# Relationship between Volume and Survival in Closed Intensive Care Units Is Weak and Apparent Only in Mechanically Ventilated Patients

Rafael Fernández, M.D., Ph.D.,* Susana Altaba, M.D.,† Lluis Cabre, M.D.,‡ Victoria Lacueva, M.D.,§ Antonio Santos, M.D.,‖ Jose-Felipe Solsona, M.D.,# Jose-Manuel Añon, M.D.,** Rosa-Maria Catalan, M.D.,†† Maria-Jose Gutierrez, M.D.,‡‡ Ramon Fernandez-Cid, M.D.,§§ Vicente Gomez-Tello, M.D.,‖‖ Emilio Curiel, M.D.,## Enrique Fernandez-Mondejar, M.D.,*** Joan-Carles Oliva,††† on behalf of the Sabadell Score Group‡‡‡



## ABSTRACT

**Background:** Recent studies have found an association between increased volume and increased intensive care unit (ICU) survival; however, this association might not hold true in ICUs with permanent intensivist coverage. Our objective was to determine whether ICU volume correlates with survival in the Spanish healthcare system.

**Methods:** *Post hoc* analysis of a prospective study of all patients admitted to 29 ICUs during 3 months. At ICU discharge, the authors recorded demographic variables, severity score, and specific ICU treatments. Follow-up variables included ICU readmission and hospital mortality. Statistics include logistic multivariate analyses for hospital mortality according to quartiles of volume of patients.

**Results:** The authors studied 4,001 patients with a mean predicted risk of death of 23% (range at hospital level: 14–46%). Observed hospital mortality was 19% (range at hospital level: 11–35%), resulting in a standardized mortality ratio of 0.81 (range: 0.5–1.3). Among the 1,923 patients needing mechanical ventilation, the predicted risk of death was 32% (14–60%) and observed hospital mortality was 30% (12–61%), resulting in a standardized mortality ratio of 0.96 (0.5–1.7). The authors found no correlation between standardized mortality ratio and ICU volume in the entire population or in mechanically ventilated patients. Only

### What We Already Know about This Topic

- It is widely believed that there is an association between increased volume and increased intensive care unit survival
- The investigators evaluated risk-adjusted survival in 29 Spanish intensive care units of varying size

### What This Article Tells Us That Is New

- There was no association between unit size and standardized mortality
- Factors other than size, such as having full-time intensivists, appear to be the major determinants of mortality

* Director, Intensive Care Unit, Fundació Althaia, Manresa, CIBERES, Universitat Internacional de Catalunya, Barcelona, Spain. † Intensive Care Unit, Hospital G.U., Castello, Castello, Spain. ‡ Intensive Care Unit, Hospital de Barcelona SCIAS, Barcelona, Spain. § Intensive Care Unit, Hospital de Sagunt, Sagunt, Spain. ‖ Intensive Care Unit, C.Hosp.U. de Santiago de Compostela, Santiago de Compostela, Spain. # Intensive Care Unit, Hospital del Mar, Barcelona, Spain. ** Intensive Care Unit, Hospital Virgen de la Luz, Cuenca, Spain. †† Intensive Care Unit, C. Hosp. de Vic, Vic, Spain. ‡‡ Intensive Care Unit, Hospital San Agustin, Aviles, Spain. §§ Intensive Care Unit, Hospital Mateu Orfila, Menorca, Spain. ‖‖ Intensive Care Unit, Hospital Moncloa, Madrid, Spain. ## Intensive Care Unit, Hospital U. Carlos Haya (Hospital Civil), Malaga, Spain. *** Intensive Care Unit, Hospital Virgen de las Nieves, Granada, Spain. ††† Statistical Department, Fundació Parc Taulí, Corporació Sanitaria Universitaria Parc Taulí, Universidad Autònoma de Barcelona, Sabadell, Spain. ‡‡‡ Members of the Sabadell Score Group are listed in the appendix.

Received from the Critical Care Department, Fundació Althaia, Manresa, Spain. Submitted for publication May 14, 2012. Accepted for publication May 1, 2013. Funding was provided solely from institutional and/or departmental sources. The authors declare no competing interests.

Address correspondence to Dr. Fernández: Servicio de Medicina Intensiva, Hospital Sant Joan de Deu, Fundació Althaia, C/Dr. Joan Soler 1, 08243 Manresa, Barcelona, Spain. rfernandezf@althaia.cat. 

 Anesthesiology 2013; 119:871-9

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org).

mechanically ventilated patients in very low-volume ICUs had slightly worse outcome.

**Conclusion:** In the currently studied healthcare system characterized by 24/7 intensivist coverage, the authors found wide variability in outcome among ICUs even after adjusting for severity of illness but no relationship between ICU volume and outcome. Only mechanically ventilated patients in very low-volume centers had slightly worse outcomes.

CRITICAL illness represents an enormous clinical and economic burden on the healthcare system. There is an accepted relationship between hospital volume and survival in some conditions, related to the "practice makes perfect" concept. This concept logically applies to technically demanding cases and is especially relevant in the context of a shortage of specialists.

