Theodore J. Iwashyna, MD, PhD; Andrew A. Kramer, PhD; Jeremy M. Kahn, MD, MSc

**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

**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 from 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.

**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 multi-centered 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.
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.

**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-
The 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-

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**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.
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 at 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.

ACKNOWLEDGMENT

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REFERENCES

association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. Med J Aust 2006; 184:208–212


Appendix. Fixed effects regression results

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<tr>
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<td>ICU admission diagnosis: cardiac arrest</td>
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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

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<td></td>
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CI, confidence interval; LL, lower limit; UL, upper limit.

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

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

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

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CI, confidence interval; LL, lower limit; UL, upper limit.
Appendix Table 4. Effect on ICU LOS of daily census for all patients

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<td>0.048 −0.081 0.177</td>
</tr>
<tr>
<td>F-Test for all deciles</td>
<td>1.77</td>
<td>9 d.f., p = 0.0689</td>
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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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death Observations Used</th>
<th>Controls for Acute Physiology and Chronic Health Evaluation-predicted LOS</th>
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<tbody>
<tr>
<td></td>
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<td>196,877</td>
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<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>1.073 0.997 1.155</td>
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<tr>
<td></td>
<td>Decile 2</td>
<td>1.028 0.957 1.104</td>
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<tr>
<td></td>
<td>Decile 3</td>
<td>1.03 0.96 1.106</td>
</tr>
<tr>
<td></td>
<td>Decile 4</td>
<td>1.02 0.951 1.095</td>
</tr>
<tr>
<td></td>
<td>Decile 5</td>
<td>1.003 0.935 1.076</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>1.052 0.981 1.128</td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.039 0.968 1.115</td>
</tr>
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<td></td>
<td>Decile 9</td>
<td>1.102 1.027 1.183</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>1.02 0.946 1.1</td>
</tr>
<tr>
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<td>1.003 0.935 1.076</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>1.052 0.981 1.128</td>
</tr>
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<td>Decile 8</td>
<td>1.039 0.968 1.115</td>
</tr>
<tr>
<td></td>
<td>Decile 9</td>
<td>1.102 1.027 1.183</td>
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<tr>
<td></td>
<td>Decile 10</td>
<td>1.02 0.946 1.1</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 5</td>
<td>1.003 0.935 1.076</td>
</tr>
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<td></td>
<td>Decile 6</td>
<td>Reference</td>
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<tr>
<td></td>
<td>Decile 7</td>
<td>1.052 0.981 1.128</td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.039 0.968 1.115</td>
</tr>
<tr>
<td></td>
<td>Decile 9</td>
<td>1.102 1.027 1.183</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>1.02 0.946 1.1</td>
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<tr>
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</table>

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

<table>
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<tr>
<th>Outcome</th>
<th>Transferred to Another Hospital Observations Used</th>
<th>Controls for Acute Physiology and Chronic Health Evaluation-predicted LOS</th>
</tr>
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<tbody>
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<td></td>
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<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>1.029 0.935 1.133</td>
</tr>
<tr>
<td></td>
<td>Decile 2</td>
<td>1.122 1.026 1.227</td>
</tr>
<tr>
<td></td>
<td>Decile 3</td>
<td>1.085 0.991 1.187</td>
</tr>
<tr>
<td></td>
<td>Decile 4</td>
<td>1.119 1.022 1.225</td>
</tr>
<tr>
<td></td>
<td>Decile 5</td>
<td>1.023 0.933 1.121</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>1.005 0.916 1.103</td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>0.953 0.868 1.046</td>
</tr>
<tr>
<td></td>
<td>Decile 9</td>
<td>1.01 0.921 1.108</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>0.997 0.906 1.097</td>
</tr>
<tr>
<td>14-Day Ratio to Mean Census</td>
<td>Decile 5</td>
<td>1.023 0.933 1.121</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>1.005 0.916 1.103</td>
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<td>Decile 8</td>
<td>0.953 0.868 1.046</td>
</tr>
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<td>Decile 9</td>
<td>1.01 0.921 1.108</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>0.997 0.906 1.097</td>
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<tr>
<td>Higher Census</td>
<td>Decile 5</td>
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<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
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<tr>
<td></td>
<td>Decile 7</td>
<td>1.005 0.916 1.103</td>
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<tr>
<td></td>
<td>Decile 8</td>
<td>0.953 0.868 1.046</td>
</tr>
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<td></td>
<td>Decile 9</td>
<td>1.01 0.921 1.108</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>0.997 0.906 1.097</td>
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<td>Wald Test for all deciles</td>
<td>24.7881</td>
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### Appendix Table 7. Effect on in-hospital death of daily census for post-operative patients

