Intensive Care Med (2015) 41:2149–2160
DOI 10.1007/s00134-015-4076-7

ORIGINAL

**Marcio Soares**
**Fernando A. Bozza**
**Derek C. Angus**
**André M. Japiassú**
**William N. Viana**
**Roberto Costa**
**Leonardo Brauer**
**Bruno F. Mazza**
**Thiago D. Corrêa**
**André L. B. Nunes**
**Thiago Lisboa**
**Fernando Colombari**
**Alexandre T. Maciel**
**Luciano C. P. Azevedo**
**Moyzés Damasceno**
**Haggeas S. Fernandes**
**Alexandre B. Cavalcanti**
**Pedro E. A. A. do Brasil**
**Jeremy M. Kahn**
**Jorge I. F. Salluh**

# Organizational characteristics, outcomes, and resource use in 78 Brazilian intensive care units: the ORCHESTRA study

Received: 20 July 2015
Accepted: 15 September 2015
Published online: 28 September 2015


For the ORCHESTRA (ORganizational CHaractEriSTics in cRitical cAre) Study Investigators. A complete list of collaborators can be found in the electronic supplementary material (file 2).

**Take-home message:** In a large contemporary sample of Brazilian ICUs, specific structure and process factors, namely implementing clinical protocols, were associated with patient outcomes and efficient resource use. In emerging countries, organizational factors are potential targets to improve patient outcomes and resource use in ICUs.

**Electronic supplementary material**
The online version of this article (doi:10.1007/s00134-015-4076-7) contains supplementary material, which is available to authorized users.

M. Soares (✉) · F. A. Bozza ·
P. E. A. A. do Brasil · J. I. F. Salluh
Department of Critical Care, D'Or Institute for Research and Education, Rua Diniz Cordeiro, 30. Botafogo, Rio De Janeiro 22281-100, Brazil
e-mail: marciosoaresms@gmail.com
Tel.: +55 21 3883-6000

F. A. Bozza · A. M. Japiassú
Instituto Nacional de Infectologia Evandro Chagas, Instituto Oswaldo Cruz-Fiocruz, Rio De Janeiro, Brazil

D. C. Angus · J. M. Kahn
Department of Critical Care Medicine, University of Pittsburgh School of Medicine, Pittsburgh, USA

A. M. Japiassú
Department of Critical Care, Rede Amil de Hospitais, Rio De Janeiro, Brazil

W. N. Viana
ICU, Hospital Copa D'Or, Rio De Janeiro, Brazil

R. Costa
ICU, Hospital Quinta D'Or, Rio De Janeiro, Brazil

L. Brauer
ICU, Hospital São Luiz-Unidade Itaim, São Paulo, Brazil

L. Brauer · A. L. B. Nunes · A. T. Maciel
Department of Critical Care, Imed Group, São Paulo, Brazil

B. F. Mazza
ICU, Hospital São Luiz-Unidade Morumbi, São Paulo, Brazil

T. D. Corrêa
ICU, Hospital Israelita Albert Einstein, São Paulo, Brazil

A. L. B. Nunes
ICU, Hospital São Luiz-Unidade Anália Franco, São Paulo, Brazil

T. Lisboa
Complexo Hospitalar, Santa Casa de Misericórdia de Porto Alegre, Porto Alegre, Brazil

F. Colombari
ICU, Hospital Alemão Oswaldo Cruz, São Paulo, Brazil

A. T. Maciel
ICU, Hospital São Camilo Pompéia, São Paulo, Brazil

L. C. P. Azevedo
ICU, Hospital Sírio-Libanês, São Paulo, Brazil

M. Damasceno
ICU, Complexo Hospitalar de Niterói, Niterói, Brazil

H. S. Fernandes
ICU, Hospital São Luiz-Unidade Brasil, Santo André, Brazil

A. B. Cavalcanti
Research Institute-Hospital do Coração (IEP- HCor), São Paulo, Brazil

J. M. Kahn
Department of Health Policy and Management, University of Pittsburgh Graduate School of Public Health, Pittsburgh, USA

**Abstract** *Purpose:* Detailed information on organization and process of care in intensive care units (ICU) in emerging countries is scarce. Here, we investigated the impact of organizational factors on the outcomes and resource use in a large sample of Brazilian ICUs. *Methods:* Retrospective cohort study of 59,693 patients (medical admissions, 67 %) admitted to 78 ICUs during 2013. We retrieved patients' data from an ICU quality registry and surveyed ICUs regarding structure, organization, staffing patterns, and process of care. We used multilevel logistic regression analysis to identify factors associated with hospital mortality. Efficient resource use was assessed by estimating standardized resource use and mortality rates adjusted for the SAPS 3 score. *Results:* ICUs were mostly medical-surgical (79 %) and located at private hospitals (86 %). Median nurse to bed ratio was 0.20 (IQR, 0.15–0.28) and board-certified intensivists were present 24/7 in 16 (21 %) of ICUs. Multidisciplinary rounds occurred in 67 (86 %) and daily checklists were used in 36 (46 %) ICUs. Most frequent protocols focused on sepsis management and prevention of healthcare-associated infections. Hospital mortality was 14.4 %. In multivariable analysis, the number of protocols was the only organizational characteristic associated with mortality [odds ratio = 0.944 (95 % CI 0.904–0.987)]. The effects of protocols were consistent across subgroups including surgical and medical patients as well as the SAPS 3 tertiles. We also observed a significant trend toward efficient resource use as the number of protocols increased. *Conclusions:* In emerging countries such as Brazil, organizational factors, including the implementation of protocols, are potential targets to improve patient outcomes and resource use in ICUs.

**Keywords** Organizational factors · Outcomes · Standardized resource use · Intensive care unit · Protocols

## Introduction

The way in which the intensive care unit (ICU) is organized and managed potentially affects quality and efficiency in critical care [1–12]. Yet despite an extensive literature addressing ICU organization and management, our understanding of the impact of these factors on outcomes remains limited, in part as a result of heterogeneity across organizational factors and the complex interplay among them. Additionally, acute care delivery may vary significantly within and among countries, with differing patient populations and local care practices affecting the ICU structure, process, and outcome relationship [4, 6, 13–15].

Delivering affordable and high-quality critical care is particularly challenging for emerging countries. These countries account for more than 50 % of the world's population and face massive demographic and socioeconomic transformation in the coming decades, with increased urbanization, economic development, and population growth [16]. In parallel, the demand for critical care is likely to increase, with severe implications in terms of resource allocation and costs. Yet even at present, patients' outcomes remain comparatively worse as compared to those in developed nations [4, 17, 18]. Optimizing ICU organization is a potential target to improve patient care and reduce mortality in these countries. However, comprehensive information on ICU organization and its relation to outcomes is mostly restricted to developed countries [1, 3, 4, 7–12] and may not fully translate to developing countries.

To address these knowledge gaps, we sought to describe the organizational characteristics of a large sample of Brazilian ICUs and to investigate their impact on the hospital mortality and resource use.

## Patients and methods

### Design and setting

We performed a multicenter retrospective cohort study of critical care organization and outcomes in 78 ICUs at 51 hospitals in 11 Brazilian states. The complete list of investigators and centers appears in the Electronic Supplementary Material (ESM). The study was coordinated by the Department of Critical Care at the D'Or Institute for Research and Education (IDOR), Rio de Janeiro, Brazil, and was endorsed by the Brazilian Research in Intensive Care Network (BRICNet), an independent research network for performing investigator-initiated multicenter studies in critical care in Brazil. The Local Ethics Committee at the IDOR (Parecer: 334.835) and the Brazilian National Ethics Committee (CAAE: 19687113.8.1001.5249) approved the study and the need for informed consent was waived. The full description of patients and methods is given in the ESM.