Increased case load is associated with improved outcomes in some areas of health care, including trauma, acute myocardial infarction, and many types of high-risk surgeries.[1–5] Recent studies have documented a relationship between volume and outcome in critical care,[6] mostly in patients with acute respiratory failure, sepsis, or high risk for death.[7–10]

Although most intensive care unit (ICU) volume–outcome studies have shown a significant relationship, at least one population-based study in patients undergoing mechanical ventilation showed no significant volume–outcome relationship.[11] Some studies found weaker volume–outcome relationships, present only in high-risk patients (Simplified Acute Physiology Score [SAPS] >41) treated at ICUs treating high volumes of high-risk patients.[8] The existence of a volume–outcome effect in selected hospitals may not reflect the true relationship in broader settings. Some studies demonstrate worse outcomes at very low-volume hospitals, but no relationship between volume and outcome in medium-, high-, or very high-volume hospitals.[12]

These issues are important not only in the United States but also in other industrialized countries, all of which struggle with increasing demand for critical care in the setting of constrained resources. Although integral to healthcare systems in developed countries, intensive care varies considerably among countries.[13] Factors related to variable outcomes include ICU bed rate, ICU models (open *vs*. closed), nurse–patient ratios, availability of coverage by trained ICU physicians 24 h a day, 7 days a week, and ICU overcrowding. The Spanish healthcare system is a mainly publicly funded hospital network characterized by closed-ICU models and 24/7 coverage by trained ICU physicians.[14] On the basis of reports demonstrating better outcomes in high-volume hospitals, most from studies at American hospitals, opinion leaders propose to regionalize Spanish ICUs. Thus, it is of the utmost interest to know the relationship between ICU volume and outcome in our publicly funded healthcare system. The objective of the current study was to examine the relationship between ICU volume and outcome in the entire group of ICU patients and in the group of ICU patients receiving mechanical ventilation. We used data from the Sabadell Score clinical database to compare mortality rates and length of stay at hospitals that care for a high volume of patients with those at hospitals that care for a low volume of patients.

## Materials and Methods

### *Study Design*

We analyzed data from a prospective, multicenter cohort of 4,001 adult patients admitted to 29 ICUs in Spain (see appendix for list of centers) during a 3-month period beginning March 1, 2008.[15] The institutional review boards at each participating center approved the study protocol and waived the need for consent.

In a specific Web-based database, we recorded the following variables for each patient admitted to the ICU:[1] on ICU admission: age, sex, diagnosis, predicted risk of death (Acute Physiology and Chronic Health Evaluation II, SAPS II, or SAPS3 depending on the clinical routine of each ICU), source of admission, and do-not-resuscitate orders;[2] during the ICU stay: tracheal intubation, mechanical ventilation, noninvasive mechanical ventilation, vasoactive drugs, parenteral nutrition, blood transfusion, dialysis, tracheostomy, acute renal failure or infection acquired in the ICU, and prognosis assessed by Sabadell Score;[3] after discharge from the ICU: ICU readmission and outcome. In patients readmitted to the ICU, only the first admission was included in the analysis.

The ward team was unaware of the study, so the care of patients in the ward should represent the standard of treatment in most of our healthcare systems.

Follow-up included ICU readmission and up-to-90-day ward outcome, even in patients who were transferred to another acute care hospital.

### *Variables and Risk Adjustment*

The exposure variable was annualized ICU volume, defined as the extrapolated number of patients per year. Moreover, we analyzed this variable separately for the group of patients who received mechanical ventilation. The primary outcome was hospital mortality. The lengths of stay in the ICU and in the hospital among survivors were secondary outcomes. For the analysis of the association between ICU volume and outcome, volume was treated as a continuous variable in which the reference category was the ICU with the lowest volume; after categorizing volume into quartiles, the reference category was the quartile with the lowest volume. Physician staffing was not included as an independent variable because all the ICUs were organized as "closed units"; in other words, all had dedicated intensivists present 24 h per day, 7 days per week, as is the norm in our healthcare system.

We addressed potential confounding due to variation in the case mix by controlling for the severity of illness and other variables related to the outcome of critical care. The severity of illness was determined by Acute Physiology and Chronic Health Evaluation II, SAPS II, or SAPS3 scores on the day of admission according to each ICU's routine approach. Other risk-adjustment variables included age, acute renal failure, ICU-acquired infection, mechanical ventilation, blood transfusion, parenteral nutrition, vasoactive drugs, and noninvasive ventilation.

### Statistical Analysis

Categorical variables were expressed as percentages and compared using chi-square tests. Normally distributed continuous variables were expressed as means and SDs and compared by one-way ANOVA; nonnormally distributed continuous variables were expressed as medians and interquartile range and compared by Kruskal–Wallis analysis. Statistical significance was set at a $P$ value of less than 0.05.

The relationship between hospital mortality and ICU volume, both in the entire population and in the group of patients who received mechanical ventilation, was assessed by simple linear regression by least squares fitting.

ICUs were grouped in quartiles according to the number of patients admitted, considering the total number of patients and mechanically ventilated patients separately. The association of the variables with hospital mortality was assessed with backward multiple logistic regression. The discrimination of the multivariate model was assessed using the area under the receiver operating characteristic curve. Accuracy was considered to be good if the area under the curve was more than 0.75 and excellent if more than 0.85. All statistical analyses were performed with STATA (version 10.0) software (StataCorp, College Station, TX). We assessed the sensitivity of our findings by repeating the primary analysis under varying assumptions about the study population in a sensitivity analysis for mortality in the hospital.

**Table 1.** Characteristics of the 29 Participating ICUs

| | |
|---|---|
| Type of ICU | |
| General | 27 (93%) |
| Medical | 2 (7%) |
| Type of hospital | |
| University hospital | 16 (55%) |
| General hospital | 13 (45%) |
| Funding | |
| Public | 26 (90%) |
| Private | 3 (10%) |
| ICU beds, median (IQR) | 14 (11–20) |
| Total ICU beds | 495 |
| Hospital beds, median (IQR) | 540 (349–840) |
| Total hospital beds | 18,597 |
| Population covered by each ICU, median (IQR), thousands | 300 (191–400) |
| Total population covered, thousands | 9,983 |
| Patients included per ICU, median (IQR) | 116 (70–182) |
| Fraction of the study population, median (IQR) | 2.8% (1.7–4.4%) |

ICU = intensive care unit; IQR = interquartile range.

