Intensive care unit occupancy and patient outcomes*

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Principle: **Although intensive care units (ICUs) with higher overall patient volume may achieve better outcomes than lower volume ICUs, there are few data on the effects of increasing patient loads on patients within the ICU.**

Objectives: **To examine the association of ICU occupancy with the patient outcomes within the same ICU.**

Methods: **We examined 200,499 patients in 108 ICUs using the Acute Physiology and Chronic Health Evaluation IV database in 2002–2005. Daily census on the day of admission was determined for each patient and defined in relation to the mean census. We used conditional logistic regression to compare inpatient outcomes of patients admitted on high census days to those admitted in the same ICU on low census days. We controlled for severity of illness at the patient level using data on clinical, demographic, and physiologic variables on admission to the ICU.**

Measurements and Main Results: **Patients admitted on high census days had the same odds of inpatient mortality or transfer to another hospital as patients admitted on average or on low census days. These findings were robust to multiple alternative definitions of day of admission census and were confirmed in several subgroup analyses.**

Conclusions: **The ICUs in this data are able to function as high reliability organizations. They are able to scale up their operations to meet the needs of a wide range of operating conditions while maintaining consistent patient mortality outcomes. (Crit Care Med 2009; 37:1545–1557)**

KEY WORDS: intensive care; mortality; volume; high reliability organizations

There is growing interest in concentrating critically ill patients into a smaller number of intensive care units (ICUs). This interest arises because of the increasing demand for critical care by a growing population at risk (1), hospital closures (2), payer-initiatives to achieve economies of scale (3), and possible policy decisions to implement a regionalized system of care (4, 5).

Several studies demonstrate that high-volume ICUs provide improved outcomes for a range of serious conditions (6–13). However, these cross-sectional studies do not address the effect of increasing patient volume within a hospital on outcomes; that is, they demonstrate average effects rather than marginal effects, although the latter are quite relevant from a policy perspective. Results of studies of the effect of changes in-patient volume on outcomes have been mixed (14–16). We are unaware of any multicentered studies focusing on the relationship between day-to-day patient volume and ICU outcomes in the United States.

In this study, we examine the association of daily ICU occupancy with the outcomes of patients admitted to that ICU on that day. We study a range of critical illnesses within the APACHE (Acute Physiology and Chronic Health Evaluation) IV database, containing detailed clinical and physiologic information on patients admitted to 108 ICUs. Day-of-admission census is our primary exposure variable because of the importance of rapid initial treatment for outcomes in many critical illnesses (17–19). A fixed effects model is used at the ICU level to compare patients with others admitted within the same ICU, but on a different day.

METHODS

Study Population and Data. Data came from patients admitted to ICUs participating in the APACHE clinical information system from January 2002 through June 2005. These units were diverse in size, geographic region, and teaching status. The APACHE program prospectively collects physiologic, clinical, demographic, and admission source data. Data are entered by teams who undergo intensive training and receive regular quality reviews. These data support several risk-adjustment models of ICU outcomes (20–22).

All patients admitted to APACHE ICUs were eligible for the study. Patients undergoing coronary artery bypass grafting were excluded because their risk-adjustment profiles are different than other critically ill patients (21, 22). We also excluded ICUs caring for fewer than 100 patients in the data and the first 100 patients at a site to ensure that our census measures were stable. Only a patient's first admission to the ICU during any given hospitalization was analyzed.

This article was considered exempt from review by the University of Pennsylvania Institutional Review Board.

Variables. Our exposure of interest is the census of each ICU on the day of ICU admission. Census is defined as the total number of patients who spent at least 2 hours in each ICU on the calendar day on which a given patient was admitted. The mean census of each ICU across the study period was computed. To take into account the differences between ICUs in their size and inherent uncertainty in determining the total capacity in each ICU, ICU census is analyzed as the ratio of the day-of-admission census to the mean census, divided into deciles. As sensitivity analyses, models were reestimated using other parameterizations of our key exposure variable. We avoided using "mean census during the patient's ICU stay" or some similar construct as ICU census after admission for a patient is endogenous to our outcomes.

*See also p. 1794.

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Table 1. Patient characteristics (n = 200,499)

Age, mean (SD)	61.54 (17.60)
In-hospital death, n (%)	26,583 (13.26)
Emergency surgery, n (%)	11,654 (5.81)
Postoperative, n (%)	61,158 (30.50)
Predicted mortality, (%)	13.83%
Intensive care unit length of stay, mean (SD)	3.94 (6.29)
Predicted intensive care unit length of stay, mean (SD)	3.69 (2.32)
Admission source, n (%)	
Operating room	61,157 (30.50)
Emergency department	75,038 (37.43)
Floor	35,524 (17.72)
Transfer from another hospital	17,369 (8.66)
Direct admission	11,411 (5.69)
Discharge destination, n (%)	
Home	126,433 (63.06)
To another hospital	10,919 (5.45)
Dead	6,583 (13.26)
Skilled nursing facility	23,112 (11.53)
Other	10,575 (5.27)
Missing	2,877 (1.43)
Admission diagnoses, n (%)	
Cardiac	32,880 (16.40)
Sepsis	11,371 (5.67)
Pneumonia	7,810 (3.90)
Other pulmonary (including chronic obstructive pulmonary disease)	17,884 (8.92)
Neurologic (including neurosurgery)	27,513 (13.72)
Trauma	14,829 (7.40)
Other surgery	30,604 (15.26)
All other admitting diagnoses	57,608 (28.73)