## Selection of centers, data collection, and definitions

### *Participating centers*

We restricted the study to ICUs registered in the BRICNet database and known to use the Epimed Monitor System® (Epimed Solutions®, Rio de Janeiro, Brazil), a commercial cloud-based registry for quality improvement, performance evaluation, and benchmarking purposes. A total of 117 ICUs met these criteria and were invited to participate in the study. Of these, 88 ICUs agreed to participate. We excluded ICUs that initiated Epimed after July 2012 ($n = 2$) and ICUs in which more than 10 % of patients were missing core data ($n = 8$), leaving 78 ICUs from 51 hospitals in the final cohort (Fig. 1).

Within each participating ICU, the ICU director and/or chief nurse completed a survey about hospital and ICU organizational, structural, and process characteristics (see ESM). Domains for the survey were based on prior studies demonstrating potential structure–outcome links in critical care [3, 5–7, 9–11], and included the following: hospital and ICU type and bed capacity, presence of residence/fellowship in critical care or training programs certified by the Brazilian Association of Intensive Care (Associação Brasileira de Medicina Intensiva, AMIB), ICU staffing patterns (excluding residents and trainees), presence of regular multidisciplinary clinical rounds and daily checklists, clinical pathways and protocols, regular debriefing and administrative multidisciplinary meetings, and family visiting policies. Detailed definitions of the organizational characteristics are given in the ESM.

In order to guarantee data accuracy, validity, and completeness, we piloted the survey among three participating centers and provided respondents with explicit definitions of the survey domains. We ensured the reliability of all data by interviewing medical and/or nurse ICU directors from every participating center on site or by phone.

## Patients

We included all consecutive patients aged at least 16 years old admitted to the participating ICUs during 2013. Readmissions and patients with missing core data [age, location before ICU admission, main ICU admission diagnosis, the simplified acute physiology score (SAPS 3), ICU and hospital length of stay (LOS), and vital status at hospital discharge] were excluded (Fig. 1). We obtained de-identified patient data from the Epimed Monitor System®. Briefly, data were prospectively entered in a structured electronic case report form, most typically by a trained case manager. Key data elements included demographics, comorbidities based on the Charlson comorbidity index [19], functional status before hospital admission, location before ICU admission, SAPS 3 score and the sequential organ failure (SOFA) score, ICU admission diagnosis, use of ICU support, ICU and hospital LOS, and destination at hospital discharge.

## Outcomes

The primary outcome of interest was in-hospital mortality at the patient level. The secondary outcome was efficient resource use [6]. We evaluated outcomes and resource use for each ICU by estimating the standardized mortality rates (SMR) and standardized resource use (SRU) according to the SAPS 3, as proposed by Rothen et al. [6]. The SRU estimates the average observed to expected ratio of resources (based on ICU LOS) used per surviving patient in a specific ICU adjusted for the severity of illness. On the basis of median SMR and median SRU, we assigned each ICU to one of four groups: "most efficient" (all units whose SMR and SRU were below the median SMR and SRU); "least efficient" (units with both SMR and SRU above the median); "overachieving" (low SMR and high SRU) and "underachieving" (high SMR and low SRU) (eFig. 1a–ll).

## Data processing and statistical analysis

We screened data for missing information, implausible and outlying values, logical errors, and insufficient details. In cases of inconsistent or implausible data, we contacted local investigators to provide the requested information. There was no missing information regarding hospital and ICU characteristics. Because missingness for patients' characteristics was minimal, we performed single imputation using the reference or "normal" category [20].

We investigated the association between organizational factors and hospital mortality adjusting for patients' characteristics using multilevel multivariable logistic regression. A two-level model was fit with patient-level fixed effects at the first level and ICU-level fixed effects at the second level, as well as an ICU-specific random effect. Patient level variables of interest included age, gender, hospital LOS before ICU admission, diagnostic category, previous functional capacity, the Charlson