## Results

Table 1 shows the characteristics of the participating hospitals. Most hospitals were funded by the public healthcare system, but the geographic location and academic status varied considerably.

Compared with ICUs with low volume, ICUs with high volume had more hospital beds and were more likely to have residency programs. The median annualized ICU volume was 464 (interquartile range: 280–728) patients per year.

Table 2 shows the patients' clinical characteristics by ICU volume quartiles. We studied 4,001 patients (mean age, 61 ± 17 yr; mean risk of death, 23% [range at hospital level, 14–46%]). Observed hospital mortality was 19% (range at hospital level, 11–35%), resulting in an observed *versus* predicted mortality ratio, or standardized mortality ratio (SMR) of 0.81 (range at hospital level, 0.5–1.3). Although no other correlations with volume were observed, age and severity of illness were higher at hospitals with very low ICU volume than at hospitals in the other quartiles. Diagnoses at admission varied widely among quartiles, but did not correlate with ICU volume. Coronary patients were less common in quartile 3, and neurological patients were less common in quartile 2. Most trauma and postsurgical patients were quartile 3, which correlated with higher use of mechanical ventilation and blood transfusion despite lower severity of illness.

The ICU length of stay, ICU readmission, and ICU mortality were very similar in all volume quartiles. Although we found a slight trend toward lower hospital mortality in higher volume ICUs, when we adjusted for predicted hospital mortality, the SMR in higher volume ICUs was very similar to that of the other groups. Figure 1 is a scatter plot showing the distribution of SMR among ICUs and differences in volume and severity of illness.

We constructed a logistic multiple regression model for variables associated with hospital mortality, including all the variables that were significant in the univariate analysis and quartiles of ICU volume. Table 3 shows the variables selected by the model (age, predicted mortality, mechanical ventilation, vasoactive drugs, acute renal failure, and ICU-acquired infection); the model discarded ICU volume. The discrimination of the model was excellent (area under the curve = 0.86).

Among patients needing mechanical ventilation (n = 1,923; 48% of the total), the predicted risk of death was 32% (range at hospital level, 14–60%) and observed hospital mortality was 30% (range at hospital level, 12–61%), resulting in an SMR of 0.96 (range at hospital level, 0.5–1.7; table 4). Figure 2 is a scatter plot showing the distribution of SMR among ICUs and differences in volume and severity of illness for mechanically ventilated patients. We found a trend toward older and sicker mechanically ventilated patients in low- and medium–low-volume ICUs.

In all ICU volume quartiles, we found very similar ICU readmission rates. However, ICU length of stay varied widely, although it did not correlate with volume. Raw ICU and hospital mortality were inversely correlated with

**Table 2.** Clinical Characteristics of Patients by ICU Volume Quartile

| Variable | Quartile 1 | Quartile 2 | Quartile 3 | Quartile 4 | *P* Value |
|---|---|---|---|---|---|
| No of patients/yr | 180–299 | 300–499 | 500–799 | 800–1,160 | |
| Age, yr | 65.2 ± 14.8 | 63.9 ± 16.4 | 60.2 ± 16.8 | 60.8 ± 16.9 | 0.001 |
| Female sex | 153 (33%) | 237 (33%) | 372 (33%) | 588 (34%) | 0.9 |
| Predicted risk of death, % | 29.8 ± 25.2 | 24.1 ± 23.9 | 21.7 ± 21.0 | 23.7 ± 22.3 | 0.001 |
| Diagnoses | | | | | 0.001 |
| Cardiovascular | 119 (26%) | 165 (23%) | 231 (21%) | 420 (25%) | |
| Coronary | 72 (16%) | 164 (23%) | 71 (6%) | 329 (19%) | |
| Neurological | 63 (14%) | 58 (8%) | 122 (11%) | 241 (14%) | |
| Postsurgical | 81 (18%) | 96 (13%) | 311 (28%) | 167 (10%) | |
| Respiratory | 81 (18%) | 139 (19%) | 162 (15%) | 249 (15%) | |
| Trauma | 9 (2%) | 21 (3%) | 110 (10%) | 94 (5%) | |
| Other | 33 (7%) | 83 (11%) | 106 (9%) | 202 (12%) | |
| Do-not-resuscitate orders | 24 (5%) | 47 (6%) | 88 (8%) | 98 (6%) | 0.1 |
| Vasoactive drugs | 196 (43%) | 282 (39%) | 512 (46%) | 777 (46%) | 0.01 |
| Mechanical ventilation | 218 (48%) | 274 (38%) | 715 (64%) | 716 (42%) | 0.001 |
| Noninvasive ventilation | 65 (14%) | 96 (13%) | 142 (13%) | 310 (18%) | 0.001 |
| Parenteral nutrition | 88 (19%) | 152 (21%) | 124 (11%) | 271 (16%) | 0.001 |
| Tracheostomy | 35 (8%) | 42 (6%) | 97 (9%) | 103 (6%) | 0.02 |
| Transfusion | 106 (23%) | 161 (22%) | 362 (32%) | 368 (22%) | 0.001 |
| Acute renal failure | 110 (24%) | 178 (24%) | 229 (21%) | 321 (19%) | 0.005 |
| ICU-acquired infection | 40 (9%) | 72 (10%) | 140 (13%) | 173 (10%) | 0.07 |
| Length of ICU stay, d | 4.5 (3–8) | 4.0 (3–7) | 4 (3–8) | 4 (3–8) | 0.4 |
| ICU mortality | 60 (13%) | 110 (15%) | 131 (12%) | 214 (13%) | 0.1 |
| ICU readmission | 19 (5%) | 34 (5%) | 58 (5%) | 76 (5%) | 0.9 |
| Length of ward stay, d | 9 (3–16) | 7 (3–13.5) | 8 (5–17) | 8 (4–15) | 0.001 |
| In-hospital mortality | 99 (21.6%) | 151 (20.8%) | 199 (17.9%) | 300 (17.6%) | 0.09 |
| Standardized mortality ratio | 0.77 (0.68–0.87) | 0.86 (0.67–1.16) | 0.82 (0.76–0.87) | 0.74 (0.63–0.89) | 0.6 |

ICU = intensive care unit.

volume; but, after we adjusted for expected mortality, this correlation disappeared, although ICU and hospital mortality in very low-volume ICUs remained higher.

