day	1.01	0.87-1.18	0.878
LOS >= 2 days	1.64	1.45-1.86	<0.001
Surgical (elective)	0.17	0.15-0.20	<0.001
Surgical (urgent)	0.59	0.50-0.69	<0.001
Weekend Checklist	0.99	0.72-1.36	0.959
Full-time Intensivist Coverage	0.91	0.64-1.29	0.590
Nurse/Bed <0.2	1.42	1.06-1.90	0.018
Protocols	0.96	0.91-1.01	0.133
Medical/Surgical Unit	1.12	0.76-1.66	0.553
Weekend Admission	1.07	0.96-1.2	0.228

Supplementary Table 12: ICUs with nurse decrease on weekends

	OR	**CI**	**p**
Age*	1.52	1.45-1.59	<0.001
SOFA*	2.50	2.41-2.59	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.31	1.2-1.44	<0.001
Severe Impairment	1.88	1.67-2.12	<0.001
LOS 1 day	1.17	1.05-1.30	0.004
LOS >= 2 days	2.46	2.25-2.69	<0.001
Surgical (elective)	0.24	0.22-0.27	<0.001
Surgical (urgent)	0.73	0.63-0.85	<0.001
Weekend Checklist	1.14	0.85-1.52	0.391

Full-time Intensivist Coverage	0.92	0.65-1.30	0.629
Nurse/Bed <0.2	1.31	0.99-1.73	0.056
Protocols	0.92	0.87-0.98	0.007
Medical/Surgical Unit	1.17	0.80-1.73	0.421
Weekend Admission	1.07	0.99-1.15	0.085

Supplementary Table 13: ICUs with no nurse decrease on weekend

	OR	CI	p
Age*	1.76	1.66-1.86	<0.001
SOFA*	2.50	2.38-2.62	<0.001
CCI*	1.45	1.39-1.52	<0.001
Moderate Impairment	1.34	1.18-1.51	<0.001
Severe Impairment	2.37	2.03-2.76	<0.001
LOS 1 day	1.17	1.02-1.34	0.025
LOS >= 2 days	2.39	2.11-2.71	<0.001
Surgical (elective)	0.24	0.21-0.28	<0.001
Surgical (urgent)	0.81	0.66-0.99	0.040
Weekend Checklist	0.74	0.45-1.20	0.222
Full-time Intensivist Coverage	1.08	0.62-1.88	0.783
Nurse/Bed <0.2	1.50	0.93-2.42	0.094
Protocols	0.94	0.87-1.01	0.085
Medical/Surgical Unit	1.97	1.18-3.27	0.009
Weekend Admission	1.02	0.93-1.13	0.642

Supplementary Table 14: ICUs with intensivist fullcover

	OR	CI	p
Age*	1.63	1.53-1.74	<0.001
SOFA*	2.21	2.09-2.33	<0.001
CCI*	1.33	1.26-1.40	<0.001
Moderate Impairment	1.35	1.16-1.57	<0.001
Severe Impairment	2.12	1.73-2.59	<0.001
LOS 1 day	1.03	0.87-1.23	0.695

LOS >= 2 days	2.40	2.10-2.75	<0.001
Surgical (elective)	0.21	0.17-0.25	<0.001
Surgical (urgent)	0.65	0.51-0.82	<0.001
Weekend Checklist	1.27	0.65-2.48	0.493
Nurse/Bed <0.2	1.49	0.77-2.87	0.240
Protocols	0.90	0.81-0.98	0.022
Medical/Surgical Unit	1.13	0.49-2.64	0.773
Weekend Admission	1.03	0.92-1.16	0.584

Supplementary Table 15: ICUs without intensivist fullcover

	OR	CI	p
Age*	1.60	1.54-1.67	<0.001
SOFA*	2.62	2.53-2.71	<0.001
CCI*	1.49	1.44-1.53	<0.001
Moderate Impairment	1.31	1.20-1.42	<0.001
Severe Impairment	2.02	1.82-2.25	<0.001
LOS 1 day	1.21	1.10-1.34	<0.001
LOS >= 2 days	2.42	2.22-2.64	<0.001
Surgical (elective)	0.26	0.23-0.29	<0.001
Surgical (urgent)	0.80	0.70-0.93	0.002
Weekend Checklist	0.91	0.69-1.22	0.535
Nurse/Bed <0.2	1.33	1.02-1.74	0.034
Protocols	0.95	0.90-1.00	0.057
Medical/Surgical Unit	1.47	1.06-2.03	0.020
Weekend Admission	1.06	0.99-1.14	0.094