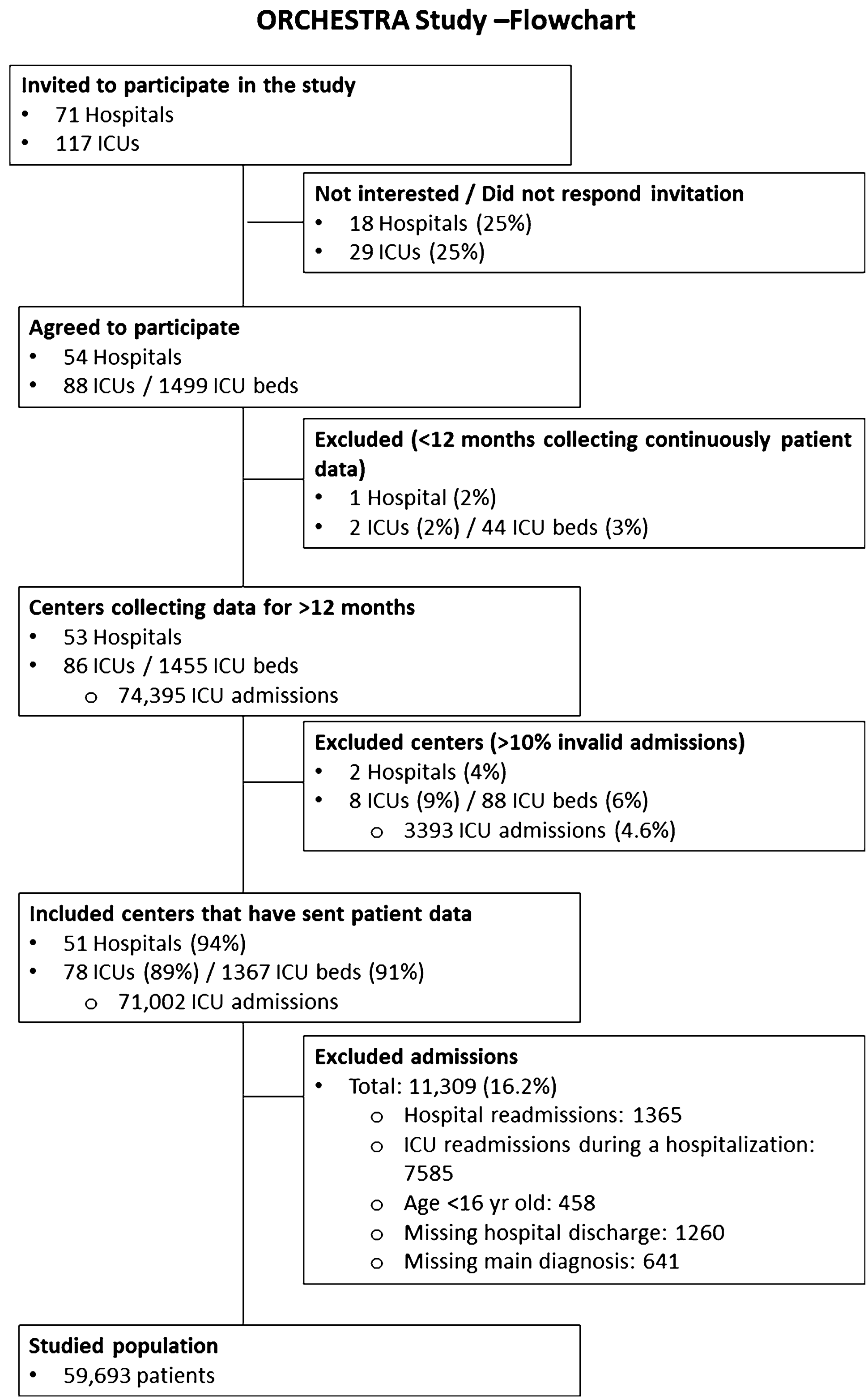


**Fig. 1** Study flowchart. *ICU* intensive care unit

comorbidity index, the use of mechanical ventilation (MV) on day 1, SOFA and SAPS 3 scores. ICU level variables of interest included ICU type [medical-surgical vs. specialty (i.e. ICUs dedicated to only specific groups of patients)], presence of training programs in critical care, ICU admission volume (number) during 2013, staffing patterns, organizational and process characteristics. We selected variables for the multivariable model using forward and backward stepwise regression. We considered variables for the model if they were associated with outcome with a $P$ value of less than 0.20 on univariate analysis, and removed variables from the model if they had a $P$ value of greater than 0.10 on multivariate analysis. We performed subgroup analyses stratifying patients according to the type of admission (medical vs. surgical) and the SAPS 3 tertiles. We used the Akaike information criterion, a measure of the relative predictive ability of a statistical model for a given set of data, to choose among the alternative models. Two-tailed $P$ values less than 0.05 were considered statistically significant. We conducted all statistical analyses in R (http://www.r-project.org) and SPSS 21 (IBM Corp., Armonk, NY).

## Results

### Characteristics of participating centers and studied population

The final sample included 78 ICUs at 51 hospitals (Fig. 1). The number of ICUs varied largely among hospitals: 37 had only one ICU; nine had two ICUs, three had three ICUs, and two hospitals had seven ICUs. ICU and hospital characteristics are reported in Tables 1 and 2, and eTables 1 and 2 of the ESM. Participating ICUs were mostly medical/surgical ($n = 62$, 79 %) and located in private hospitals ($n = 72$, 93 %). Half ($n = 40$, 51 %) had training programs in critical care. The average physician/bed ratio was 0.15 (0.11–0.19). Board-certified physicians and nurses were present 24/7 in 16 (21 %) and 9 (12 %) ICUs. Few ICUs had fully dedicated clinical pharmacists ($n = 18$, 23 %), nutritionists ($n = 28$, 36 %), and psychologists ($n = 9$, 12 %). Multidisciplinary clinical rounds occurred on a regular basis in 67 (86 %) and daily checklists were applied in 36 (46 %) ICUs. In general, checklists were applied by varying healthcare providers and were used to both monitor and prompt the adherence to best practices. Median number of clinical protocols per ICU was 7 (25 %–75 % IQR, 5–9) (Fig. 2). Protocols were in use for the following domains: ventilator-associated pneumonia prevention ($n = 71$, 91 %), central-line associated bloodstream infection prevention ($n = 71$, 91 %), sepsis ($n = 62$, 79 %), liberation from MV ($n = 58$, 74 %), lung-protective ventilation in acute lung injury ($n = 51$, 65 %), acute coronary syndromes ($n = 51$, 65 %), sedation in MV patients ($n = 50$, 64 %), early mobilization ($n = 44$, 56 %), cerebrovascular accident management ($n = 36$, 42 %), and therapeutic hypothermia in cardiac arrest patients ($n = 34$, 44 %) (Fig. 2). There were several differences among ICUs according to the type of hospital (eTable 2). Of note, ICUs located at both private for-profit and philanthropic hospitals more often had 24/7 intensivists, clinical rounds, checklists, protocols, and managerial meetings.

A total of 71,002 admissions occurred in the participating ICUs during 2013, of which 59,693 met inclusion criteria (Fig. 1). Of included admissions, there were 39,863 (66.8 %) medical, 16,652 (27.9 %) scheduled surgical, and 3178 (5.3 %) emergency surgical. Comorbidities were present in 32,940 (55.2 %) patients, with the most frequent being systemic arterial hypertension (50.1 %), diabetes mellitus (23.1 %), and cancer (17.0 %). Overall in-hospital mortality was 14.4 % (8581/59,693). The vast majority of the 51,112 surviving patients were discharged home (92.8 %); very few were transferred to another hospital (1.5 %) or hospice care (0.7 %). The main patient characteristics are given in Table 3.

### Organizational, structural, and process factors associated with hospital mortality

In the ESM, eTables 3 and 4 depict the results of univariate analyses of patients' and centers' characteristics associated with hospital mortality. Patient-level factors associated with worse outcomes included older age, male gender, longer hospital LOS prior to ICU admission, compromised previous chronic health status, the use of MV on day 1, and higher Charlson comorbidity, SAPS 3, and SOFA scores. ICU characteristics associated with lower hospital mortality included higher nurse/bed ratios, the presence of physiotherapists and clinical pharmacists exclusively dedicated to the ICUs, higher numbers of implemented protocols, the occurrence of multidisciplinary clinical rounds, daily checklists, and regular debriefing and managerial meetings.

In the multivariable analysis, the number of fully implemented clinical protocols was the only organizational characteristic associated with hospital mortality [odds ratio (OR) for each additional protocol = 0.944 (95 % confidence interval (CI) 0.904–0.987), $P = 0.011$] (Fig. 3 and eTable 5). In a second model evaluating all patients, we observed that the availability of jointly managed clinical protocols [OR = 0.231 (95 % CI 0.083–0.645), $P = 0.005$] was also independently associated with lower mortality (Fig. 3). Similar results were observed in the subgroup analyses, with significant reductions in mortality (Fig. 3 and eTable 6). Finally, we forced into the final model the following covariates at center level: physiotherapists and pharmacists fully dedicated to the ICU, daily checklists, and regular debriefing and administrative meetings. None of them were statistically significantly associated with mortality.