We constructed a logistic multiple regression model for variables associated with hospital mortality, including all the variables that were significant in the univariate analysis and

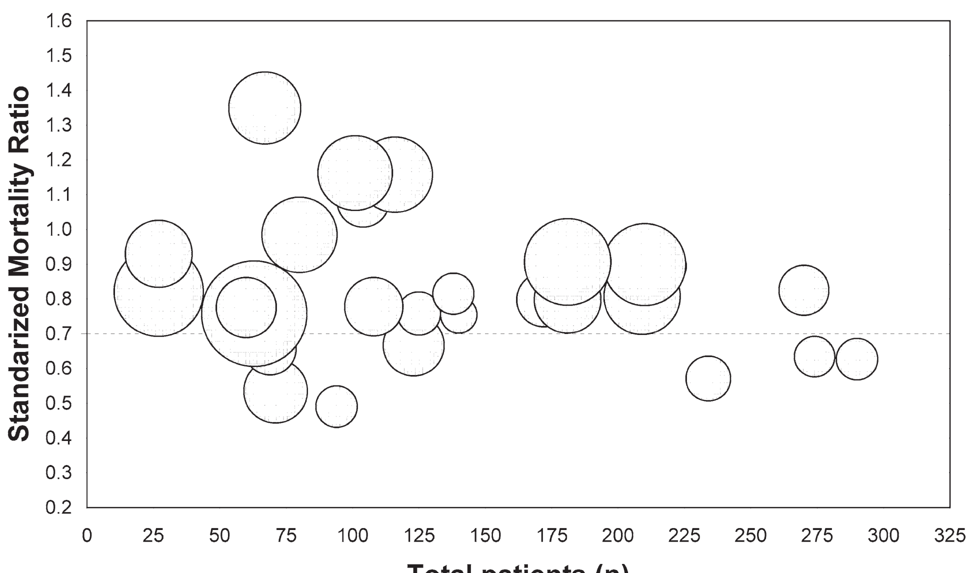


**Fig. 1.** Standardized mortality ratio by the number of patients admitted to each intensive care unit. There was no statistical correlation between standard mortality ratio and the number of patients admitted to the intensive care unit. The size of the symbols is proportional to unadjusted mortality.

**Table 3.** Multilevel Logistic Regression Analysis of Variables Associated with Hospital Mortality after Including Quartiles of ICU Volume of Patients

| | Odds Ratio (95% CI) | *P* Value |
|---|---|---|
| Age, yr | 1.014 (1.007–1.022) | <0.001 |
| Predicted risk of death | 1.036 (1.03–1.04) | <0.001 |
| Diagnosis (high risk *vs.* low risk) | 1.7 (1.3–2.1) | <0.001 |
| Do-not-resuscitate orders | 4.2 (3.0–5.8) | <0.001 |
| Vasoactive drugs | 1.98 (1.5–2.5) | <0.001 |
| Mechanical ventilation | 2.3 (1.8–3.0) | <0.001 |
| Acute renal failure | 1.8 (1.4–2.2) | <0.001 |
| ICU-acquired infection | 1.4 (1.1–1.8) | <0.05 |
| Blood transfusion | 1.1 (0.8–1.3) | 0.6 |
| Parenteral nutrition | 1.1 (0.8–1.3) | 0.8 |
| University hospital *vs.* others | 0.9 (0.7–1.2) | 0.5 |
| Public *vs.* private funding | 1.5 (0.9–2.4) | 0.1 |
| ICU volume (first quartile *vs.* others) | 1.03 (0.7–1.4) | 0.9 |

ICU = intensive care unit.

quartiles of ICU mechanical ventilation volume. Table 5 shows the variables selected by the model (age, predicted mortality, parenteral nutrition, vasoactive drugs, acute renal failure, ICU-acquired infection, and the first quartile, but not the other quartiles). The discrimination of the model was very good (area under the curve = 0.84).

To explore the sensitivity of our findings, we repeated the analysis with varying assumptions about the patient population (tables 6 and 7). Our results were not affected by exclusion of the variables related to ICU-specific treatments or by the exclusion of the ICU-acquired complications (infections and acute renal failure), which may be associated with poor performance. Our results were not affected by using a multilevel model with patients as the basic observation and hospital as the second-level of aggregation, with quartile of hospital volume as a hospital-level characteristic in a random-intercept model (fig. 1, see Supplemental Digital Content 1, http://links.lww.com/ALN/A951, which is a figure demonstrating an intraclass correlation coefficient of 3%). ICU volume was also modeled as a continuous predictor, but failed to prove to be a significant factor (table 1, see Supplemental Digital Content 2, http://links.lww.com/ALN/A952, which is a table of variables associated with mortality).

## Discussion

The current data failed to demonstrate an association between higher ICU volume and lower risk-adjusted mortality in ICU patients. We found only slightly worse outcome for patients receiving mechanical ventilation in very low-volume (<100 patients/yr) ICUs.