Table 2. Intensive care unit characteristics (n = 108)

Mean daily census	12.8
Median daily census	11
Interquartile range for daily census	9–15
Median total patients	1831
Interquartile range for total patients	1107–2869
Teaching status, n (%)	
Members of the Council of Teaching Hospitals	41 (38.0)
Small teaching hospitals	30 (27.8)
Nonteaching hospitals	37 (34.3)
Intensive care unit type, n (%)	
General	38 (35.2)
Medical	5 (4.6)
Cardiac	6 (5.6)
Neurologic	9 (8.3)
Cardiothoracic	27 (25.0)
Surgical	21 (19.4)
Trauma	2 (1.9)

The primary outcomes were in-hospital mortality and discharge to another hospital. As a secondary outcome, we examined length of stay in the ICU, which is recorded directly in the database; for these analyses, we excluded 16,400 patients in eight ICUs whose precise entrance and exit times within a given day are not in the dataset.

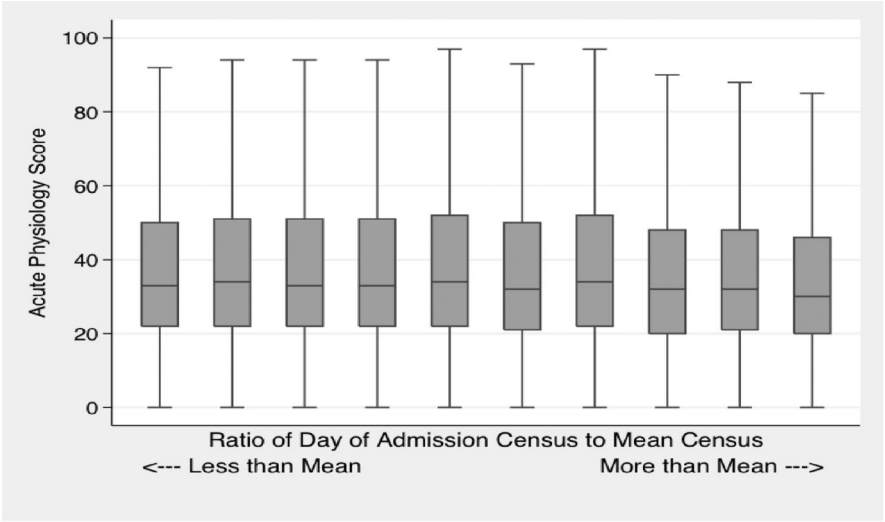

Figure 1. Unadjusted acute physiology score across deciles of census ratio. Box plot shows the median (*center line*) and interquartile range (*box*). There is little meaningful association with census (on the horizontal axis).

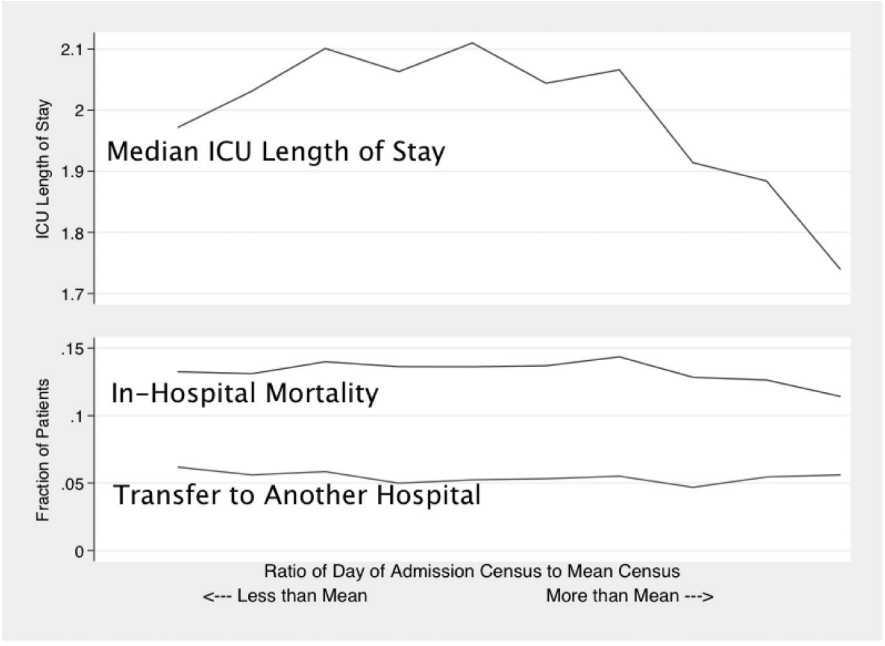

Figure 2. Unadjusted mortality, transfer rates, and intensive care unit (*ICU*) length of stay across deciles of census ratio (on the horizontal axis).

Risk Adjustment. Risk adjustment was performed using the APACHE IV risk-adjustment formulae. The risk equations include the day one acute physiology score, age, select chronic health items, primary diagnosis, hospital admission source, pre-ICU length of stay, whether a sedated patient could have his/her Glasgow Coma Score assessed, a patient was receiving invasive mechanical ventilation, and the patient had received emergency surgery, as described elsewhere (21, 22). Separate risk-adjustment formulae are available for inpatient mortality and ICU length of stay.