**Table 1** ICU characteristics, staffing patterns, and comparisons between medical-surgical and specialty ICUs

| Characteristics | All ICUs ($n = 78$) | Medical-surgical ($n = 62$, 79 %) | Specialty ICUs[a] ($n = 16$, 21 %) | *P* value |
|---|---|---|---|---|
| ICU characterization | | | | |
| Type of hospital | | | | |
| Private, for profit | 58 (74 %) | 44 (71 %) | 14 (87.5 %) | 0.309 |
| Private, philanthropic | 14 (18 %) | 12 (19 %) | 2 (12.5 %) | |
| Public | 6 (8 %) | 6 (10 %) | 0 | |
| Training programs in critical care | | | | |
| No | 38 (49 %) | 33 (53 %) | 5 (31 %) | 0.198 |
| Yes | 40 (51 %) | 29 (47 %) | 11 (69 %) | |
| Active ICU beds (*n*) | 17 ± 11; 13 (10–22) | 19 ± 12; 16 (10–24) | 11 ± 2; 11 (9–12) | 0.004 |
| ≤10 | 26 (33 %) | 18 (29 %) | 8 (50 %) | 0.018 |
| 10–20 | 30 (39 %) | 22 (35.5 %) | 8 (50 %) | |
| >20 | 22 (28 %) | 22 (35.5 %) | 0 | |
| ICU bed occupancy rate (%) | 73 ± 14; 73 (63–84) | 73 ± 14; 73 (62–83) | 72 ± 64; 72 (64–88) | 0.738 |
| Staffing patterns: physicians and nurses (excluding trainees and residents) | | | | |
| Total number of physicians working in the ICU | 21 ± 12; 17 (13–24) | 22 ± 13; 19 (14–28) | 15 ± 3; 15 (12–17) | 0.037 |
| % of intensivists (board–certified in critical care) | 34 ± 25; 26 (14–48) | 35 ± 25; 28 (14–50) | 32 ± 29; 24 (14–35) | 0.540 |
| Board-certified intensivists present in the ICU 24/7 | 16 (21 %) | 14 (23 %) | 2 (12.5 %) | 0.501 |
| Number of graduate nurses working in the ICU | 16 ± 12; 13 (9–18) | 17 ± 16; 13 (9–22) | 11 ± 4; 11 (9–13) | 0.202 |
| Average graduate nurse/bed ratio during shifts | 0.23 ± 0.11; 0.20 (0.15–0.28) | 0.23 ± 0.11; 0.20 (0.15–0.26) | 0.25 ± 0.11; 0.20 (0.15–0.33) | 0.718 |
| Average nurse staff (graduate + auxiliary)/bed ratio during shifts | 0.73 ± 0.17; 0.71 (0.61–0.84) | 0.72 ± 0.76; 0.70 (0.61–0.84) | 0.76 ± 0.14; 0.76 (0.64–0.86) | 0.373 |
| % of critical care nurses (board-certified in critical care) | 16 ± 25; 0 (0–24) | 17 ± 26; 0 (0–27) | 13 ± 22; 0 (0–22) | 0.500 |
| Board-certified critical care nurses present in the ICU 24/7 | 9 (12 %) | 8 (13 %) | 1 (6 %) | 0.676 |
| Staffing patterns: other care providers | | | | |
| Physiotherapists exclusively dedicated to the ICU | | | | |
| No | 13 (17 %) | 8 (13 %) | 5 (31 %) | 0.160 |
| Only during day shifts | 12 (15 %) | 9 (15 %) | 3 (19 %) | |
| During day and night shifts | 53 (63 %) | 45 (73 %) | 8 (50 %) | |
| Psychologists | | | | |
| No | 15 (19 %) | 14 (23 %) | 1 (6 %) | 0.333 |
| Yes, but not dedicated to ICU | 54 (69 %) | 41 (66 %) | 13 (81 %) | |
| Yes, dedicated to the ICU | 9 (12 %) | 7 (11 %) | 2 (13 %) | |
| Nutritionists | | | | |
| No | 1 (1 %) | 1 (2 %) | 0 | 0.071 |
| Yes, but not dedicated to ICU | 49 (63 %) | 35 (56 %) | 14 (87.5 %) | |
| Yes, dedicated to the ICU | 28 (36 %) | 26 (42 %) | 2 (12.5) | |
| Clinical pharmacists | | | | |
| No | 10 (13 %) | 9 (15 %) | 1 (6 %) | 0.088 |
| Yes, but not dedicated to ICU | 50 (64 %) | 36 (58 %) | 14 (87.5 %) | |
| Yes, dedicated to the ICU | 18 (23 %) | 17 (27 %) | 1 (6 %) | |

Results for continuous variables are reported as mean ± SD and median (IQR)

*IQR* interquartile range, *ICU* intensive care unit, *SD* standard deviation

[a] Specialty ICUs included surgical ($n = 7$), neurological ($n = 2$), cardiac/coronary care ($n = 6$), and solid transplant ($n = 1$)

## Organizational, structural, and process factors associated with efficient resource use

Median estimated SMR and SRU were 0.97 (0.72–1.15) and 1.06 (0.89–1.37). There were 28 (36 %) "most efficient", 28 (36 %) "least efficient", 11 (14 %) "over-achieving", and 11 (14 %) "underachieving" ICUs. Comparing key organizational factors between "most efficient" with "lowest efficient ICUs, we found that "most efficient" ICUs were usually located in private

**Table 2** Organizational characteristics, clinical protocols and processes of care, and comparisons between medical-surgical and specialty ICUs

| Characteristics | All ICUs ($n = 78$) | Medical-surgical ($n = 62$, 79 %) | Specialty ICUs ($n = 16$, 21 %) | $P$ value |
|---|---|---|---|---|
| Clinical rounds | | | | |
| Formal clinical rounds | | | | |
| No | 1 (1 %) | 1 (2 %) | 0 | |
| Yes, but not daily | 9 (12 %) | 8 (13 %) | 1 (6 %) | 0.578 |
| Yes, daily, except for the weekends | 21 (27 %) | 18 (29 %) | 3 (19 %) | |
| Yes, daily, including the weekends | 47 (60 %) | 35 (56 %) | 12 (75 %) | |
| Care providers participating in the clinical rounds | | | | |
| Physicians | 77 (99 %) | 61 (98 %) | 16 (100 %) | |
| Nurses | 76 (97 %) | 60 (97 %) | 16 (100 %) | |
| Physiotherapists | 76 (97 %) | 60 (97 %) | 16 (100 %) | |
| Clinical pharmacists | 34 (44 %) | 31 (50 %) | 3 (19 %) | |
| Nutritionists | 51 (65 %) | 45 (73 %) | 6 (37.5 %) | |
| Psychologists | 27 (35 %) | 22 (35 %) | 5 (31 %) | |
| Regular multidisciplinary clinical rounds ($\geq$5 days/week) | | | | |
| No | 11 (14 %) | 10 (16 %) | 1 (6 %) | 0.444 |
| Yes | 67 (86 %) | 52 (84 %) | 15 (94 %) | |
| Checklists | | | | |
| Checklists to assist patients' care and management | | | | |
| No | 8 (10 %) | 6 (10 %) | 2 (12.5 %) | 0.720 |
| Yes, but not daily | 16 (21 %) | 12 (19 %) | 4 (25 %) | |
| Yes, daily, except for the weekends | 18 (23 %) | 16 (26 %) | 2 (12.5 %) | |
| Yes, daily, including the weekends | 36 (46 %) | 28 (45 %) | 8 (50 %) | |
| Roles of checklists | | | | |
| There are no checklists | 8 (10 %) | 6 (10 %) | 2 (12.5 %) | 0.876 |
| Only monitoring the adherence to best practices | 7 (9 %) | 6 (10 %) | 1 (6 %) | |
| Monitoring and prompting the adherence to best practices | 63 (81 %) | 50 (81 %) | 13 (81 %) | |
| Care providers regularly applying checklists | | | | |
| Physicians | 61 (78 %) | 49 (79 %) | 12 (75 %) | |
| Nurses | 66 (85 %) | 53 (85 %) | 13 (81 %) | |
| Physiotherapists | 47 (60 %) | 40 (65 %) | 7 (44 %) | |
| Clinical pharmacists | 10 (13 %) | 9 (15 %) | 1 (6 %) | |
| Nutritionists | 20 (26 %) | 17 (27 %) | 3 (19 %) | |
| Psychologists | 1 (1 %) | 1 (2 %) | 0 | |
| Other regular activities in the ICU (at least monthly) | | | | |
| Debriefing meetings | | | | |
| None | 29 (37 %) | 23 (37 %) | 6 (37.5 %) | 0.573 |
| Only physicians and nurses participate | 4 (5 %) | 4 (7 %) | 0 | |
| Physicians, nurses, and other care providers participate | 45 (58 %) | 35 (57 %) | 10 (62.5 %) | |
| Administrative and managerial meetings | | | | |
| None | 28 (36 %) | 20 (32 %) | 8 (50 %) | 0.028 |
| Only physicians and nurses participate | 9 (12 %) | 5 (8 %) | 4 (25 %) | |
| Physicians, nurses, and other care providers participate | 41 (53 %) | 37 (60 %) | 4 (25 %) | |
| Teaching and training activities | | | | |
| None | 19 (24 %) | 16 (26 %) | 3 (19 %) | 0.666 |
| Only physicians and nurses participate | 10 (13 %) | 7 (11 %) | 3 (19 %) | |
| Physicians, nurses, and other care providers participate | 49 (63 %) | 39 (63 %) | 10 (62.5 %) | |
| Clinical pathways and protocols | | | | |
| Clinical protocols/pathways fully implemented for >6 months ($n$) | 7 ± 3; 7 (5–9) | 7 ± 3; 7 (5–9) | 8 ± 3; 8 (6–10) | 0.384 |
| No | 3 (4 %) | 2 (3 %) | 1 (6 %) | 0.503 |
| Yes | 75 (96 %) | 60 (97 %) | 15 (94 %) | |
| Protocols jointly managed by different care providers[a] | | | | |
| No | 58 (74 %) | 47 (76 %) | 11 (69 %) | 0.540 |
| Yes | 20 (26 %) | 15 (24 %) | 5 (31 %) | |