There are many possible causes of a relationship between ICU volume and outcome among patients receiving critical care. It has been suggested that high-volume ICUs may improve outcomes by implementing a broad range of best practices, including higher nurse-to-patient ratios, multidisciplinary care teams, lung-protective ventilation strategies, and protocols for sedation and weaning. Nevertheless, recent studies found no relationship between hospital volume and adherence to clinical guidelines.[16] Clinicians may gain experience in the care of the critically ill by treating more severe patients, but the ratio of clinicians to patients is by no means correlated with ICU volume. More experienced clinicians may be better at recognizing and treating the complications of critical illness or they may be better at translating evidence



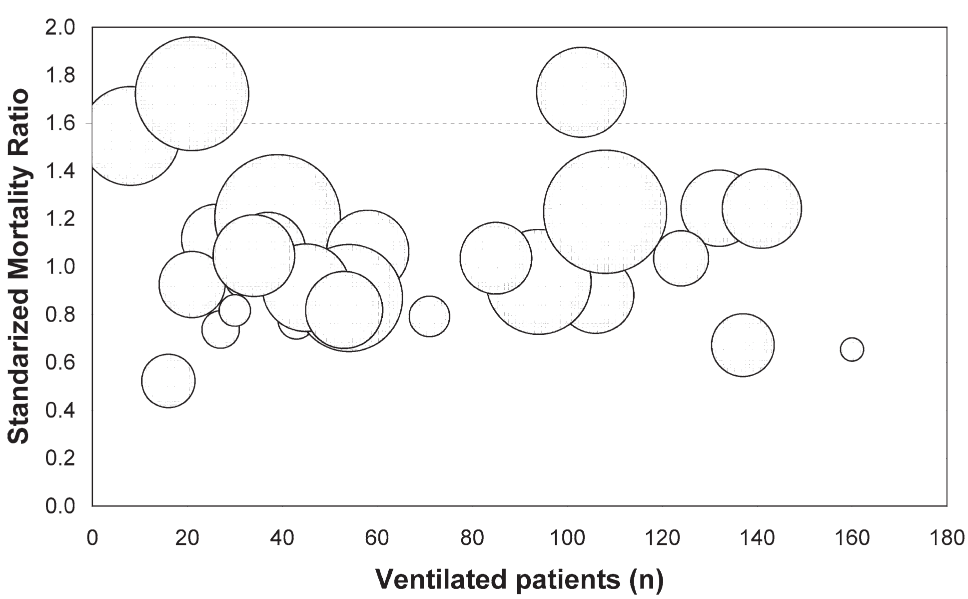


**Fig. 2.** Standardized mortality ratio by the number of patients mechanically ventilated in each intensive care unit. There was no statistical correlation between standard mortality ratio and the number of patients mechanically ventilated in the intensive care unit. The size of the symbols is proportional to unadjusted mortality.

**Table 4.** Clinical Characteristics of Mechanically Ventilated Patients by ICU Volume Quartile

| Variable | Quartile 1 | Quartile 2 | Quartile 3 | Quartile 4 | *P* Value |
|---|---|---|---|---|---|
| Patients per year | 30–99 | 100–199 | 200–399 | 400–640 | |
| Age, yr | 64.7 ± 15.7 | 65.9 ± 14.4 | 60.9 ± 16.6 | 60.6 ± 16.2 | 0.001 |
| Female sex | 60 (33%) | 95 (33%) | 193 (36%) | 312 (34%) | 0.8 |
| Predicted risk of death, % | 39.2 ± 24.9 | 39.4 ± 27.1 | 31.5 ± 26.4 | 27.9 ± 23.4 | 0.001 |
| Diagnoses | | | | | 0.001 |
| Cardiovascular | 28 (15%) | 62 (21%) | 100 (18%) | 219 (24%) | |
| Coronary | 7 (4%) | 2 (1%) | 11 (2%) | 26 (3%) | |
| Neurological | 18 (10%) | 46 (16%) | 106 (20%) | 142 (16%) | |
| Postsurgical | 69 (37%) | 90 (31%) | 108 (20%) | 227 (25%) | |
| Respiratory | 33 (18%) | 63 (22%) | 126 (23%) | 129 (14%) | |
| Trauma | 5 (3%) | 7 (2%) | 39 (7%) | 90 (10%) | |
| Other | 24 (13%) | 20 (7%) | 51 (9%) | 75 (8%) | |
| Vasoactive drugs | 140 (76%) | 181 (62%) | 329 (61%) | 594 (65%) | 0.002 |
| Parenteral nutrition | 100 (54%) | 105 (36%) | 128 (24%) | 162 (18%) | 0.001 |
| Tracheostomy | 24 (13%) | 39 (13%) | 69 (13%) | 119 (13%) | 0.9 |
| Transfusion | 90 (49%) | 106 (37%) | 213 (39%) | 395 (43%) | 0.02 |
| Acute renal failure | 83 (45%) | 87 (30%) | 169 (31%) | 219 (24%) | 0.001 |
| ICU-acquired infection | 38 (21%) | 57 (20%) | 134 (25%) | 152 (17%) | 0.003 |
| Length of ICU stay, d | 8 (4–15) | 6 (3–13) | 7 (3–15) | 5 (3–11) | 0.001 |
| ICU mortality | 69 (37%) | 65 (22%) | 140 (26%) | 178 (20%) | 0.001 |
| ICU readmission | 7 (5%) | 16 (6%) | 25 (6%) | 44 (5%) | 0.7 |
| Length of ward stay, d | 5 (1–13) | 10 (2–22) | 8 (1–17) | 8 (4–16) | 0.001 |
| In-hospital mortality | 90 (49%) | 92 (32%) | 170 (31%) | 231 (25%) | 0.001 |
| Standardized mortality ratio | 1.22 (0.90–1.59) | 0.82 (0.66–0.98) | 1.12 (1.04–1.19) | 0.93 (0.78–1.00) | 0.01 |

ICU = intensive care unit.

into practice.[17] Thus, our universal intensivist coverage may improve overall outcome; however, patients at high-volume hospitals may be exposed to physicians in-training more frequently than those in low-volume hospitals. Recent reports have demonstrated that periods of major change in resident surgical staff are associated with increased risk-adjusted in-hospital mortality after complex cardiac operations.[18] It is conceivable that a similar relationship might exist in the ICU.