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<th>Outcome</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
<th>In-hospital Death</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>108</td>
<td>Post-Operative Patients</td>
<td>1.176</td>
<td>0.954</td>
<td>1.449</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 2</td>
<td>1.026</td>
<td></td>
<td>0.897</td>
<td>1.258</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Decile 3</td>
<td>1.021</td>
<td></td>
<td>0.836</td>
<td>1.247</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 4</td>
<td>0.966</td>
<td></td>
<td>0.788</td>
<td>1.185</td>
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<tr>
<td></td>
<td>Decile 5</td>
<td>0.95</td>
<td></td>
<td>0.768</td>
<td>1.176</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td>1.04</td>
<td>0.852</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>0.961</td>
<td></td>
<td>0.776</td>
<td>1.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.04</td>
<td></td>
<td>0.852</td>
<td>1.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>0.963</td>
<td></td>
<td>0.783</td>
<td>1.185</td>
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</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>0.99</td>
<td></td>
<td>0.797</td>
<td>1.23</td>
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<td>Wald Test for all deciles</td>
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<td>9 d.f., p = 0.7321</td>
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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

<table>
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<tr>
<th>Outcome</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
<th>In-hospital Death</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
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<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>108</td>
<td>Non-Post-operative Patients</td>
<td>0.973</td>
<td>0.897</td>
<td>1.054</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>0.864</td>
<td>1.014</td>
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</tr>
<tr>
<td></td>
<td>Decile 3</td>
<td>1.021</td>
<td></td>
<td>0.887</td>
<td>1.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 4</td>
<td>0.966</td>
<td></td>
<td>0.914</td>
<td>1.071</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>0.861</td>
<td>1.012</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td>1.054</td>
<td>0.971</td>
<td>1.144</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>0.986</td>
<td></td>
<td>0.909</td>
<td>1.069</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.04</td>
<td></td>
<td>0.971</td>
<td>1.144</td>
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<td></td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>1.012</td>
<td></td>
<td>0.933</td>
<td>1.098</td>
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<tr>
<td></td>
<td>Decile 10</td>
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<td></td>
<td>0.909</td>
<td>1.079</td>
<td></td>
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<tr>
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<td></td>
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</table>

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

<table>
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<th>Outcome</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
<th>In-hospital Death</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
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<td>Lower Census</td>
<td>Decile 1</td>
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<td>High Predicted Risk of Death</td>
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<td>0.867</td>
<td>1.207</td>
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<td>0.747</td>
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<td></td>
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<td>0.995</td>
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</tr>
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<td>0.798</td>
<td>1.098</td>
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<td>0.803</td>
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<tr>
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<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td>0.962</td>
<td>0.819</td>
<td>1.13</td>
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<tr>
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<td>0.819</td>
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<td>Wald Test for all deciles</td>
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<td>9 d.f., p = 0.1101</td>
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</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>1.013</td>
<td>0.928</td>
<td>1.105</td>
</tr>
<tr>
<td></td>
<td>Decile 2</td>
<td>0.924</td>
<td>0.848</td>
<td>1.007</td>
</tr>
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<td></td>
<td>Decile 3</td>
<td>0.968</td>
<td>0.890</td>
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<td>Decile 4</td>
<td>0.977</td>
<td>0.899</td>
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<tr>
<td>Ratio to Mean Census</td>
<td>Decile 5</td>
<td>0.934</td>
<td>0.858</td>
<td>1.016</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>0.979</td>
<td>0.901</td>
<td>1.064</td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.043</td>
<td>0.960</td>
<td>1.133</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>0.971</td>
<td>0.894</td>
<td>1.054</td>
</tr>
<tr>
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<td>Decile 10</td>
<td>0.969</td>
<td>0.889</td>
<td>1.056</td>
</tr>
</tbody>
</table>