Specialty ICUs included surgical ($n = 7$), neurological ($n = 2$), cardiac/coronary care ($n = 6$), and solid transplant ($n = 1$)

Results for continuous variables are reported as mean ± SD and median (IQR)

*IQR* interquartile range, *ICU* intensive care unit, *A&M* administrative and managerial, *SD* standard deviation, *IQR* interquartile range

[a] Clinical protocols and pathways jointly managed by at least two different care providers

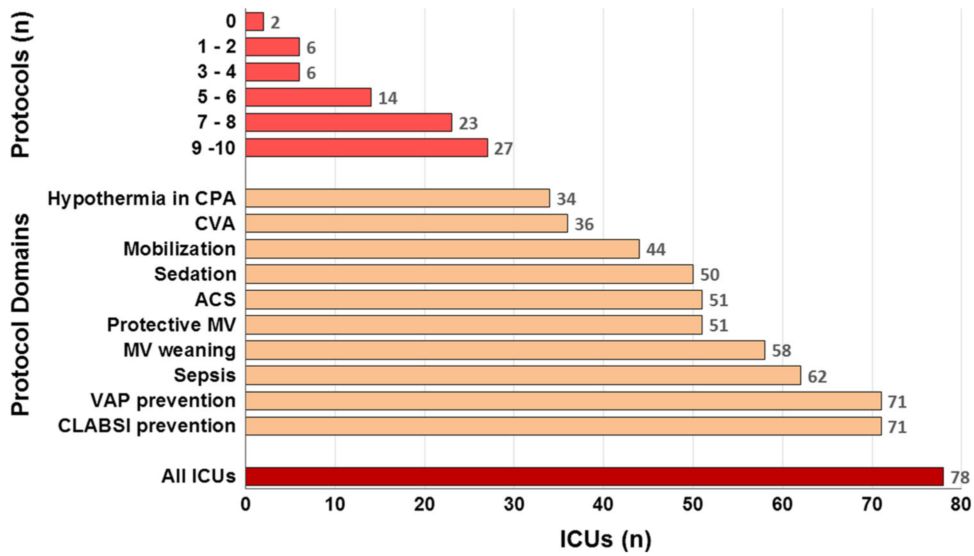


**Fig. 2** Implementation of clinical protocols in the participating ICUs ($n = 78$). *CPA* cardiopulmonary arrest, *CVA* cerebrovascular accident, *ACS* acute coronary syndromes, *MV* mechanical ventilation, *CLABSI* central-line associated bloodstream infection, *VAP* ventilator-associated pneumonia

hospitals, with step-down units and training programs in critical care (eTable 7). We also observed a significant trend toward efficient resource use as the number of implemented clinical protocols increased (eTable 7 and eFig. 1k). The presence of daily checklists also tended to be associated with efficient resource use [OR = 2.89 (0.95–8.72), $P = 0.057$]. In addition, we observed a trend toward highest efficiency as the graduate nurse/bed ratio increased [OR = 2.88 (0.76–10.99), for ratios between 0.17 and 0.25; and OR = 4.40 (1.04–18.60), for a ratios >0.25, $P = 0.116$] and when board-certified nurses were available 24/7 in the ICU [OR = 5.87 (0.64–53.93), $P = 0.084$] (eTable 7). SMR and SRU for the different participating ICUs according to different organizational, structure, and process characteristics are given in eFig. 1a–ll.

## Discussion

In this study, we report detailed information on structure, organization, and process of care for a large sample of Brazilian ICUs. We found that ICU organization as well as standardized resource use and mortality rates varied substantially among the participating ICUs. Adoption of clinical protocols was associated with both improved patient survival and more efficient resource use. Other structural variables thought to be associated with mortality and resource use in some settings, such as 24/7 coverage by intensivists and regular multidisciplinary rounds, were not associated with mortality and resource use in this sample.

Although many studies evaluating ICU organization and process of care are available in the literature, the understanding of their effect on outcomes and resource use is limited by the complex interplay among them. Moreover, data from emerging countries remain scarce [18, 21–24]. The present study adds to this literature by examining the relationship between ICU organization, patient outcomes, and resource use in a large sample of Brazilian ICUs. Recent studies demonstrate that there is significant variation in the capacity and outcomes in critical care around the globe [13, 14]. An increasing challenge in emerging countries is to provide access and high-quality and affordable care for the large urban populations [14, 25].

A higher number of protocols was associated with improved patient outcomes and more efficient resource use—a finding that was significant for both medical and surgical patients and across all severity of illness strata. This finding supports that the implementation of clinical protocols may be a potentially valuable strategy to achieve high-quality ICU outcomes, at least in some ICUs [12, 26]. Previous experiences on implementation of sepsis management strategies and sedation protocols carried out in Asian countries and Brazil were cost-effective and associated with better outcomes and less use of resources (as evaluated by ICU LOS and MV duration) [18, 21, 27]. In addition, our results suggest that collaborative multidisciplinary work among ICU care providers impacts favorably on the patients' outcomes, since hospital mortality was lower in ICUs where protocols were jointly managed by different care providers. Conversely, in a recent study performed in the USA, protocols were not associated with outcomes [26]. A better understanding of which organizational and structural factors influence the successful implementation of protocols in ICUs requires further investigation.