Supplementary Table 16: ICUs with checklists

	OR	CI	p
Age*	1.69	1.60-1.79	<0.001
SOFA*	2.56	2.44-2.68	<0.001
CCI*	1.45	1.40-1.51	<0.001
Moderate Impairment	1.41	1.25-1.58	<0.001
Severe Impairment	2.30	2.00-2.64	<0.001
LOS 1 day	1.23	1.08-1.41	0.003
LOS >= 2 days	2.57	2.29-2.89	<0.001

Surgical (elective)	0.28	0.24-0.32	<0.001
Surgical (urgent)	0.70	0.57-0.86	0.001
Full-time Intensivist Coverage	1.16	0.71-1.91	0.554
Nurse/Bed <0.2	1.18	0.85-1.64	0.314
Protocols	0.97	0.91-1.04	0.44
Medical/Surgical Unit	1.56	1.04-2.34	0.031
Weekend Admission	1.01	0.92-1.11	0.816

Supplementary Table 17: ICUs without checklist

	OR	CI	p
Age*	1.55	1.49-1.63	<0.001
SOFA*	2.46	2.37-2.55	<0.001
CCI*	1.44	1.39-1.49	<0.001
Moderate Impairment	1.25	1.14-1.38	<0.001
Severe Impairment	1.84	1.62-2.09	<0.001
LOS 1 day	1.13	1.01-1.26	0.034
LOS >= 2 days	2.35	2.15-2.58	<0.001
Surgical (elective)	0.22	0.20-0.25	<0.001
Surgical (urgent)	0.78	0.67-0.90	0.001
Full-time Intensivist Coverage	0.91	0.61-1.35	0.627
Nurse/Bed <0.2	1.53	1.04-2.25	0.032
Protocols	0.91	0.86-0.97	0.003
Medical/Surgical Unit	1.53	0.94-2.49	0.086
Weekend Admission	1.08	1.00-1.17	0.045

Supplementary Table 18: ICUs with less than 8 protocols

	OR	CI	p
Age*	1.67	1.59-1.75	<0.001
SOFA*	2.48	2.38-2.58	<0.001
CCI*	1.42	1.37-1.48	<0.001
Moderate Impairment	1.36	1.22-1.51	<0.001
Severe Impairment	2.25	1.94-2.60	<0.001
LOS 1 day	1.20	1.06-1.35	0.005

LOS >= 2 days	2.11	1.90-2.34	<0.001
Surgical (elective)	0.26	0.23-0.30	<0.001
Surgical (urgent)	0.84	0.71-0.99	0.042
Weekend Checklist	0.76	0.51-1.12	0.168
Full-time Intensivist Coverage	1.06	0.68-1.67	0.790
Nurse/Bed <0.2	1.68	1.13-2.51	0.011
Medical/Surgical Unit	2.17	1.23-3.82	0.007
Weekend Admission	1.08	0.99-1.18	0.088

Supplementary Table 19: ICUs with at least 8 protocols

	OR	CI	p
Age*	1.54	1.46-1.62	<0.001
SOFA*	2.51	2.42-2.61	<0.001
CCI*	1.46	1.41-1.51	<0.001
Moderate Impairment	1.29	1.17-1.43	<0.001
Severe Impairment	1.93	1.70-2.18	<0.001
LOS 1 day	1.13	1.01-1.27	0.035
LOS >= 2 days	2.78	2.52-3.07	<0.001
Surgical (elective)	0.22	0.19-0.25	<0.001
Surgical (urgent)	0.68	0.57-0.80	<0.001
Weekend Checklist	0.99	0.75-1.30	0.930
Full-time Intensivist Coverage	0.80	0.55-1.15	0.231
Nurse/Bed <0.2	1.15	0.88-1.49	0.307
Medical/Surgical Unit	1.17	0.87-1.57	0.298
Weekend Admission	1.03	0.95-1.12	0.474