**Table 5.** Multilevel Logistic Regression Analysis of Variables Associated with Mortality of Mechanically Ventilated Patients after Including Quartiles of ICU Volume

| | Odds Ratio (95% CI) | *P* Value |
|---|---|---|
| Age, yr | 1.011 (1.003–1.020) | <0.01 |
| Predicted risk of death | 1.038 (1.03–1.04) | <0.001 |
| Diagnosis (high risk *vs.* low risk) | 2.5 (1.9–3.4) | <0.001 |
| Do-not-resuscitate orders | 5.2 (3.2–8.5) | <0.001 |
| Vasoactive drugs | 3.3 (2.4–4.6) | <0.001 |
| Acute renal failure | 2.2 (1.7–2.9) | <0.001 |
| ICU-acquired infection | 1.2 (0.9–1.6) | 0.3 |
| Blood transfusion | 1.1 (0.8–1.3) | 0.6 |
| Parenteral nutrition | 0.8 (0.6–1.1) | 0.2 |
| University hospital *vs.* others | 0.9 (0.7–1.2) | 0.6 |
| Public *vs.* private funding | 1.6 (0.9–2.8) | 0.1 |
| ICU volume (first quartile *vs.* others) | 2.2 (1.5–3.4) | <0.001 |

ICU = intensive care unit.

A closed-ICU model has been reported to improve outcome in critically ill patients.[19,20] In our healthcare system, nearly all ICUs are staffed by intensivists 24 h a day, 7 days a week,[14] whereas in the United States most small-community hospitals lack full coverage by trained intensivists. Some observational studies have shown that the presence of a trained intensivist is associated with lower ICU mortality.[21] Consequently, some groups advocate using the permanent presence of intensivists as a measure of hospital quality.[22] Moreover, although patients with acute lung injury cared for in-closed model ICUs are more likely to receive lower tidal volume mechanical ventilation, the difference in delivered tidal volume did not completely account for the improved mortality observed in closed-model ICUs.[19]

If outcome is partly related to exportable factors such as protocols, guidelines, and multidisciplinary care models, then centers with low volume of mechanically ventilated patients might achieve the same outcome as the others by adopting these practices.[22]

Like all analyses of the association between volume and outcome, our study cannot determine the direction of the association.[23] Some investigators suggested that higher-quality hospitals might attract more patients on the basis of superior care when performance data are publicly reported.[9]

**Table 6.** Logistic Regression Model for Variables Associated with Mortality in Ventilated Patients after Inclusion of Specific Critical Care Treatments

| | Odds Ratio (95% CI) | *z*-statistic | *P* Value |
|---|---|---|---|
| Age, yr | 1.01 (1.001–1.02) | 2.9 | 0.003 |
| Predicted risk of death | 1.04 (1.03–1.05) | 15.8 | <0.001 |
| Do-not-resuscitate orders | 5.1 (3.2–8.2) | 6.7 | <0.001 |
| Diagnosis (high risk) | 2.3 (1.7–3.1) | 5.7 | <0.001 |
| First quartile | 2.3 (1.5–3.3) | 4.2 | <0.001 |
| Parenteral nutrition | 1.0 (0.8–1.3) | 0.1 | 0.9 |
| Vasoactive drugs | 3.9 (2.8–5.5) | 8.3 | <0.001 |
| Constant | N/A | –13.9 | <0.001 |

N/A = constant has no odds ratio by definition.

Nevertheless, our mainly public healthcare system is not influenced by this issue, as each hospital provides care for its catchment area, and very few patients seek care outside their own area.

Our results agree with those of two previous studies that found no association between volume and outcome in critically ill patients.[7,24] Many patients are admitted to the ICU for observation only, especially those not requiring mechanical ventilation or other interventions. As Kahn *et al.*[9] pointed out, an association between ICU volume and outcome would be unlikely in a population of patients who are at low risk for death and who do not receive active intervention in the ICU. Nevertheless, the ICU case mix is highly influenced by the rate of ICU beds per population, as was recently demonstrated by Wunsch *et al.*,[25] who reported a clear-cut difference in the severity of illness, age, length of ICU stay, and outcome between ICUs in the United States and United Kingdom. Conceivably, our Spanish healthcare system is more similar to the United Kingdom system than to the U.S. system.

The predicted risk of death was inversely associated with volume, both in the general ICU population and in mechanically ventilated patients, being higher in very low-volume ICUs. It is commonly accepted that mortality-prediction models are reliable at any level of severity. Moreover, the concentration of very sick patients in a given unit has been suggested to increase ICU-acquired infections by cross-contamination and that this increase is even greater in cases of nursing shortage or excess ICU workload,[26] which can worsen the outcome of severely ill patients.

Nguyen *et al.*[27] recently reviewed three alternative organizational models that may expand access to high-quality critical care: tiered regionalization, ICU telemedicine, and quality improvement through regional outreach. They conclude that existing evidence does not strongly support the exclusive use of a particular model. We reemphasize the need for strong data about the relationship between ICU volume and outcome in a given healthcare system before deciding whether ICU regionalization is the best solution.

### *Limitations of the Study*

The hospitals analyzed in this study were not a random sample of all hospitals in Spain. After a formal country-based invitation, each hospital decided to participate in the Sabadell score study. Nevertheless, the wide variation in ICU size, academic affiliation, and population coverage strongly suggests that this sample could be representative of a large proportion of Spanish ICUs.