Ratio of to Mean Census |

| Lower 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 |

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

<table>
<thead>
<tr>
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<th>In-hospital Death</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
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<td>Lower Census</td>
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<td>0.999</td>
<td>0.928</td>
<td>1.145</td>
</tr>
<tr>
<td></td>
<td>Decile 2</td>
<td>0.999</td>
<td>0.917</td>
<td>1.145</td>
</tr>
<tr>
<td></td>
<td>Decile 3</td>
<td>0.974</td>
<td>0.848</td>
<td>1.120</td>
</tr>
<tr>
<td></td>
<td>Decile 4</td>
<td>0.994</td>
<td>0.861</td>
<td>1.147</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 5</td>
<td>0.927</td>
<td>0.799</td>
<td>1.076</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>1.003</td>
<td>0.859</td>
<td>1.170</td>
</tr>
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<td>Decile 8</td>
<td>1.094</td>
<td>0.957</td>
<td>1.278</td>
</tr>
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<td>1.117</td>
<td>0.948</td>
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<td>Decile 10</td>
<td>1.060</td>
<td>0.887</td>
<td>1.268</td>
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</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th>Strata</th>
<th>Obs Used</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Census</td>
<td>Decile 1</td>
<td>0.974</td>
<td>0.852</td>
<td>1.113</td>
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<tr>
<td></td>
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<td>0.903</td>
<td>0.79</td>
<td>1.033</td>
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<td>0.952</td>
<td>0.828</td>
<td>1.095</td>
</tr>
<tr>
<td></td>
<td>Decile 4</td>
<td>0.927</td>
<td>0.8</td>
<td>1.075</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 5</td>
<td>1.019</td>
<td>0.799</td>
<td>1.056</td>
</tr>
<tr>
<td></td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decile 7</td>
<td>0.968</td>
<td>0.839</td>
<td>1.118</td>
</tr>
<tr>
<td></td>
<td>Decile 8</td>
<td>1.019</td>
<td>0.892</td>
<td>1.164</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>0.947</td>
<td>0.825</td>
<td>1.088</td>
</tr>
<tr>
<td></td>
<td>Decile 10</td>
<td>0.993</td>
<td>0.865</td>
<td>1.14</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs Used</td>
<td>Subgroup</td>
<td></td>
</tr>
<tr>
<td>Lower Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 1</td>
<td>0.941</td>
<td>0.828</td>
<td>1.07</td>
</tr>
<tr>
<td>Decile 2</td>
<td>0.904</td>
<td>0.793</td>
<td>1.031</td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.987</td>
<td>0.87</td>
<td>1.119</td>
</tr>
<tr>
<td>Decile 4</td>
<td>0.91</td>
<td>0.801</td>
<td>1.035</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 5</td>
<td>0.881</td>
<td>0.77</td>
</tr>
<tr>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 7</td>
<td>0.92</td>
<td>0.809</td>
<td>1.046</td>
</tr>
<tr>
<td>Decile 8</td>
<td>0.979</td>
<td>0.85</td>
<td>1.126</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>0.973</td>
<td>0.854</td>
</tr>
<tr>
<td>Decile 10</td>
<td>0.91</td>
<td>0.798</td>
<td>1.038</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>7.8223</td>
<td>9 d.f., p = 0.5522</td>
<td></td>
</tr>
<tr>
<td>Rescaled R²</td>
<td>0.382</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs Used</td>
<td>Subgroup</td>
<td></td>
</tr>
<tr>
<td>Lower Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 1</td>
<td>1.108</td>
<td>0.978</td>
<td>1.254</td>
</tr>
<tr>
<td>Decile 2</td>
<td>1.029</td>
<td>0.918</td>
<td>1.155</td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.949</td>
<td>0.848</td>
<td>1.061</td>
</tr>
<tr>
<td>Decile 4</td>
<td>1.077</td>
<td>0.967</td>
<td>1.198</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>Decile 5</td>
<td>0.973</td>
<td>0.867</td>
</tr>
<tr>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 7</td>
<td>1.044</td>
<td>0.93</td>
<td>1.172</td>
</tr>
<tr>
<td>Decile 8</td>
<td>1.124</td>
<td>1.002</td>
<td>1.261</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>1.043</td>
<td>0.927</td>
</tr>
<tr>
<td>Decile 10</td>
<td>1.011</td>
<td>0.875</td>
<td>1.167</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>12.889</td>
<td>9 d.f., p = 0.11005</td>
<td></td>
</tr>
<tr>
<td>Rescaled R²</td>
<td>0.3981</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs Used</td>
<td>Subgroup</td>
<td></td>
</tr>
<tr>
<td>Lower Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 1</td>
<td>0.958</td>
<td>0.890</td>
<td>1.030</td>
</tr>
<tr>
<td>Decile 2</td>
<td>0.958</td>
<td>0.892</td>
<td>1.030</td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.947</td>
<td>0.882</td>
<td>1.016</td>
</tr>
<tr>
<td>Decile 4</td>