In contrast to prior work, we did not observe a significant impact of physician or nurse staffing patterns on patients' outcomes. In the early 2000s, a meta-analysis reported that high-intensity intensivist staffing (mandatory intensivist consultation or closed ICU) was associated with both reduced ICU and hospital mortality rates and LOS [11]. However, more recently, four

**Table 3** Main patient characteristics and outcomes, and comparisons between medical-surgical and specialty ICUs

| Characteristics | All ICUs ($n = 78$) | Medical-surgical ($n = 62$, 79 %) | Specialty ICUs ($n = 16$, 21 %) | $P$ value |
|---|---|---|---|---|
| Patients ($n$) | 59,693 | 49,642 (83.2 %) | 10,051 (16.8 %) | |
| Age (years) | 62 ± 19; 65 (49–78) | 62 ± 20; 65 (49–78) | 63 ± 18; 64 (51–77) | 0.169 |
| <45 | 11,886 (19.9 %) | 10,149 (20.4 %) | 1737 (17.3 %) | <0.001 |
| 45–64 | 17,877 (29.9 %) | 14,476 (29.2 %) | 3401 (33.8 %) | |
| 65–74 | 12,115 (20.3 %) | 9980 (20.1 %) | 2135 (21.2 %) | |
| 75–84 | 10,477 (17.6 %) | 8751 (17.6 %) | 1726 (17.2 %) | |
| ≥85 | 7338 (12.3 %) | 6286 (12.7 %) | 1052 (10.5 %) | |
| Gender | | | | |
| Female | 29,921 (50.1 %) | 24,936 (50.2 %) | 4985 (49.6 %) | 0.250 |
| Male | 29,772 (49.9 %) | 24,706 (49.8 %) | 5066 (50.4 %) | |
| Health insurance coverage | | | | |
| Public health insurance | 6314 (10.6 %) | 5377 (10.8 %) | 937 (9.3 %) | <0.001 |
| Private health insurance | 45,928 (76.9 %) | 37,050 (74.6 %) | 8878 (88.3 %) | |
| Admission costs paid with patient's own resources | 7451 (12.5 %) | 7215 (14.5 %) | 236 (2.3 %) | |
| Comorbidities | | | | |
| Diabetes mellitus | 13,810 (23.1 %) | 11,482 (23.1 %) | 2328 (23.2 %) | 0.944 |
| Cancer | 10,167 (17.0 %) | 8627 (17.4 %) | 1540 (15.4 %) | <0.001 |
| Chronic renal failure | 5152 (8.6 %) | 4181 (8.4 %) | 971 (9.7 %) | <0.001 |
| Coronary artery disease | 5012 (8.4 %) | 3893 (7.8 %) | 1119 (11.1 %) | <0.001 |
| Cardiac failure | 3103 (5.2 %) | 2656 (5.4 %) | 447 (4.4 %) | <0.001 |
| Chronic pulmonary disease | 2815 (4.7 %) | 2399 (4.9 %) | 416 (4.1 %) | 0.002 |
| Charlson comorbidity index (points) | 1.43 ± 1.88; 1 (0–2) | 1.44 ± 1.89; 1 (0–2) | 1.40 ± 1.87; 1 (0–2) | 0.041 |
| Functional status before hospital admission | | | | |
| Ambulant | 46,498 (77.9 %) | 38,464 (77.5 %) | 8034 (79.9 %) | <0.001 |
| Minor assistance | 9511 (15.9 %) | 8081 (16.3 %) | 1430 (14.2 %) | |
| Major assistance or bedridden | 3684 (6.2 %) | 3097 (6.2 %) | 587 (5.8 %) | |
| Source of ICU admission | | | | |
| Emergency department | 31,349 (52.5 %) | 26,816 (54.0 %) | 4533 (45.1 %) | <0.001 |
| Operating room | 17,319 (29.0 %) | 13,878 (28.0 %) | 3441 (34.2 %) | |
| Ward/floor | 4472 (7.5 %) | 4040 (8.1 %) | 432 (4.3 %) | |
| Transfer from other hospitals | 2402 (4.0 %) | 2126 (4.3 %) | 276 (2.7 %) | |
| Other | 4151 (7.0 %) | 2782 (5.6 %) | 1369 (13.6 %) | |
| Hospital days prior to ICU admission ($n$) | 2.7 ± 42.9; 0 (0–1) | 2.8 ± 46.9; 0 (0–1) | 2.2 ± 17.2; 0 (0–1) | 0.206 |
| Admission diagnostic category | | | | |
| Scheduled surgery | 16,652 (27.9 %) | 12,721 (25.6 %) | 3931 (39.1 %) | |
| Emergency surgery | 3178 (5.3 %) | 2771 (5.6 %) | 407 (4.0 %) | |
| Cardiovascular[a] | 11,434 (19.2 %) | 8591 (17.3 %) | 2843 (28.3 %) | |
| Sepsis[a] | 11,121 (18.6 %) | 10,167 (20.5 %) | 954 (9.5 %) | |
| Neurological[a] | 5707 (9.6 %) | 4979 (10.0 %) | 728 (7.2 %) | |
| Respiratory[a] | 2658 (4.5 %) | 2397 (4.8 %) | 261 (2.6 %) | |
| Gastrointestinal[a] | 2320 (3.9 %) | 2106 (4.2 %) | 214 (2.1 %) | |
| Other medical admissions[a] | 6623 (11.1 %) | 5910 (11.9 %) | 713 (7.1 %) | |
| SAPS 3 (points) | 43 ± 15; 41 (33–52) | 44 ± 15; 42 (33–52) | 40 ± 14; 38 (29–48) | <0.001 |
| SOFA score on day 1 (points) | 2.4 ± 31; 1 (0–4) | 2.5 ± 3.1; 1 (0–4) | 1.9 ± 2.7; 1 (0–3) | <0.001 |
| Support on day 1 | | | | |
| Mechanical ventilation | 9064 (15.2 %) | 7917 (15.9 %) | 1147 (11.4 %) | <0.001 |
| Noninvasive ventilation | 5678 (9.5 %) | 4762 (9.6 %) | 916 (9.1 %) | 0.140 |
| Vasopressors | 7650 (12.8 %) | 6572 (13.1 %) | 1123 (11.2 %) | <0.001 |
| Renal replacement therapy | 1672 (2.8 %) | 1334 (2.7 %) | 338 (3.4 %) | <0.001 |
| ICU LOS (days) | 5 ± 9; 2 (1–5) | 5 ± 10; 2 (1–5) | 4 ± 6; 2 (1–4) | <0.001 |
| Hospital LOS (days) | 16 ± 29; 8 (4–16) | 16 ± 30; 8 (4–17) | 14 ± 27; 6 (3–15) | <0.001 |
| ICU mortality | 5723 (9.6 %) | 5187 (10.4 %) | 536 (5.3 %) | <0.001 |
| Hospital mortality | 8581 (14.4 %) | 7639 (15.4 %) | 942 (9.4 %) | <0.001 |
| Destination at hospital discharge | | | | |
| Home | 47,450 (79.5 %) | 38,482 (77.5 %) | 8968 (89.2 %) | <0.001 |
| Other hospital | 763 (1.3 %) | 703 (1.4 %) | 60 (0.6 %) | |
| Hospice/home-care | 375 (0.6 %) | 351 (0.7 %) | 24 (0.2 %) | |
| Other/Unknown | 2524 (4.2 %) | 2467 (5.0 %) | 57 (0.6 %) | |
| Died | 8581 (14.4 %) | 7639 (15.4 %) | 942 (9.4 %) | |

Specialty ICUs included surgical ($n = 7$), neurological ($n = 2$), cardiac/coronary care ($n = 6$), and solid transplant ($n = 1$)

Results for continuous variables are reported as mean ± SD and median (IQR)

*IQR* interquartile range, *ICU* intensive care unit, *SAPS* simplified acute physiology score, *SOFA* sequential organ failure score, *LOS* length of stay, *SD* standard deviation