Analysis on Unscheduled Admissions

Supplementary Table 20: Main model

	OR	CI	p
Age*	1.59	1.53-1.65	<0.001
SOFA*	2.49	2.42-2.57	<0.001
CCI*	1.46	1.42-1.5	<0.001
Moderate Impairment	1.30	1.20-1.41	<0.001
Severe Impairment	1.96	1.78-2.17	<0.001
LOS 1 day	1.12	1.02-1.23	0.013
LOS >= 2 days	2.35	2.18-2.55	<0.001
Weekend Checklist	0.95	0.73-1.23	0.685
Full-time Intensivist Coverage	1.03	0.76-1.40	0.850
Nurse/Bed <0.2	1.37	1.07-1.74	0.012
Protocols	0.93	0.89-0.98	0.002
Medical/Surgical Unit	1.42	1.04-1.92	0.026
Weekend Admission	1.02	0.96-1.09	0.473

Supplementary Table 21: Nurse decrease on weekends

	OR	CI	p
Age*	1.50	1.43-1.57	<0.001
SOFA*	2.49	2.40-2.58	<0.001
CCI*	1.46	1.40-1.51	<0.001
Moderate Impairment	1.30	1.18-1.44	<0.001
Severe Impairment	1.86	1.64-2.11	<0.001
LOS 1 day	1.11	0.99-1.25	0.076
LOS >= 2 days	2.39	2.17-2.63	<0.001
Weekend Checklist	1.09	0.82-1.46	0.55
Full-time Intensivist Coverage	0.96	0.68-1.36	0.824
Nurse/Bed <0.2	1.37	1.04-1.81	0.026
Protocols	0.92	0.87-0.97	0.005
Medical/Surgical Unit	1.13	0.77-1.67	0.535
Weekend Admission	1.04	0.96-1.12	0.38

Supplementary Table 22: No nurse decrease on weekends

	OR	CI	p
Age*	1.74	1.64-1.85	<0.001
SOFA*	2.49	2.37-2.62	<0.001
CCI*	1.47	1.41-1.54	<0.001
Moderate Impairment	1.31	1.14-1.49	<0.001
Severe Impairment	2.18	1.85-2.55	<0.001
LOS 1 day	1.15	0.99-1.33	0.067
LOS >= 2 days	2.27	1.98-2.60	<0.001
Weekend Checklist	0.74	0.46-1.18	0.206
Full-time Intensivist Coverage	1.17	0.68-1.99	0.571
Nurse/Bed <0.2	1.51	0.95-2.38	0.080
Protocols	0.94	0.87-1.01	0.075
Medical/Surgical Unit	1.95	1.19-3.19	0.008
Weekend Admission	1.00	0.90-1.11	0.995

Supplementary Table 23: Weekend Checklist

	OR	CI	p
Age*	1.66	1.56-1.76	<0.001
SOFA*	2.54	2.42-2.67	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.38	1.23-1.56	<0.001
Severe Impairment	2.28	1.98-2.63	<0.001
LOS 1 day	1.16	1.00-1.34	0.048
LOS >= 2 days	2.48	2.19-2.81	<0.001
Full-time Intensivist Coverage	1.22	0.73-2.02	0.450
Nurse/Bed <0.2	1.25	0.90-1.76	0.187
Protocols	0.98	0.91-1.05	0.502
Medical/Surgical Unit	1.48	0.97-2.24	0.066
Weekend Admission	0.99	0.90-1.10	0.860

Supplementary Table 24: No weekend Checklist

	OR	CI	p

Age*	1.54	1.47-1.62	<0.001
SOFA*	2.46	2.36-2.55	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.24	1.12-1.38	<0.001
Severe Impairment	1.72	1.50-1.97	<0.001
LOS 1 day	1.10	0.98-1.24	0.117
LOS >= 2 days	2.27	2.05-2.51	<0.001
Full-time Intensivist Coverage	0.97	0.66-1.43	0.873
Nurse/Bed <0.2	1.55	1.06-2.25	0.022
Protocols	0.91	0.86-0.97	0.002
Medical/Surgical Unit	1.53	0.96-2.45	0.076
Weekend Admission	1.05	0.97-1.14	0.233