<td>0.943</td>
<td>0.877</td>
<td>1.014</td>
</tr>
<tr>
<td>Absolute Difference</td>
<td>Decile 5</td>
<td>0.928</td>
<td>0.862</td>
</tr>
<tr>
<td>from Mean Census</td>
<td>Decile 6</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Decile 7</td>
<td>0.93</td>
<td>0.864</td>
<td>1.001</td>
</tr>
<tr>
<td>Decile 8</td>
<td>0.995</td>
<td>0.925</td>
<td>1.009</td>
</tr>
<tr>
<td>Higher Census</td>
<td>Decile 9</td>
<td>0.999</td>
<td>0.928</td>
</tr>
<tr>
<td>Decile 10</td>
<td>0.946</td>
<td>0.875</td>
<td>1.023</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>10.335</td>
<td>9 d.f., p = 0.3244</td>
<td></td>
</tr>
<tr>
<td>Rescaled R²</td>
<td>0.3942</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>In-hospital Death</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strata</td>
<td>Obs Used</td>
<td>Subgroup</td>
<td>Only First Visit of First Hospitalization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108</td>
<td>178,775</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Census</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decile 1</td>
<td>1.011</td>
<td>0.937</td>
<td>1.092</td>
</tr>
<tr>
<td>Decile 2</td>
<td>0.953</td>
<td>0.883</td>
<td>1.028</td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.967</td>
<td>0.896</td>
<td>1.042</td>
</tr>
<tr>
<td>Decile 4</td>
<td>0.987</td>
<td>0.915</td>
<td>1.065</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 5</td>
<td>0.931</td>
<td>0.862</td>
<td>1.007</td>
</tr>
<tr>
<td>Decile 6 (Reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 7</td>
<td>0.995</td>
<td>0.921</td>
<td>1.076</td>
</tr>
<tr>
<td>Decile 8</td>
<td>1.036</td>
<td>0.959</td>
<td>1.119</td>
</tr>
<tr>
<td>Higher Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 9</td>
<td>0.994</td>
<td>0.920</td>
<td>1.074</td>
</tr>
<tr>
<td>Decile 10</td>
<td>0.986</td>
<td>0.909</td>
<td>1.070</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>10.6621</td>
<td>9 d.f., $p = 0.2996$</td>
<td></td>
</tr>
<tr>
<td>Rescaled $R^2$</td>
<td>0.4013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Admitted after Cardiac Arrest</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strata</td>
<td>Obs Used</td>
<td>Subgroup</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108</td>
<td>196,877</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Census</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decile 1</td>
<td>1.041</td>
<td>0.893</td>
<td>1.213</td>
</tr>
<tr>
<td>Decile 2</td>
<td>1.065</td>
<td>0.915</td>
<td>1.241</td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.974</td>
<td>0.835</td>
<td>1.137</td>
</tr>
<tr>
<td>Decile 4</td>
<td>0.953</td>
<td>0.816</td>
<td>1.113</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 5 (Reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 6</td>
<td>1.072</td>
<td>0.917</td>
<td>1.253</td>
</tr>
<tr>
<td>Decile 7</td>
<td>1.042</td>
<td>0.893</td>
<td>1.217</td>
</tr>
<tr>
<td>Decile 8</td>
<td>1.016</td>
<td>0.866</td>
<td>1.191</td>
</tr>
<tr>
<td>Higher Census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decile 9</td>
<td>0.959</td>
<td>0.821</td>
<td>1.121</td>
</tr>
<tr>
<td>Decile 10</td>
<td>0.919</td>
<td>0.784</td>
<td>1.078</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>8.4609</td>
<td>9 d.f., $p = 0.4885$</td>
<td></td>
</tr>
<tr>
<td>Rescaled $R^2$</td>
<td>0.0003</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Obs Used</th>
<th>Subgroup</th>
<th>Odds Ratio</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Census</td>
<td>108</td>
<td>All</td>
<td>1.001</td>
<td>0.891</td>
<td>1.125</td>
</tr>
<tr>
<td>Decile 1</td>
<td>1.001</td>
<td>Decile 1</td>
<td>0.986</td>
<td>0.88</td>
<td>1.105</td>
</tr>
<tr>
<td>Decile 2</td>
<td>1.002</td>
<td>Decile 2</td>
<td>1.078</td>
<td>0.963</td>
<td>1.206</td>
</tr>
<tr>
<td>Ratio to Mean Census</td>
<td>0.944</td>
<td>Decile 5</td>
<td>0.944</td>
<td>0.839</td>
<td>1.062</td>
</tr>
<tr>
<td>Higher Census</td>
<td>178,657</td>
<td>Reference</td>
<td>1.007</td>
<td>0.895</td>
<td>1.132</td>
</tr>
<tr>
<td>Decile 6</td>
<td>1.004</td>
<td>Decile 6</td>
<td>1.004</td>
<td>0.896</td>
<td>1.126</td>
</tr>
<tr>
<td>Decile 7</td>
<td>1.034</td>
<td>Decile 7</td>
<td>1.002</td>
<td>0.889</td>
<td>1.129</td>
</tr>
<tr>
<td>Decile 8</td>
<td>1.034</td>
<td>Decile 8</td>
<td>1.034</td>
<td>0.922</td>
<td>1.126</td>
</tr>
<tr>
<td>Decile 9</td>
<td>1.034</td>
<td>Decile 9</td>
<td>1.002</td>
<td>0.889</td>
<td>1.129</td>
</tr>
<tr>
<td>Decile 10</td>
<td>1.034</td>
<td>Decile 10</td>
<td>1.002</td>
<td>0.889</td>
<td>1.129</td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>5.9396</td>
<td></td>
<td>5.9396</td>
<td>9 d.f., p = 0.7459</td>
<td></td>
</tr>
<tr>
<td>Rescaled $R^2$</td>
<td>0.0105</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