For regressions examining the association with discharge to another hospital, we have adjusted for APACHE IV-predicted risk of death as a marker of severity of illness, as we are unaware of a validated risk-adjustment model for that precise outcome.

Statistical Analysis. In key analyses, the relationship between census and outcome was examined using multivariable conditional logistic and linear regression, adjusting for APACHE risk of death. All regression models were parameterized with an ICU-level fixed effect to fully control for all shared, time-invariant characteristics of the ICU (including the nominal capacity of the ICU—"how many beds the unit has"), without having to measure those characteristics (23). Individual-

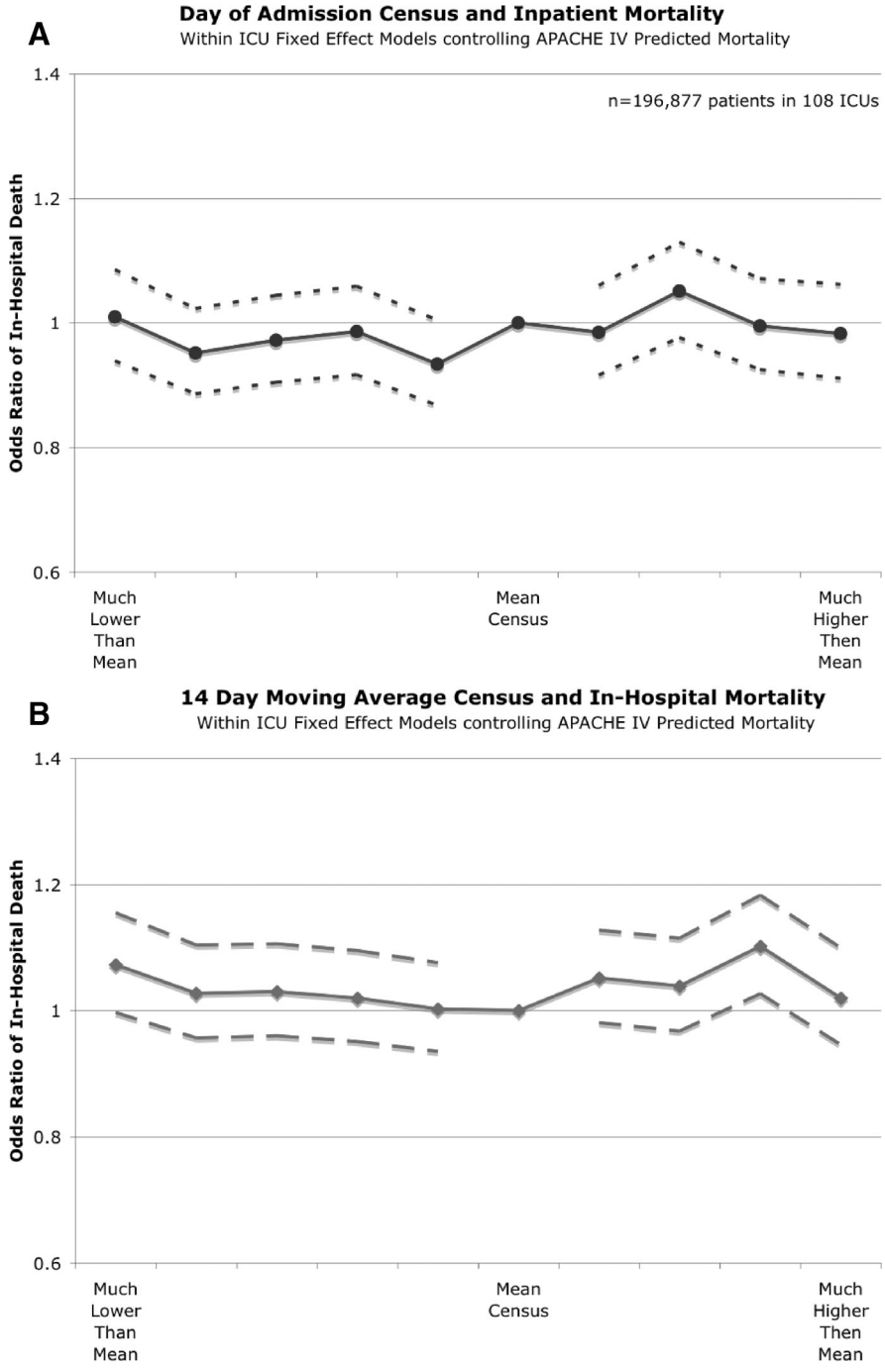

Figure 3. Conditional logistic regression for mortality. Ratio of census to mean census parameterized as separate indicator variables for each decile and with decile 6 as reference category. *ICU*, intensive care unit; *APACHE IV*, Acute Physiology and Chronic Health Evaluation IV.

level risk-adjusted predicted outcome was included in all regression models with linear, quadratic, and cubic terms to ensure flexibility. The regression results can be interpreted as the effect of the day-of-admission census comparing each patient to other patients admitted to the same ICU. An adjusted R^2 measure is reported in the Appendix for each regression, rescaled as maximum R^2 is less than one for a dichotomous outcome (24). Analyses were carried out in Stata 9.2 and SAS 9.0–9.2.

RESULTS

We examined 200,499 patients admitted to 108 ICUs in 46 hospitals. Patient characteristics are given in Table 1. The mean age was 61.5 years; the median Acute Physiology Score was 34. A total of 63.1% of patients were discharged home, and 13.3% died during their hospitalization. Characteristics of the ICUs are given in Table 2. The average daily census was 12.8 across ICUs, with a median of 11 and an interquartile range of 9–15.