The short time span of our study (3 months in the spring) may introduce a seasonal bias, mainly in the proportion of mechanically ventilated patients or those undergoing scheduled surgery. The use of different scoring systems may be a source of bias, but SMR was stable irrespective of the scoring system used in our original description.[15] Moreover, no

**Table 7.** Logistic Regression Model for Variables Associated with Mortality in Mechanically Ventilated Patients after Inclusion of Complications Acquired during ICU Stay

| | Odds Ratio (95% CI) | *z*-statistic | *P* Value |
|---|---|---|---|
| Age, yr | 1.01 (1.001–1.02) | 2.4 | 0.02 |
| Predicted risk of death | 1.04 (1.03–1.05) | 15.9 | <0.001 |
| Do-not-resuscitate orders | 4.4 (2.7–7.1) | 6.2 | <0.001 |
| Diagnosis (high risk) | 2.2 (1.7–2.9) | 5.5 | <0.001 |
| First quartile | 2.2 (1.5–3.2) | 4.2 | <0.001 |
| Acute renal failure | 2.6 (1.99–3.43) | 6.9 | <0.001 |
| ICU-acquired infection | 1.4 (1.1–1.9) | 2.3 | 0.02 |
| Constant | N/A | –12.9 | <0.001 |

ICU = intensive care unit; N/A = constant has no odds ratio by definition.

association was found between hospital volume and the scoring system used.

Patient referral practices could influence the results of this study. Commonly, high-volume hospitals are both more likely to receive patients transferred from another hospital and less likely to transfer patients from their ICUs than are other hospitals. Because transferred patients have a higher rate of death than predicted, the referral bias would tend to make high-volume hospitals seem to have worse risk-adjusted mortality.[28]

The worsened risk-adjusted outcomes at ICUs with a very low volume of mechanically ventilated patients may simply reflect less-accurate coding of the severity of illness (*i.e.*, designating an illness as less severe than it is) at these centers.[29] Nevertheless, investigators in each ICU were unaware of plans for this secondary analysis, making any pretended "up-coding" in high-performing hospitals unlikely. Additionally, our public system offered no budgetary incentives to hospitals based on coding strategies, which could bias our results; nevertheless, we have no data about quality control of the accuracy of coding. Very recently, Breslow and Badawi[30] stated that "simple SMRs are disproportionately affected by outcomes in high-risk patients, and differences in population composition, even when performance is otherwise identical, can result in different SMRs." Consequently, we cannot rule out whether our observed worse SMR in low-volume hospitals was an expression of poor performance or simply a mathematical coupling due to a higher proportion of high-risk patients.

In conclusion, we confirmed the wide variability in outcome among ICUs, even after adjusting for severity and confounding factors, but we found no relationship between ICU volume and outcome in our healthcare system. Only mechanically ventilated patients in very low-volume centers experienced slightly worse outcome.

## References


1. Bardach NS, Zhao S, Gress DR, Lawton MT, Johnston SC: Association between subarachnoid hemorrhage outcomes and number of cases treated at California hospitals. Stroke 2002; 33:1851–6
2. Brown DL: Analysis of the institutional volume-outcome relations for balloon angioplasty and stenting in the stent era in California. Am Heart J 2003; 146:1071–6
3. Carr BG, Kahn JM, Merchant RM, Kramer AA, Neumar RW: Inter-hospital variability in post-cardiac arrest mortality. Resuscitation 2009; 80:30–4
4. Nathens AB, Jurkovich GJ, Maier RV, Grossman DC, MacKenzie EJ, Moore M, Rivara FP: Relationship between trauma center volume and outcomes. JAMA 2001; 285:1164–71
5. Halm EA, Lee C, Chassin MR: Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. Ann Intern Med 2002; 137:511–20
6. Kahn JM, Linde-Zwirble WT, Wunsch H, Barnato AE, Iwashyna TJ, Roberts MS, Lave JR, Angus DC: Potential value of regionalized intensive care for mechanically ventilated medical patients. Am J Respir Crit Care Med 2008; 177:285–91
7. Durairaj L, Torner JC, Chrischilles EA, Vaughan Sarrazin MS, Yankey J, Rosenthal GE: Hospital volume-outcome relationships among medical admissions to ICUs. Chest 2005; 128:1682–9
8. Glance LG, Li Y, Osler TM, Dick A, Mukamel DB: Impact of patient volume on the mortality rate of adult intensive care unit patients. Crit Care Med 2006; 34:1925–34
9. Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD: Hospital volume and the outcomes of mechanical ventilation. N Engl J Med 2006; 355:41–50
10. Peelen L, de Keizer NF, Peek N, Scheffer GJ, van der Voort PH, de Jonge E: The influence of volume and intensive care unit organization on hospital mortality in patients admitted with severe sepsis: A retrospective multicentre cohort study. Crit Care 2007; 11:R40
11. Needham DM, Bronskill SE, Rothwell DM, Sibbald WJ, Pronovost PJ, Laupacis A, Stukel TA: Hospital volume and mortality for mechanical ventilation of medical and surgical patients: A population-based analysis using administrative data. Crit Care Med 2006; 34:2349–54
12. Ross JS, Normand SL, Wang Y, Ko DT, Chen J, Drye EE, Keenan PS, Lichtman JH, Bueno H, Schreiner GC, Krumholz HM: Hospital volume and 30-day mortality for three common medical conditions. N Engl J Med 2010; 362:1110–8
13. Wunsch H, Angus DC, Harrison DA, Collange O, Fowler R, Hoste EA, de Keizer NF, Kersten A, Linde-Zwirble WT, Sandiumenge A, Rowan KM: Variation in critical care services across North America and Western Europe. Crit Care Med 2008; 36:2787–93, e1–9
14. Junta Directiva de la Sociedad Española de Medicina Intensiva, Crítica y Unidades Coronarias (SEMICYUC): Intensive medicine in Spain. Med Intensiva 2011; 35:92–1
15. Fernandez R, Serrano JM, Umaran I, Abizanda R, Carrillo A, Lopez-Pueyo MJ, Rascado P, Balerdi B, Suberviola B, Hernandez G; Sabadell Score Study Group: Ward mortality after ICU discharge: A multicenter validation of the Sabadell score. Intensive Care Med 2010; 36:1196–201
16. Ferrer R, Artigas A, Levy MM, Blanco J, González-Díaz G, Garnacho-Montero J, Ibáñez J, Palencia E, Quintana M, de la Torre-Prados MV; Edusepsis Study Group: Improvement in process of care and outcome after a multicenter severe sepsis educational program in Spain. JAMA 2008; 299:2294–303
17. Dimick JB, Pronovost PJ, Heitmiller RF, Lipsett PA: Intensive care unit physician staffing is associated with decreased length of stay, hospital cost, and complications after esophageal resection. Crit Care Med 2001; 29:753–8
18. Shuhaiber JH, Goldsmith K, Nashef SA: Impact of cardiothoracic resident turnover on mortality after cardiac surgery: A dynamic human factor. Ann Thorac Surg 2008; 86:123–30; discussion 130–1
19. Cooke CR, Watkins TR, Kahn JM, Treggiari MM, Caldwell E, Hudson LD, Rubenfeld GD: The effect of an intensive care unit staffing model on tidal volume in patients with acute lung injury. Crit Care 2008; 12:R134
20. Treggiari MM, Martin DP, Yanez ND, Caldwell E, Hudson LD, Rubenfeld GD: Effect of intensive care unit organizational model and structure on outcomes in patients with acute lung injury. Am J Respir Crit Care Med 2007; 176:685–90
21. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL: Physician staffing patterns and clinical outcomes in critically ill patients: A systematic review. JAMA 2002; 288:2151–62
22. Angus DC, Black N: Improving care of the critically ill: Institutional and health-care system approaches. Lancet 2004; 363:1314–20
23. Luft HS, Hunt SS, Maerki SC: The volume-outcome relationship: Practice-makes-perfect or selective-referral patterns? Health Serv Res 1987; 22:157–82
24. Jones J, Rowan K: Is there a relationship between the volume of work carried out in intensive care and its outcome? Int J Technol Assess Health Care 1995; 11:762–9
25. Wunsch H, Angus DC, Harrison DA, Linde-Zwirble WT, Rowan KM: Comparison of medical admissions to intensive