Supplementary Table 25: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.62	1.51-1.73	<0.001
SOFA*	2.21	2.09-2.34	<0.001
CCI*	1.36	1.29-1.44	<0.001
Moderate Impairment	1.29	1.10-1.53	0.002
Severe Impairment	1.98	1.61-2.44	<0.001
LOS 1 day	1.00	0.83-1.21	0.984
LOS >= 2 days	2.30	1.98-2.66	<0.001
Weekend Checklist	1.20	0.65-2.24	0.562
Nurse/Bed <0.2	1.55	0.84-2.85	0.163
Protocols	0.89	0.82-0.98	0.012
Medical/Surgical Unit	1.11	0.50-2.46	0.791
Weekend Admission	0.99	0.88-1.12	0.856

Supplementary Table 26: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.58	1.51-1.65	<0.001
SOFA*	2.60	2.51-2.70	<0.001
CCI*	1.50	1.45-1.55	<0.001
Moderate Impairment	1.30	1.19-1.43	<0.001

Severe Impairment	1.96	1.76-2.19	<0.001
LOS 1 day	1.16	1.05-1.29	0.005
LOS >= 2 days	2.36	2.15-2.59	<0.001
Weekend Checklist	0.89	0.67-1.19	0.437
Nurse/Bed <0.2	1.36	1.04-1.78	0.025
Protocols	0.95	0.90-1.00	0.065
Medical/Surgical Unit	1.43	1.04-1.98	0.030
Weekend Admission	1.04	0.96-1.12	0.326

Supplementary Table 27: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.67	1.58-1.76	<0.001
SOFA*	2.49	2.38-2.60	<0.001
CCI*	1.45	1.39-1.51	<0.001
Moderate Impairment	1.37	1.22-1.54	<0.001
Severe Impairment	2.15	1.85-2.50	<0.001
LOS 1 day	1.13	0.99-1.30	0.071
LOS >= 2 days	2.05	1.82-2.30	<0.001
Weekend Checklist	0.75	0.51-1.09	0.133
Full-time Intensivist Coverage	1.14	0.73-1.76	0.566
Nurse/Bed <0.2	1.72	1.17-2.54	0.006
Medical/Surgical Unit	2.08	1.20-3.61	0.009
Weekend Admission	1.04	0.95-1.14	0.349

Supplementary Table 28: At least 8 protocols in ICU

	OR	CI	p
Age*	1.51	1.43-1.59	<0.001
SOFA*	2.49	2.39-2.60	<0.001
CCI*	1.47	1.42-1.53	<0.001
Moderate Impairment	1.26	1.13-1.41	<0.001
Severe Impairment	1.87	1.64-2.13	<0.001
LOS 1 day	1.11	0.98-1.26	0.097
LOS >= 2 days	2.64	2.37-2.94	<0.001
Weekend Checklist	0.96	0.72-1.26	0.757

Full-time Intensivist Coverage	0.84	0.58-1.22	0.352
Nurse/Bed <0.2	1.19	0.91-1.55	0.203
Medical/Surgical Unit	1.14	0.84-1.55	0.389
Weekend Admission	1.01	0.92-1.10	0.912

Analysis on Scheduled Admissions

Supplementary Table 29: Main model

	OR	CI	p
Age*	1.81	1.62-2.01	<0.001
SOFA*	2.45	2.26-2.66	<0.001
CCI*	1.39	1.30-1.49	<0.001
Moderate Impairment	1.48	1.20-1.83	<0.001
Severe Impairment	3.82	2.73-5.35	<0.001
LOS 1 day	1.35	1.06-1.71	0.014
LOS >= 2 days	2.55	2.06-3.14	<0.001
Weekend Checklist	1.18	0.77-1.80	0.445
Full-time Intensivist Coverage	0.82	0.52-1.30	0.399
Nurse/Bed <0.2	1.24	0.83-1.84	0.291
Protocols	0.88	0.82-0.95	0.001
Medical/Surgical Unit	1.47	0.90-2.40	0.121
Weekend Admission	1.34	1.10-1.64	0.004