There was wide variability in the day-of-admission census. The lowest decile of patients were admitted to ICUs with a census at 65% of their mean daily census; the highest decile of patients were admitted to ICUs operating at 147% of their mean daily census.

Response to Unusually High Daily Census. Severity of illness as measured by Acute Physiology Scores (APS) of patients did not markedly change with increasing occupancy of the ICU (Fig. 1). In a fixed effects model comparing patients to other patients in the same ICU, there was a small decline in mean APS with increasing patient occupancy (Appendix Table A1). Patients admitted on the highest census days had an APS 2.57 ($\pm$0.26 SE, $p < 0.0001$) lower than those on the lowest census days (comparing deciles 1 and 10).

There was little difference in mortality with increasing census on day of admission. As shown in Figure 2 without adjustment, patients admitted on the highest census days were slightly less likely to die as an inpatient; there was no increase in rates of transfers of patients to other hospitals with increasing census. As shown in Figure 3, there was no significant change in mortality with increasing census when a fixed effects regression is used to compare patients with others within the same ICU, and after adjustment for differences in predicted inpatient mortality using APACHE IV (Appendix Table A2; the joint test for the occupancy variables was insignificant at $p = 0.149$). Furthermore, the estimates are quite precise, ruling out large associations—patients in the highest decile have an odds ratio for inpatient mortality of 0.98 (95% CI 0.91–1.06) relative to those in decile 6 (the mean census) (Fig. 3). Fixed effects models confirmed that there was no significant increase in rates of transfer to other hospitals with increasing census (Appendix Table A3).

Unadjusted length of stay in the ICU decreased modestly with increasing volume. This apparent effect disappeared when APACHE IV predicted length of stay was included as a covariate in the fixed effects regression (Appendix Table A4).

Sustained (14 Day) High Census. A very similar pattern was seen when examining the effects of the census during the 14 days before and including the day of admission. This was parameterized as a ratio of the 14-day moving average cen-

Table 3. Sensitivity analyses

Subpopulations of potential interest:
• Surgical patients (Table A7)
• Nonsurgical patients (Table A8)
• Patients with predicted inpatient mortality of greater than 50% (Table A9)
• Patients admitted on weekdays (Table A10)
• Patients admitted on weekends (Table A11)
• Nonteaching hospitals (Table A12)
• Small teaching hospitals (Table A13)
• Members of the Council of Teaching Hospitals (Table A14)
Alternative parameterizations:
• Absolute (rather than relative) difference between day-of-admission census and mean census (Table A15)
• Using only the first ICU stay of the first hospitalization for each patient (Table A16)
Alternative outcomes:
• No increased rate of admission to ICU with cardiac arrest on high census days (Table A17)
• No increased rate of readmission to ICU within 7 days of discharge among patients admitted on higher census days (Table A18)

ICU, intensive care unit.

Our results were consistent across all of these analyses; full regression results are presented in the Appendix.

sus to the mean census across the study period. There was no clinically significant change in the odds of death with increasing 14-day census in unadjusted or the fixed effects regression models (see Fig. 3 and Appendix Table A5). In the regression, the joint test for the occupancy variables was insignificant ($p = 0.21$). Of note, there was an effect of occupancy on rates of transfers to other hospitals (joint test, $p = 0.0032$); however, transfers were more common on days of the lowest occupancy (Appendix Table A6).

Sensitivity Analyses. We conducted several sensitivity tests to confirm our mortality results, as shown in Table 3. In no case was there evidence of increased mortality with increased patient load.

DISCUSSION

Our results demonstrate that unusually high census on day of admission is not associated with clinically meaningful negative outcomes among critically ill patients across a range of conditions. This result was robust to alternative specifications of day-of-admission census and was true in important subgroups, including the subset of highest acuity patients. This result is consistent with some earlier works done in the Unites States and United Kingdom (14, 15), although the result contradicts a single-center study in a UK ICU (16). Although individual practitioners may suffer from the effects of increased workload (25), the existing organizational structure in the ICUs in our data seems to be able to buffer patients from any mortal adverse effects of increased workloads.

Why Might Increasing Census Worsen Patient Outcomes? In economics, the finding of so-called declining marginal productivity is common. Beyond a certain point, a worker cannot manufacture an item as quickly as the previous one. In the healthcare, this effect has been robustly studied in Emergency Department (ED) crowding. Patients seen during busy periods in the ED have longer inpatient lengths of stay and poorer care (26–28). Australian data suggests that ED crowding may even be associated with increased all-cause mortality (29, 30). These results dovetail with the literature demonstrating improved outcome for patients with lower nursing ratios (16, 25, 31).

Given these prior results suggesting that mortality of ICU patients would be increasing with day-of-admission census, our findings are reassuring. We find no evidence of a meaningful increase in mortality across a broad range of observed census ratios. Our analysis has intentionally focused at the organizational level of the ICU as a whole. We look at the total number of patients cared for in an ICU a day, because that may be under the control of ICU managers and policy directors. This complements other research that has taken a more microlevel perspective, looking at the workloads of particular practitioners. At the organizational level, diverse compensating mechanisms exist to support individual practitioners. Although studying the effectiveness of individual-level approaches (e.g., reducing nursing workloads) is valuable, there are also policy implications from studying the organizational aggregate effect.