[a] These admission categories refer to medical diagnosis only

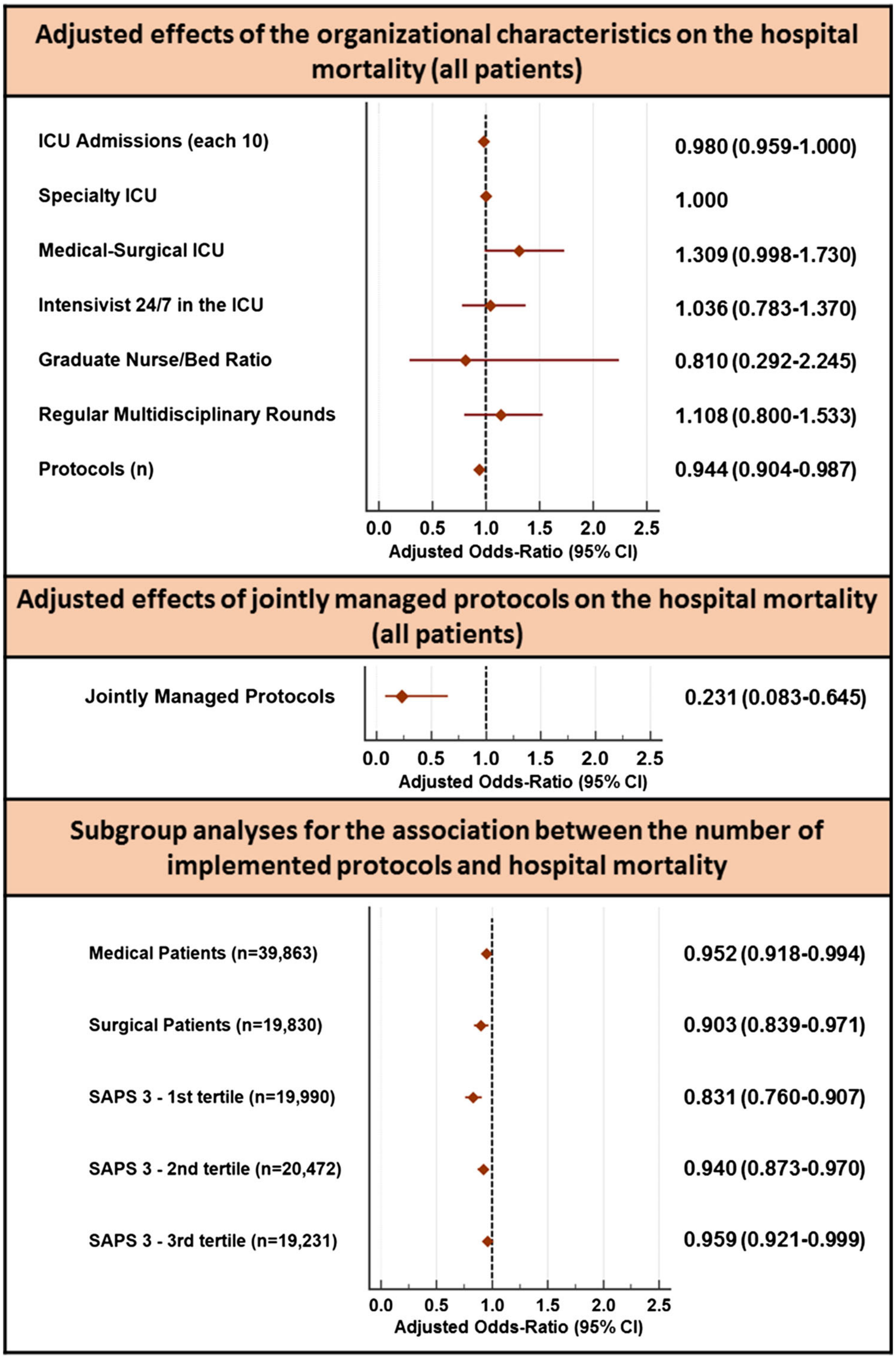


**Fig. 3** Association of organizational characteristics and hospital mortality: results from the multilevel multivariable analyses. *Upper panel* final model studying all patients, including the number of protocols. *Middle panel* model studying all patients, including jointly managed protocols. *Lower panel* adjusted effects of protocols in subgroup analyses (see also eTables 5 and 6). Estimates were adjusted for SAPS 3 score, need for mechanical ventilation, previous chronic health status, admission diagnostic category, ICU type, intensivists 24/7 in the ICU, average graduate nurse/bed ratio, regular clinical rounds, and annual ICU admission volume. *ICU* intensive care unit

multicenter studies investigated the association between the presence of 24-h intensivists and patients' outcomes with different results, suggesting that this relationship seems less relevant that previously reported [2, 3, 10, 12]. On the other hand, the number of critical care nurses may play an important role in clinical outcomes of severely ill patients [2, 3, 28]. However, this was not the case for the present study. We can hypothesize that Brazilian ICUs have developed systems to make patient outcomes robust to variation in nurse staffing levels. Alternatively, our results might also be explained in part because graduate-nurse bed ratios higher than 1:1.5 were present in only two ICUs. Despite the introduction in almost all ICUs, regular multidisciplinary rounds were not associated with mortality and resource use, corroborating the findings of two recent studies carried out in the USA [3, 12].

We found that ICU admission volume was not independently associated with mortality, which contrasts early work [7] but is in agreement with contemporary studies [2, 3, 29, 30]. One of the potential explanatory mechanisms in volume–outcome associations is that organizational factors associated with outcomes are common at high-volume centers [31]. Therefore, our results are not unexpected, as we have controlled for these confounders in multivariable analyses. Additionally, some investigators hypothesized that even in scenarios with wide variation in admission volumes, the use of evidence-based practices and implementation of quality improvement strategies may be of help to allow low-volume centers to achieve good outcomes [30].

Our study has several limitations. First, we did not audit the implementation of protocols. The reported presence of a protocol does not necessarily imply that it was successfully implemented. Moreover, we cannot guarantee that protocols were similar in all units. Second, although we have evaluated a large number of Brazilian ICUs, as we used a convenience sample, our data may not be representative of the entire nation. The average number of ICU beds in Brazil is comparable to Europe (13 vs. 11.5 per 100,000 people), but wide variation within the country exists in terms of ICU beds and provision of healthcare [32, 33]. Third, we cannot rule out the possibility that the study was underpowered to test the association between some covariates at center level (e.g., nurse to bed ratios) and the dependent variable, nor that our results can be explained by unmeasured confounders. Fourth, the evaluation of SRU is beyond the original scope of SAPS 3. However, it has been used to assess variability in resource use between ICUs [6]. Fifth, as with most of the previous studies using patients' data from already existing standardized databases [7–10, 29, 30], we were able to only evaluate hospital mortality. When evaluating ICU performance, assessments based on hospital mortality can be subject to biases related to discharge practices [34]. Nonetheless, the proportion of patients discharged to other hospitals and hospice care facilities in our study was relatively low. Sixth, we studied a population with an overall relatively low severity of illness and some caution is needed in the generalization of our results. Finally, we only assessed resource use in the ICU. Although we acknowledge that organization and process of care outside the ICU can potentially affect the overall resource use, such information was not collected.

In conclusion, specific organizational and process factors, including the implementation of protocols, were associated with patient outcomes and efficient resource use. These observations can assist in policies and interventions to bridge the current quality gap in the delivery of critical care in emerging countries.

**Acknowledgments** This study was supported by the National Council for Scientific and Technological Development (CNPq) (Grant No. 304240/2014-1), Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro (FAPERJ), and by departmental funds from the D'Or Institute for Research and Education. We dedicate this work to the memory of our colleague, Dr. Marcelo Lugarinho, who recently passed away. A complete list of collaborators can be found in the electronic supplementary material (file 2).