Supplementary Table 30: Nurse decrease on weekends

	OR	CI	p
Age*	1.72	1.50-1.96	<0.001
SOFA*	2.44	2.20-2.70	<0.001
CCI*	1.40	1.27-1.53	<0.001
Moderate Impairment	1.40	1.08-1.83	0.012
Severe Impairment	2.62	1.63-4.21	<0.001
LOS 1 day	1.41	1.05-1.89	0.023
LOS >= 2 days	2.60	2.01-3.36	<0.001
Weekend Checklist	1.33	0.81-2.19	0.255
Full-time Intensivist	0.75	0.43-1.31	0.303

Coverage			
Nurse/Bed <0.2	1.07	0.67-1.73	0.769
Protocols	0.88	0.79-0.97	0.013
Medical/Surgical Unit	1.24	0.61-2.53	0.556
Weekend Admission	1.40	1.09-1.79	0.008

Supplementary Table 31: No nurse decrease on weekends

	OR	CI	p
Age*	2.01	1.67-2.41	<0.001
SOFA*	2.44	2.13-2.8	<0.001
CCI*	1.37	1.22-1.54	<0.001
Moderate Impairment	1.68	1.18-2.39	0.004
Severe Impairment	5.90	3.61-9.63	<0.001
LOS 1 day	1.25	0.83-1.87	0.282
LOS >= 2 days	2.46	1.70-3.55	<0.001
Weekend Checklist	1.00	0.48-2.09	0.996
Full-time Intensivist Coverage	0.93	0.44-1.93	0.836
Nurse/Bed <0.2	1.92	0.95-3.89	0.069
Protocols	0.87	0.78-0.97	0.012
Medical/Surgical Unit	1.70	0.86-3.36	0.127
Weekend Admission	1.26	0.89-1.78	0.193

Supplementary Table 32: Weekend Checklist

	OR	CI	p
Age*	2.03	1.70-2.44	<0.001
SOFA*	2.56	2.23-2.93	<0.001
CCI*	1.55	1.38-1.74	<0.001
Moderate Impairment	1.59	1.15-2.20	0.005
Severe Impairment	2.86	1.69-4.82	<0.001
LOS 1 day	1.69	1.15-2.46	0.007
LOS >= 2 days	2.85	2.04-3.98	<0.001
Full-time Intensivist Coverage	0.91	0.43-1.92	0.800
Nurse/Bed <0.2	1.27	0.70-2.28	0.432

Protocols	0.90	0.78-1.04	0.145
Medical/Surgical Unit	1.76	0.84-3.71	0.135
Weekend Admission	1.27	0.93-1.75	0.134

Supplementary Table 33: No weekend Checklist

	OR	CI	p
Age*	1.68	1.47-1.92	<0.001
SOFA*	2.37	2.14-2.62	<0.001
CCI*	1.32	1.20-1.44	<0.001
Moderate Impairment	1.36	1.03-1.79	0.033
Severe Impairment	4.86	3.11-7.60	<0.001
LOS 1 day	1.16	0.85-1.58	0.347
LOS >= 2 days	2.33	1.77-3.06	<0.001
Full-time Intensivist Coverage	0.78	0.44-1.38	0.399
Nurse/Bed <0.2	1.30	0.73-2.29	0.373
Protocols	0.87	0.79-0.95	0.002
Medical/Surgical Unit	1.38	0.70-2.73	0.357
Weekend Admission	1.41	1.09-1.83	0.009

Supplementary Table 34: Full-time Intensivist Coverage

	OR	CI	p
Age*	1.90	1.55-2.33	<0.001
SOFA*	2.05	1.77-2.37	<0.001
CCI*	1.24	1.08-1.43	0.002
Moderate Impairment	1.77	1.20-2.61	0.004
Severe Impairment	5.71	2.75-11.88	<0.001
LOS 1 day	0.95	0.62-1.46	0.825
LOS >= 2 days	2.06	1.41-3.01	<0.001
Weekend Checklist	1.39	0.53-3.63	0.502
Nurse/Bed <0.2	1.03	0.38-2.77	0.951
Protocols	0.84	0.72-0.97	0.018
Medical/Surgical Unit	1.12	0.32-3.89	0.856
Weekend Admission	1.44	1.02-2.04	0.038