Our data suggest that these ICUs are able to function as high reliability organizations. They are able to safely scale up their operations as needed to meet the demands of a wide range of operating conditions while maintaining consistent patient mortality outcomes (32, 33). This is true when increased demand is acute—measured at a single-day level—or more chronic, measured across 2 weeks of sustained activity. Given the pessimism about the reliability of healthcare organizations, this finding is encouraging and suggests an area for detailed process studies (34, 35). Our data neither allow us to investigate the particular processes that generate this aggregate mortality result nor guarantee that the results are present for other measures of quality. But our data have important implications for regionalization of critical care, disaster planning, and selection of high-quality critical care.

Implications. Regionalization is generally understood as a process of centralizing the care of patients of some type in designated centers of excellence, as in trauma and neonatal care (36). Trauma networks have been associated with remarkable improvements in outcomes (37–41). Leading critical care organizations are engaged in a discussion of regionalization of nontrauma critical care (5, 12).

Analyses of the potential value of regionalization have emphasized the difference between average outcomes for patients cared for in low volume vs. high-volume hospital. Thus, Krumholz et al (42) suggest that nearly 10,000 patients with acute myocardial infarction, were they to receive the same quality of care provided by the best hospitals, might be saved each year. Similar results have been found for non-postoperative mechanical ventilation (43). These analyses assume, without data, that the average effectiveness of the ICU is the same as the marginal effect of the ICU. That is, they assume that ICUs will be able to provide the same quality of care for the patients during high occupancy as they have for the average of the preceding patients. This study supports such an assumption, at least in the short term.

In particular, this study suggests that when assigning patients to providers to maximize the quality of care, across the observed range of variability, the highest quality providers are able to maintain

their quality even at workloads much above their mean census. This implies, but does not prove, the viability of regionalization strategies and related approaches such as concentrating high-risk procedures (3, 44) and when designing evacuations during disasters. Our results suggest that these ICUs maintain high quality despite high census—if the unit will accept the patient, it may be safe to send them.

Limitations. Our results have several limitations. First, they may not be generalizable to all ICUs. The APACHE hospitals invested in information technology and may not be representative of ICUs in the United States—or of the more constrained ICU resources typical of other developed countries (45). Second, in any observational study, an unobserved confounder might be present. Such a confounder would need to be associated with improved survival in the ICU and more common on high census days to explain our results. Third, given the importance of early response for several key critical illnesses, we have chosen to focus on census on day of admission. For some conditions, particularly safety-related complications such as catheter-related bloodstream infections, the workload throughout the entire ICU stay may be more important. Fourth, limitations of our data require that we use inpatient mortality and inpatient discharge destination as key outcomes. We hope that replications of this work will use unambiguous 30-day outcomes. Fifth, our data do not address the outcomes of patients who could not be admitted to the ICU due to high census, so we cannot speak to population health effects—high census days may affect outcomes on the hospital ward or ED. Finally, we have chosen to use a minimally parametric fixed effects estimator. As such, our standard errors may be somewhat less precise than a model that made more restrictive assumptions; however, our point estimates suggest only very small effects, if any.

CONCLUSIONS

A diverse set of ICUs seems able to maintain consistent mortality outcomes across a range of daily censuses. Some ICUs display a hallmark of high reliability organizations: consistent outcomes despite wide range of operating conditions. Further, this implies, but does not yet prove, that patients may be concentrated in high-volume ICUs without overwhelming those ICUs, and without thereby losing the potential benefits of concentration.

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Appendix. Fixed effects regression results

Table	Outcomes	Exposure	Subgroup
Appendix Table 1	Acute Physiology Score	Daily census	All
Appendix Table 2	In-hospital death	Daily census	All
Appendix Table 3	Transfer to another hospital	Daily census	All
Appendix Table 4	ICU length of stay	Daily census	All
Appendix Table 5	In-hospital death	14-Day census	All
Appendix Table 6	Transfer to another hospital	14-Day census	All
Appendix Table 7	In-hospital death	Daily census	Post-operative
Appendix Table 8	In-hospital death	Daily census	Non-post-operative
Appendix Table 9	In-hospital death	Daily census	High risk of death
Appendix Table 10	In-hospital death	Daily census	Weekday admits
Appendix Table 11	In-hospital death	Daily census	Weekend admits
Appendix Table 12	In-hospital death	Daily census	Nonteaching hospital
Appendix Table 13	In-hospital death	Daily census	Small teaching hospita
Appendix Table 14	In-hospital death	Daily census	Member of Council of Teaching Hospitals
Appendix Table 15	In-hospital death	Absolute difference	All
Appendix Table 16	In-hospital death	Daily census	First ICU of first hospitalization
Appendix Table 17	ICU admission diagnosis: cardiac arrest	Daily census	All
Appendix Table 18	Readmitted to ICU within 7 days	Daukt census	All
Appendix Table 19	ICU length of stay	14-Day census	All

All regressions control for Acute Physiology and Chronic Health Evaluation IV predicted mortality, *except* as indicated.
ICU, intensive care unit.