### Compliance with ethical standards

**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.

## References

1. Weled BJ, Adzhigirey LA, Hodgman TM et al (2015) Critical care delivery: the importance of process of care and ICU structure to improved outcomes: an update from the American College of Critical Care Medicine Task Force on Models of Critical Care. Crit Care Med 43:1520–1525. doi:10.1097/CCM.0000000000000978
2. Sakr Y, Moreira CL, Rhodes A et al (2015) The impact of hospital and ICU organizational factors on outcome in critically ill patients: results from the extended prevalence of infection in intensive care study. Crit Care Med 43:519–526. doi:10.1097/CCM.0000000000000754
3. Checkley W, Martin GS, Brown SM et al (2014) Structure, process, and annual ICU mortality across 69 centers: United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study. Crit Care Med 42:344–356. doi:10.1097/CCM.0b013e3182a275d7
4. Vincent J-L, Marshall JC, Namendys-Silva SA et al (2014) Assessment of the worldwide burden of critical illness: the intensive care over nations (ICON) audit. Lancet Respir Med 2:380–386. doi:10.1016/S2213-2600(14)70061-X
5. Nguyen Y-L, Wunsch H, Angus DC (2010) Critical care: the impact of organization and management on outcomes. Curr Opin Crit Care 16:487–492. doi:10.1097/MCC.0b013e32833d9180
6. Rothen HU, Stricker K, Einfalt J et al (2007) Variability in outcome and resource use in intensive care units. Intensive Care Med 33:1329–1336. doi:10.1007/s00134-007-0690-3
7. Kahn JM, Goss CH, Heagerty PJ et al (2006) Hospital volume and the outcomes of mechanical ventilation. N Engl J Med 355:41–50. doi:10.1056/NEJMsa053993

8. Wunsch H, Harrison DA, Jones A, Rowan K (2015) The impact of the organization of high-dependency care on acute hospital mortality and patient flow for critically ill patients. Am J Respir Crit Care Med 191:186–193. doi:10.1164/rccm.201408-1525OC
9. Kim MM, Barnato AE, Angus DC et al (2010) The effect of multidisciplinary care teams on intensive care unit mortality. Arch Intern Med 170:369–376. doi: 10.1001/archinternmed.2009.521
10. Wallace DJ, Angus DC, Barnato AE et al (2012) Nighttime intensivist staffing and mortality among critically ill patients. N Engl J Med 366:2093–2101. doi: 10.1056/NEJMsa1201918
11. Pronovost PJ, Angus DC, Dorman T et al (2002) Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. JAMA 288:2151–2162
12. Costa DK, Wallace DJ, Kahn JM (2015) The association between daytime intensivist physician staffing and mortality in the context of other ICU organizational practices: a multicenter cohort study. Crit Care Med. doi: 10.1097/CCM.0000000000001259
13. Austin S, Murthy S, Wunsch H et al (2014) Access to urban acute care services in high- vs. middle-income countries: an analysis of seven cities. Intensive Care Med 40:342–352. doi: 10.1007/s00134-013-3174-7
14. Adhikari NKJ, Fowler RA, Bhagwanjee S, Rubenfeld GD (2010) Critical care and the global burden of critical illness in adults. Lancet 376:1339–1346. doi: 10.1016/S0140-6736(10)60446-1
15. Mills A (2014) Health care systems in low- and middle-income countries. N Engl J Med 370:552–557. doi: 10.1056/NEJMra1110897
16. United Nations Population Division, Department of Economic and Social Affairs. http://www.un.org/en/development/desa/population/publications/trends/wpp2012.shtml. Accessed 25 Aug 2015
17. Beale R, Reinhart K, Brunkhorst FM et al (2009) Promoting Global Research Excellence in Severe Sepsis (PROGRESS): lessons from an international sepsis registry. Infection 37:222–232. doi: 10.1007/s15010-008-8203-z
18. Phua J, Koh Y, Du B et al (2011) Management of severe sepsis in patients admitted to Asian intensive care units: prospective cohort study. BMJ 342:d3245
19. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40:373–383
20. Vesin A, Azoulay E, Ruckly S et al (2013) Reporting and handling missing values in clinical studies in intensive care units. Intensive Care Med 39:1396–1404. doi: 10.1007/s00134-013-2949-1
21. Noritomi DT, Ranzani OT, Monteiro MB et al (2014) Implementation of a multifaceted sepsis education program in an emerging country setting: clinical outcomes and cost-effectiveness in a long-term follow-up study. Intensive Care Med 40:182–191. doi: 10.1007/s00134-013-3131-5
22. Du B, An Y, Kang Y et al (2013) Characteristics of critically ill patients in ICUs in mainland China. Crit Care Med 41:84–92. doi: 10.1097/CCM.0b013e31826a4082
23. Chittawatanarat K, Sataworn D, Thongchai C, Thai Society of Critical Care Medicine Study Group (2014) Effects of ICU characters, human resources and workload to outcome indicators in Thai ICUs: the results of ICU-RESOURCE I study. J Med Assoc Thai 97(Suppl 1):S22–S30
24. Vukoja M, Riviello E, Gavrilovic S et al (2014) A survey on critical care resources and practices in low- and middle-income countries. Glob Heart 9:337–342. doi: 10.1016/j.gheart.2014.08.002
25. Bozza FA, Salluh JI (2010) An urban perspective on sepsis in developing countries. Lancet Infect Dis 10:290–291. doi: 10.1016/S1473-3099(10)70074-8
26. Sevransky JE, Checkley W, Herrera P et al (2015) Protocols and hospital mortality in critically ill patients: the United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study. Crit Care Med. doi: 10.1097/CCM.0000000000001157
27. Ranzani OT, Simpson ES, Augusto TB et al (2014) Evaluation of a minimal sedation protocol using ICU sedative consumption as a monitoring tool: a quality improvement multicenter project. Crit Care 18:580. doi: 10.1186/s13054-014-0580-3
28. Neuraz A, Guérin C, Payet C et al (2015) Patient mortality is associated with staff resources and workload in the ICU: a multicenter observational study. Crit Care Med 43:1587–1594. doi: 10.1097/CCM.0000000000001015
29. Nguyen Y-L, Milbrandt EB, Weissfeld LA et al (2011) Intensive care unit renal support therapy volume is not associated with patient outcome. Crit Care Med 39:2470–2477. doi: 10.1097/CCM.0b013e3182257631
30. Cooke CR, Kennedy EH, Wiitala WL et al (2012) Despite variation in volume, veterans affairs hospitals show consistent outcomes among patients with non-postoperative mechanical ventilation. Crit Care Med 40:2569–2575. doi: 10.1097/CCM.0b013e3182591eee
31. Kahn JM (2013) What's new in ICU volume-outcome relationships? Intensive Care Med 39:1635–1637. doi: 10.1007/s00134-013-2992-y
32. Rhodes A, Moreno RP (2012) Intensive care provision: a global problem. Rev Bras Ter Intensiv 24:322–325
33. Rhodes A, Ferdinande P, Flaatten H et al (2012) The variability of critical care bed numbers in Europe. Intensive Care Med 38:1647–1653. doi: 10.1007/s00134-012-2627-8
34. Reineck LA, Pike F, Le TQ et al (2014) Hospital factors associated with discharge bias in ICU performance measurement. Crit Care Med 42:1055–1064. doi: 10.1097/CCM.0000000000000132