Supplementary Table 35: No Full-time Intensivist Coverage

	OR	CI	p
Age*	1.79	1.58-2.03	<0.001
SOFA*	2.65	2.40-2.93	<0.001
CCI*	1.46	1.34-1.59	<0.001
Moderate Impairment	1.40	1.08-1.80	0.010
Severe Impairment	3.38	2.30-4.96	<0.001
LOS 1 day	1.57	1.17-2.09	0.002
LOS >= 2 days	2.82	2.19-3.63	<0.001
Weekend Checklist	1.17	0.73-1.88	0.513
Nurse/Bed <0.2	1.34	0.86-2.09	0.190
Protocols	0.88	0.81-0.97	0.007
Medical/Surgical Unit	1.50	0.90-2.53	0.123
Weekend Admission	1.29	1.01-1.66	0.042

Supplementary Table 36: Less than 8 protocols in ICU

	OR	CI	p
Age*	1.70	1.49-1.95	<0.001
SOFA*	2.42	2.16-2.70	<0.001
CCI*	1.32	1.19-1.47	<0.001
Moderate Impairment	1.30	0.97-1.74	0.079
Severe Impairment	3.91	2.36-6.49	<0.001
LOS 1 day	1.50	1.09-2.08	0.014
LOS >= 2 days	2.16	1.61-2.90	<0.001
Weekend Checklist	0.84	0.46-1.52	0.565
Full-time Intensivist Coverage	0.96	0.51-1.79	0.892
Nurse/Bed <0.2	1.63	0.90-2.94	0.106
Medical/Surgical Unit	2.17	0.98-4.82	0.056
Weekend Admission	1.42	1.06-1.89	0.018

Supplementary Table 37: At least 8 protocols in ICU

	OR	CI	p
Age*	1.94	1.63-2.32	<0.001
SOFA*	2.51	2.23-2.83	<0.001
CCI*	1.46	1.32-1.61	<0.001

Moderate Impairment	1.65	1.22-2.25	0.001
Severe Impairment	3.60	2.28-5.68	<0.001
LOS 1 day	1.18	0.82-1.69	0.372
LOS >= 2 days	2.96	2.19-4.00	<0.001
Weekend Checklist	1.12	0.68-1.83	0.664
Full-time Intensivist Coverage	0.54	0.28-1.03	0.062
Nurse/Bed <0.2	1.02	0.62-1.69	0.925
Medical/Surgical Unit	1.18	0.67-2.07	0.567
Weekend Admission	1.29	0.97-1.70	0.081