Appendix Table 1. Effect on Acute Physiology Score of daily census for all patients

	Outcome Obs Used Subgroup	Acute Physiology Score 183,774 All	No Control for Acute Physiology and Chronic Health Evaluation Prediction	
		Beta	95% CI LL	95% CI UL
Lower Census	Decile 1	Reference		
	Decile 2	−0.299	−0.811	0.212
	Decile 3	−0.539	−1.053	−0.026
	Decile 4	−0.570	−1.093	−0.048
Ratio to Mean Census	Decile 5	−0.801	−1.317	−0.285
	Decile 6	−0.641	−1.171	−0.111
	Decile 7	−0.942	−1.457	−0.427
	Decile 8	−1.349	−1.869	−0.830
Higher Census	Decile 9	−1.781	−2.295	−1.267
	Decile 10	−2.570	−3.085	−2.055
	F-Test for all Deciles	16.39	9 d.f., $p < 0.0001$	
	R^2	0.049149		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 2. Effect on in-hospital death of daily census for all patients

	Outcome Strata Obs Used Subgroup	In-hospital Death 108 196,877 All		
		Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1	1.01	0.939	1.086
	Decile 2	0.952	0.886	1.023
	Decile 3	0.972	0.905	1.044
	Decile 4	0.986	0.917	1.059
Ratio to Mean Census	Decile 5	0.934	0.868	1.005
	Decile 6	Reference		
	Decile 7	0.985	0.916	1.06
	Decile 8	1.051	0.977	1.13
Higher Census	Decile 9	0.995	0.925	1.071
	Decile 10	0.983	0.911	1.062
	Wald Test for all deciles	13.3162	9 d.f., $p = 0.1488$	
	Rescaled R^2	0.3943		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 3. Effect on transfer to another hospital of daily census for all patients

	Outcome Strata Obs Used Subgroup	Transferred to Another Hospital 108 196,877 All		
		Odds Ratio	95% CI LL	95%CI UL
Lower Census	Decile 1	1.074	0.98	1.176
	Decile 2	1.024	0.934	1.123
	Decile 3	1.056	0.963	1.158
	Decile 4	0.99	0.899	1.09
Ratio to Mean Census	Decile 5	1.016	0.922	1.119
	Decile 6	Reference		
	Decile 7	0.946	0.86	1.041
	Decile 8	0.957	0.869	1.054
Higher Census	Decile 9	1.029	0.937	1.129
	Decile 10	0.95	0.864	1.045
	Wald Test for all deciles	16.4675	9 d.f., $p = 0.0577$	
	Rescaled R^2	0.004		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 4. Effect on ICU LOS of daily census for all patients

	Outcome Obs Used Subgroup	ICU LOS 178,657 Full ICU LOS Data Beta	Controls for Acute Physiology and Chronic Health Evaluation-predicted LOS 95% CI LL	 95% CI UL
Lower Census	Decile 1	0.143	0.018	0.268
	Decile 2	0.056	−0.067	0.179
	Decile 3	0.025	−0.097	0.148
	Decile 4	0.088	−0.034	0.211
Ratio to Mean Census	Decile 5	0.117	−0.007	0.242
	Decile 6	Reference		
	Decile 7	−0.052	−0.177	0.073
	Decile 8	0.017	−0.107	0.141
Higher Census	Decile 9	0.031	−0.094	0.156
	Decile 10	0.048	−0.081	0.177
	F-Test for all deciles	1.77	9 d.f., $p = 0.0689$	
	R^2	0.1862		

ICU, intensive care unit; LOS, length of stay; CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 5. Effect on in-hospital death of 14-day census for all patients

	Outcome Strata Obs Used Subgroup	In-hospital Death 108 196,877 All Odds Ratio	 95% CI LL	 95% CI UL
Lower Census	Decile 1	1.073	0.997	1.155
	Decile 2	1.028	0.957	1.104
	Decile 3	1.03	0.96	1.106
	Decile 4	1.02	0.951	1.095
14-Day Ratio to Mean Census	Decile 5	1.003	0.935	1.076
	Decile 6	Reference		
	Decile 7	1.052	0.981	1.128
	Decile 8	1.039	0.968	1.115
Higher Census	Decile 9	1.102	1.027	1.183
	Decile 10	1.02	0.946	1.1
	Wald Test for all deciles	12.1474	9 d.f., $p = 0.2051$	
	Rescaled R^2	0.3943		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 6. Effect on transfer to another hospital of 14-day census for all patients

	Outcome Strata Obs Used Subgroup	Transferred to Another Hospital 108 196,877 All Odds Ratio	 95% CI LL	 95% CI UL
Lower Census	Decile 1	1.029	0.935	1.133
	Decile 2	1.122	1.026	1.227
	Decile 3	1.085	0.991	1.187
	Decile 4	1.119	1.022	1.225
14-Day Ratio to Mean Census	Decile 5	1.023	0.933	1.121
	Decile 6	Reference		
	Decile 7	1.005	0.916	1.103
	Decile 8	0.953	0.868	1.046
Higher Census	Decile 9	1.01	0.921	1.108
	Decile 10	0.997	0.906	1.097
	Wald Test for all deciles	24.7881	9 d.f., $p = 0.0032$	
	Rescaled R^2	0.0043		

Appendix Table 7. Effect on in-hospital death of daily census for post-operative patients