| Controls for Acute Physiology and Chronic Health Evaluation-predicted LOS |
|-----------------------------|-----------------------------|

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Obs Used</th>
<th>Subgroup</th>
<th>ICU LOS</th>
<th>Data Beta</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Census</td>
<td>178,657</td>
<td>Full ICU LOS</td>
<td>Data Beta</td>
<td>95% CI LL</td>
<td>95% CI UL</td>
<td></td>
</tr>
<tr>
<td>Decile 1</td>
<td>0.007</td>
<td>Decile 1</td>
<td>−0.007</td>
<td>−0.131</td>
<td>0.117</td>
<td></td>
</tr>
<tr>
<td>Decile 2</td>
<td>0.044</td>
<td>Decile 2</td>
<td>0.044</td>
<td>−0.115</td>
<td>0.124</td>
<td></td>
</tr>
<tr>
<td>Decile 3</td>
<td>0.016</td>
<td>Decile 3</td>
<td>0.016</td>
<td>−0.102</td>
<td>0.135</td>
<td></td>
</tr>
<tr>
<td>14-Day Ratio to Mean Census</td>
<td>0.041</td>
<td>Decile 4</td>
<td>−0.041</td>
<td>−0.159</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>Decile 5</td>
<td>−0.022</td>
<td>Decile 5</td>
<td>−0.022</td>
<td>−0.140</td>
<td>0.095</td>
<td></td>
</tr>
<tr>
<td>Decile 6</td>
<td>0.034</td>
<td>Reference</td>
<td>0.034</td>
<td>−0.083</td>
<td>0.151</td>
<td></td>
</tr>
<tr>
<td>Decile 7</td>
<td>−0.051</td>
<td>Decile 7</td>
<td>−0.051</td>
<td>−0.170</td>
<td>0.067</td>
<td></td>
</tr>
<tr>
<td>Decile 8</td>
<td>−0.005</td>
<td>Decile 8</td>
<td>−0.005</td>
<td>−0.127</td>
<td>0.117</td>
<td></td>
</tr>
<tr>
<td>Decile 9</td>
<td>0.069</td>
<td>Decile 9</td>
<td>0.069</td>
<td>−0.057</td>
<td>0.196</td>
<td></td>
</tr>
<tr>
<td>Decile 10</td>
<td>0.069</td>
<td>Decile 10</td>
<td>0.069</td>
<td>−0.057</td>
<td>0.196</td>
<td></td>
</tr>
<tr>
<td>Wald Test for all deciles</td>
<td>0.61</td>
<td></td>
<td>0.61</td>
<td>9 d.f., p = 0.7886</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rescaled $R^2$</td>
<td>0.829409</td>
<td></td>
<td>0.829409</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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