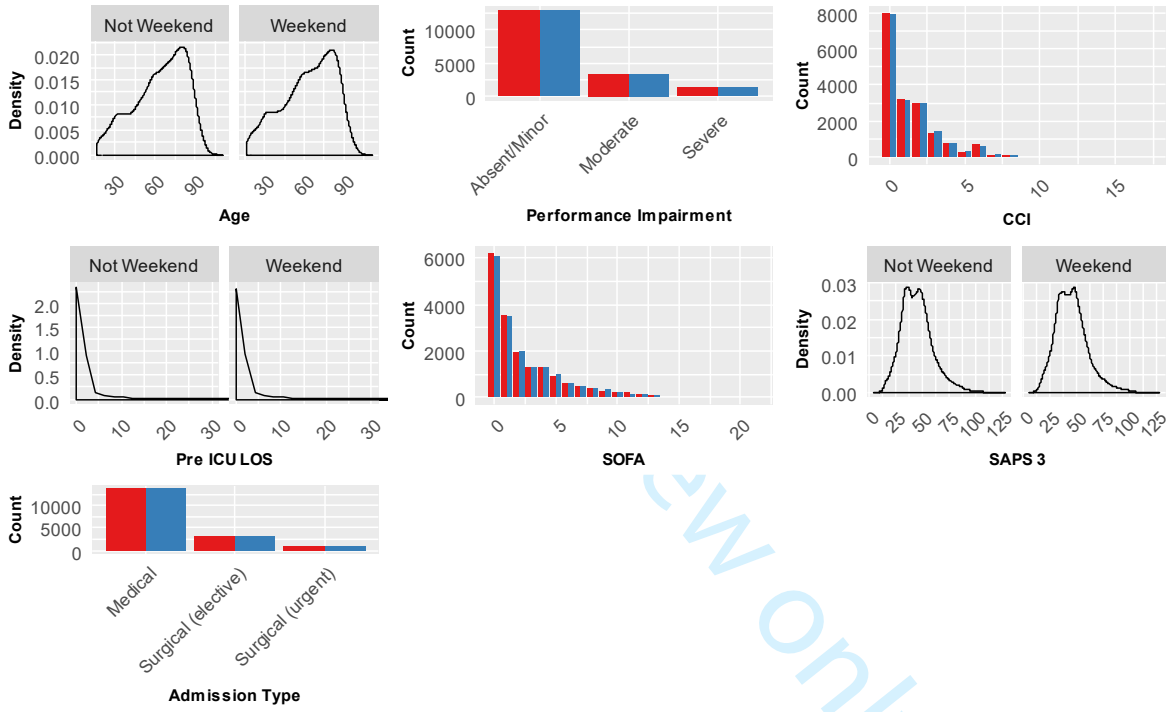
Propensity Score Analysis

Method: 1:1 patient matching controlling for age, CCI, admission type, performance status impairment, LOS before ICU admission, SOFA, SAPS3 and admission type

Results: 35,440 patients (17,720 in each arm) were matched. Mortality was 15.5% for patients admitted on weekdays and 16.1% for patients admitted on weekends (p=0.112)

Matching: Matching was adequate. Figure below shows density plot and barplots for the variables included in the propensity score

Supplementary Figure 4: Variable comparison after propensity score matching



List of Protocols Inquired to Participating ICUs:

Only protocols fully implemented for at least 6 months were considered. If the participating unit reported that protocol was in place, the careprovider responsible for the protocol was also obligatorily reported.

1. Sepsis (i.e. according to the current recommendations of the Surviving Sepsis Campaign)
2. Sedation (i.e. daily interruption or protocolized sedation in ventilated patients)
3. Cerebrovascular accident (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive thrombolysis)
4. Acute coronary syndromes (i.e. systematic initial approach including risk stratification and checking for the eligibility to receive reperfusion therapies or interventions)
5. Liberation from the mechanical ventilation (i.e. care provider-driven spontaneous breathing trials)
6. Lung protective ventilation (i.e. ventilation with low tidal volumes in patients with acute lung injury/ARDS)
7. Therapeutic hypothermia in patients who experienced cardiac arrest
8. Catheter-associated bloodstream infection prevention (i.e. implementation of checklists during insertion and maintenance of vascular catheters)
9. Ventilator-associated pneumonia (VAP) prevention (i.e. implementation of daily checklists to best practices to prevent VAP in ventilated patients)
10. Early mobilization in ventilated patients (i.e protocolized early exercise and mobilization including physical and occupational therapy during periods of daily interruption of sedation in ventilated patients)

STROBE Checklist

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7, first paragraph
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, first paragraph
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, first paragraph
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5, third paragrapg
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 7
Study size	10	Explain how the study size was arrived at	NA

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9, specific subtopic on this
		(*c*) Explain how missing data were addressed	Page 8, specific topic
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Page 7.
		(*e*) Describe any sensitivity analyses	Only subgroup analyses were performed.

Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12, first patagraph
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	All patients in dataset were eligible
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Figures 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Described in methods. Only performance status missing

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Mortality reported on Table 1.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 15 and 16
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 17, first paragraph
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pages 19 and 20.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 19.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 19.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	First page.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and

Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

STROBE Checklist

	Item No	Recommendation	Page
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Study design	4	Present key elements of study design early in the paper	7, first paragraph
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Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, first paragraph
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5, third paragrapg
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 7
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9, specific subtopic on this

		(*c*) Explain how missing data were addressed	Page 8, specific topic
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Page 7.
		(*e*) Describe any sensitivity analyses	Only subgroup analyses were performed.
Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12, first patagraph
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	All patients in dataset were eligible
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Figures 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Described in methods. Only performance status missing
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Mortality reported on Table 1.
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
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		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 15 and 16
Discussion			

Key results	18	Summarise key results with reference to study objectives	Page 17, first paragraph
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Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	First page.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.