		Outcome	In-hospital Death		
		Strata	108		
		Obs Used	60,454		
		Subgroup	Post-Operative Patients		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		1.176	0.954	1.449
	Decile 2		1.026	0.837	1.258
	Decile 3		1.021	0.836	1.247
	Decile 4		0.966	0.788	1.185
Ratio to Mean Census	Decile 5		0.95	0.768	1.176
	Decile 6		Reference		
	Decile 7		0.961	0.776	1.19
	Decile 8		1.04	0.852	1.27
Higher Census	Decile 9		0.963	0.783	1.185
	Decile 10		0.99	0.797	1.23
	Wald Test for all deciles		6.0775	9 d.f., $p = 0.7321$	
	Rescaled R^2		0.1961		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 8. Effect on in-hospital death of daily census for non-post-operative patients

		Outcome	In-hospital Death		
		Strata	108		
		Obs Used	136,423		
		Subgroup	Non-Post-operative Patients		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		0.973	0.897	1.054
	Decile 2		0.936	0.864	1.014
	Decile 3		0.961	0.887	1.04
	Decile 4		0.989	0.914	1.071
Ratio to Mean Census	Decile 5		0.934	0.861	1.012
	Decile 6		Reference		
	Decile 7		0.986	0.909	1.069
	Decile 8		1.054	0.971	1.144
Higher Census	Decile 9		1.012	0.933	1.098
	Decile 10		0.99	0.909	1.079
	Wald Test for all deciles		13.8071	9 d.f., $p = 0.1294$	
	Rescaled R^2		0.3994		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 9. Effect on in-hospital death of daily census for patients with a high predicted risk of death

		Outcome	In-hospital Death		
		Strata	107		
		Obs Used	15,464		
		Subgroup	High Predicted Risk of Death		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		1.023	0.867	1.207
	Decile 2		0.876	0.747	1.029
	Decile 3		0.995	0.85	1.166
	Decile 4		0.936	0.798	1.098
Ratio to Mean Census	Decile 5		0.943	0.803	1.107
	Decile 6		Reference		
	Decile 7		0.962	0.819	1.13
	Decile 8		1.168	0.986	1.384
Higher Census	Decile 9		0.997	0.844	1.179
	Decile 10		0.928	0.78	1.104
	Wald Test for all deciles		14.3608	9 d.f., $p = 0.1101$	
	Rescaled R^2		0.1138		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 10. Effect on in-hospital death of daily census for patients admitted to the intensive care unit on weekdays

		Outcome	In-hospital Death		
		Strata	108		
		Obs Used	152,133		
		Subgroup	Weekday Admissions		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		1.013	0.928	1.105
	Decile 2		0.924	0.848	1.007
	Decile 3		0.968	0.890	1.052
	Decile 4		0.977	0.899	1.062
Ratio to Mean Census	Decile 5		0.934	0.858	1.016
	Decile 6		Reference		
	Decile 7		0.979	0.901	1.064
	Decile 8		1.043	0.960	1.133
Higher Census	Decile 9		0.971	0.894	1.054
	Decile 10		0.969	0.889	1.056
	Wald Test for all deciles		11.953	9 d.f., $p = 0.216$	
	Rescaled R^2		0.390		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 11. Effect on in-hospital death of daily census for patients admitted to the intensive care unit on weekends

		Outcome	In-hospital Death		
		Strata	108		
		Obs Used	44,744		
		Subgroup	Weekend Admissions		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		0.999	0.872	1.145
	Decile 2		0.999	0.871	1.145
	Decile 3		0.974	0.848	1.120
	Decile 4		0.994	0.861	1.147
Ratio to Mean Census	Decile 5		0.927	0.799	1.076
	Decile 6		Reference		
	Decile 7		1.003	0.859	1.170
	Decile 8		1.094	0.937	1.278
Higher Census	Decile 9		1.117	0.948	1.316
	Decile 10		1.060	0.887	1.268
	Wald Test for all deciles		8.1966	9 d.f., $p = 0.5145$	
	Rescaled R^2		0.405		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 12. Effect on in-hospital death of daily census for nonteaching hospital patients

		Outcome	In-hospital Death		
		Strata	37		
		Obs Used	67,163		
		Subgroup	Nonteaching Hospital		
			Odds Ratio	95% CI LL	95%CI UL
Lower Census	Decile 1		0.974	0.852	1.113
	Decile 2		0.903	0.79	1.033
	Decile 3		0.952	0.828	1.095
	Decile 4		0.927	0.8	1.075
Ratio to Mean Census	Decile 5		0.919	0.799	1.056
	Decile 6		Reference		
	Decile 7		0.968	0.839	1.118
	Decile 8		1.019	0.892	1.164
Higher Census	Decile 9		0.947	0.825	1.088
	Decile 10		0.993	0.865	1.14
	Wald Test for all deciles		6.6208	9 d.f., $p = 0.6765$	
	Rescaled R^2		0.4025		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 13. Effect on in-hospital death of daily census for small teaching hospital patients

		Outcome	In-hospital Death		
		Strata	30		
		Obs Used	62,958		
		Subgroup	Small Teaching Hospital		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		0.941	0.828	1.07
	Decile 2		0.904	0.793	1.031
	Decile 3		0.987	0.87	1.119
	Decile 4		0.91	0.801	1.035
Ratio to Mean Census	Decile 5		0.881	0.77	1.008
	Decile 6		Reference		
	Decile 7		0.92	0.809	1.046
	Decile 8		0.979	0.85	1.126
Higher Census	Decile 9		0.973	0.854	1.109
	Decile 10		0.91	0.798	1.038
	Wald Test for all deciles		7.8223	9 d.f., $p = 0.5522$	
	Rescaled R^2		0.382		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 14. Effect on in-hospital death of daily census for Council of Teaching Hospital Patients