care units in the United States and United Kingdom. Am J Respir Crit Care Med 2011; 183:1666–73
26. Tarnow-Mordi WO, Hau C, Warden A, Shearer AJ: Hospital mortality in relation to staff workload: A 4-year study in an adult intensive-care unit. Lancet 2000; 356:185–9
27. Nguyen YL, Kahn JM, Angus DC: Reorganizing adult critical care delivery: The role of regionalization, telemedicine, and community outreach. Am J Respir Crit Care Med 2010; 181:1164–9
28. Rosenberg AL, Hofer TP, Strachan C, Watts CM, Hayward RA: Accepting critically ill transfer patients: Adverse effect on a referral center's outcome and benchmark measures. Ann Intern Med 2003; 138:882–90
29. Hannan EL, Wu C, Ryan TJ, Bennett E, Culliford AT, Gold JP, Hartman A, Isom OW, Jones RH, McNeil B, Rose EA, Subramanian VA: Do hospitals and surgeons with higher coronary artery bypass graft surgery volumes still have lower risk-adjusted mortality rates? Circulation 2003; 108: 795–1
30. Breslow MJ, Badawi O: Severity scoring in the critically ill. Part 2: Maximizing value from outcome prediction scoring systems. Chest 2012; 141:518–27

## Appendix

The Sabadell Score Group includes the following collaborators:

Ana Isabel Tizon, M.D. (Hospital Xeral Cies, Vigo, Spain), Javier Gonzalez, M.D. (Hospital de Salamanca, Salamanca, Spain), Pablo Monedero, M.D. (Clinica Universitaria de Navarra, Navarra, Spain), Manuela Garcia Sanchez, M.D. (Hospital Virgen Macarena, Sevilla, Spain), Mª Victoria de la Torre, M.D. (Hospital Virgen de la Victoria, Malaga, Spain), Pedro Ibañez, M.D. (Hospital Son Llatzer, Mallorca, Spain), Fernando Frutos, M.D. (Hospital Universitario de Getafe, Getafe, Spain, CIBER Enfermedades Respiratorias), Frutos del Nogal, M.D. (Hospital Severo Ochoa, Leganes, Spain), Mª Jesus Gomez, M.D. (Hospital Reina Sofia, Murcia, Spain), Alfredo Marcos, M.D. (Hospital Virgen de la Concha, Zamora, Spain), Paula Vera, M.D. (Hospital Sant Joan de Reus, Reus, Spain), Jose Manuel Serrano, M.D. (Hospital Reina Sofia, Cordoba, Spain), Isabel Umaran, M.D. (Hospital de Cruces, Baracaldo, Spain), Andres Carrillo, M.D. (Hospital Morales Messeguer, Murcia, Spain), Mª-Jose Lopez-Pueyo, M.D. (Hospital General Yague, Burgos, Spain), Pedro Rascado, M.D. (Hospital Universitario de A Coruña, A Coruña, Spain), Begoña Balerdi, M.D. (Hospital La Fe, Valencia, Spain), Borja Suberviola, M.D. (Hospital Marques de Valdecilla, Santander, Spain), Gonzalo Hernandez, M.D. (Hospital Infanta Sofia, San Sebastian de los Reyes, Spain).