		Outcome	In-hospital Death		
		Strata	41		
		Obs Used	66,756		
		Subgroup	Member of Council of Teaching Hospitals		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		1.108	0.978	1.254
	Decile 2		1.029	0.918	1.155
	Decile 3		0.949	0.848	1.061
	Decile 4		1.077	0.967	1.198
Ratio to Mean Census	Decile 5		0.973	0.867	1.093
	Decile 6		Reference		
	Decile 7		1.044	0.93	1.172
	Decile 8		1.124	1.002	1.261
Higher Census	Decile 9		1.043	0.927	1.174
	Decile 10		1.011	0.875	1.167
	Wald Test for all deciles		12.889	9 d.f., $p = 0.1677$	
	Rescaled R^2		0.3981		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 15. Effect on in-hospital death of absolute difference between day of admission census and mean census for all patients

		Outcome	In-hospital Death		
		Strata	108		
		Obs Used	196,877		
		Subgroup	All		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		0.958	0.890	1.030
	Decile 2		0.958	0.892	1.030
	Decile 3		0.947	0.882	1.016
Absolute Difference	Decile 4		0.943	0.877	1.014
from Mean Census	Decile 5		0.928	0.862	0.999
	Decile 6		Reference		
	Decile 7		0.93	0.864	1.001
	Decile 8		0.995	0.925	1.069
Higher Census	Decile 9		0.999	0.928	1.075
	Decile 10		0.946	0.875	1.023
	Wald Test for all deciles		10.335	9 d.f., $p = 0.324$	
	Rescaled R^2		0.3942		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 16. Effect on in-hospital death of daily census for patients during the first intensive care unit stay of their first hospitalization

		Outcome: In-hospital Death Strata: 108 Obs Used: 178,775 Subgroup: Only First Visit of First Hospitalization Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1	1.011	0.937	1.092
	Decile 2	0.953	0.883	1.028
	Decile 3	0.967	0.896	1.042
	Decile 4	0.987	0.915	1.065
Ratio to Mean Census	Decile 5	0.931	0.862	1.007
	Decile 6	Reference		
	Decile 7	0.995	0.921	1.076
	Decile 8	1.036	0.959	1.119
Higher Census	Decile 9	0.994	0.920	1.074
	Decile 10	0.986	0.909	1.070
	Wald Test for all deciles	10.6621	9 d.f., $p = 0.2996$	
	Rescaled R^2	0.4013		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 17. Effect on being admitted to the intensive care unit with a diagnosis of cardiac arrest of daily census for all patients

		Outcome: Admitted after Cardiac Arrest Strata: 108 Obs Used: 196,877 Subgroup: All Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1	1.041	0.893	1.213
	Decile 2	1.065	0.915	1.241
	Decile 3	0.974	0.835	1.137
	Decile 4	0.953	0.816	1.113
Ratio to Mean Census	Decile 5	1.072	0.917	1.253
	Decile 6	Reference		
	Decile 7	1.042	0.893	1.217
	Decile 8	1.016	0.866	1.191
Higher Census	Decile 9	0.959	0.821	1.121
	Decile 10	0.919	0.784	1.078
	Wald Test for all deciles	8.4609	9 d.f., $p = 0.4885$	
	Rescaled R^2	0.0003		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 18. Effect on readmission to the intensive care unit within 7 days of daily census for all patients

		Outcome Strata Obs Used Subgroup	Readmission to Intensive Care Unit within 7 Days of Discharge 108 196,877 All		
			Odds Ratio	95% CI LL	95% CI UL
Lower Census	Decile 1		1.001	0.891	1.125
	Decile 2		0.986	0.88	1.105
	Decile 3		1.02	0.911	1.143
	Decile 4		1.078	0.963	1.206
Ratio to Mean Census	Decile 5		0.944	0.839	1.062
	Decile 6		Reference		
	Decile 7		1.007	0.895	1.132
	Decile 8		1.004	0.896	1.126
Higher Census	Decile 9		1.034	0.922	1.16
	Decile 10		1.002	0.889	1.129
	Wald Test for all deciles		5.9396	9 d.f., $p = 0.7459$	
	Rescaled R^2		0.0105		

CI, confidence interval; LL, lower limit; UL, upper limit.

Appendix Table 19. Effect on ICU LOS of 14-day census for all patients

		Outcome Obs Used Subgroup	ICU LOS 178,657 Full ICU LOS Data Beta	Controls for Acute Physiology and Chronic Health Evaluation-predicted LOS	
				95% CI LL	95% CI UL
Lower Census	Decile 1		−0.007	−0.131	0.117
	Decile 2		0.004	−0.115	0.124
	Decile 3		0.016	−0.102	0.135
14-Day Ratio to Mean Census	Decile 4		−0.041	−0.159	0.077
	Decile 5		−0.022	−0.140	0.095
	Decile 6		Reference		
	Decile 7		0.034	−0.083	0.151
	Decile 8		−0.051	−0.170	0.067
Higher Census	Decile 9		−0.005	−0.127	0.117
	Decile 10		0.069	−0.057	0.196
	F-test for all deciles		0.61	9 d.f., $p = 0.7886$	
	R^2		0.829409		

ICU, intensive care unit; LOS, length of stay; CI, confidence interval; LL, lower limit; UL, upper limit.