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Hospital-level changes in adult ICU bed supply in the United States

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Abstract

Objective—Although the number of intensive care beds in the United States is increasing, little is known about the hospitals responsible for this growth. We sought to better characterize national growth in intensive care beds by identifying hospital-level factors associated with increasing numbers of intensive care beds over time.

Design—We performed a repeated-measures time series analysis of hospital-level intensive care bed supply using data from Centers for Medicare and Medicaid Services.

Setting—All United States acute care hospitals with adult intensive care beds over the years 1996 to 2011.

Measurements & Main Results—We described the number of beds, teaching status, ownership, intensive care occupancy and urbanicity for each hospital in each year of the study. We then examined the relationship between increasing intensive care beds and these characteristics, controlling for other factors. The study included 4,457 hospitals and 55,865 hospital-years. Overall, the majority of intensive care bed growth occurred in teaching hospitals (net +13,471 beds, 72.1% of total growth), hospitals with 250 or more beds (net +18,327 beds, 91.8% of total growth) and hospitals in the highest quartile of occupancy (net +10,157 beds, 54.0% of total growth). In a longitudinal multivariable model, larger hospital size, teaching status, and high intensive care occupancy were associated with subsequent-year growth. Furthermore, the effects of hospital size and teaching status were modified by occupancy: the greatest odds of increasing intensive care unit beds were in hospitals with 500 or more beds in the highest quartile of

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occupancy (adjusted OR: 18.9; 95% CI: 14.0 – 25.5; p<0.01) and large teaching hospitals in the highest quartile of occupancy (adjusted OR: 7.3; 95% CI: 5.3 – 9.9; p<0.01).

Conclusions—Increasingly, intensive care bed expansion in the United States is occurring in larger hospitals and teaching centers, particularly following a year with high intensive care unit occupancy.

Keywords

intensive care units; beds; hospitals; United States

Introduction

In the last 30 years the United States (US) has witnessed a transformation of acute care delivery where the number of hospitals decreased but the number of intensive care unit (ICU) beds increased (1, 2). As a consequence, the US is not only providing more intensive care but also concentrating intensive care in ever fewer numbers of hospitals. Yet surprisingly little is known about the hospitals themselves that are driving these aggregate changes (3). Characterizing the types of hospitals that are increasing their ICU bed supply is important not only for understanding the potential drivers of this growth, but also for understanding how the ongoing transformation of intensive care delivery may impact patient outcomes.

The objectives of this study were to describe and better characterize growth in the US ICU bed supply by identifying the types of hospitals that were adding beds. Using national data from the Centers for Medicare and Medicaid Services, we quantified the number of ICU beds for each hospital in each year, and then identified hospital-level factors associated with an increased number of ICU beds in the following year. Based on previous trends observed at the regional level (4), we hypothesized that larger hospitals, teaching hospitals, and hospitals with high baseline occupancy would be responsible for the majority of overall bed supply expansion.

Materials and Methods

Study Design and Data Sources

We performed a repeated-measures time series analysis of US ICU bed supply during the 16-year period between 1996 and 2011. We obtained data on hospital characteristics and intensive care occupancy from the Centers for Medicare and Medicaid Services Hospital Cost Report Information System (HCRIS), a publicly available hospital-level database with detailed information on structural, organizational and cost data for all US hospitals. We excluded skilled nursing facilities, long term acute care hospitals, hospitals located in US territories and stand-alone pediatric hospitals (1, 2). We augmented the HCRIS data with data from the US Census Bureau's 2010 urban-rural classification file which we used to designate hospitals as urban or rural by ZIP code (5).

Variables

The primary dependent variable was each hospital's number of ICU beds compared to the previous year. We defined total ICU beds using the summed counts of four HCRIS bed categories that were available throughout the study interval: intensive care beds, surgical intensive care beds, cardiac intensive care beds and burn intensive care beds (1). For each study year we categorized hospitals into five mutually exclusive groups according to their change in ICU bed numbers from the prior year: i.) new hospitals with ICU beds, ii.) previously existing hospitals with increased numbers of ICU beds, iii.) previously existing hospitals with unchanged numbers of ICU beds, iv.) previously existing hospitals with decreased numbers of ICU beds, and v.) previously existing hospitals that closed. We did not categorize 1996 since this was the first year of our data, instead using 1996 data only to categorize 1997 hospitals.

Some hospitals had reporting gaps during the study interval. To avoid classifying these hospitals as closed and then subsequently reopened in a later reporting year, we considered records to be missing in error if there were cost reports both before and after the year of the missing report. In these cases we carried forward and replaced the most recent values for hospital characteristics.

The independent variables of interest were hospital size, intensive care unit size, hospital teaching status, hospital ownership, urbanicity and intensive care unit occupancy. We selected these variables based on their availability in the HCRIS reports and because of their hypothesized relationship with ICU bed growth (4). We defined hospital size using four categories: small (< 100 beds), medium (100 to 249 beds), large (250 to 499 beds) and very large (≥ 500 beds). We defined ICU size using four categories: small (1–5 beds), medium (6–15 beds), large (16–30 beds) and very large (> 30 beds). We defined teaching status using the resident-to-bed ratio, classifying hospitals as non-teaching if they had no resident trainees, small teaching if the ratio was more than zero and less than 0.2, and large teaching if the ratio was 0.2 or greater (6). We obtained ownership information directly from HCRIS, classifying hospitals as nonprofit, for-profit and government. We defined a hospital as urban if its address was located inside a US Census Bureau urban area (5). We obtained occupancy information from HCRIS by dividing each hospital's number of ICU bed days by the number of ICU bed days available. To simplify reporting, we categorized intensive care occupancy into quartiles based on the overall distribution.

Analysis

We performed the analysis in two parts. First we summarized ICU bed counts by hospitals characteristics over time. Second we created a multivariable model to evaluate hospital characteristics associated with an increasing number of ICU beds.

In the first part of the analysis we graphically analyzed ICU bed counts over the years 1997 to 2011. We showed annual counts using figures, superimposing three graphs: (1) bar charts showing the annual change in ICU beds for each hospital change category (new, increased, unchanged, decreased and closed), (2) line plots showing the net annual change in ICU beds, and (3) area plots showing the cumulative annual number of ICU beds. We created separate graphs for all hospitals, and hospitals stratified by total hospital bed size, intensive care size, teaching status, ownership and urbanicity. We created these figures to show the direction and magnitude of ICU bed changes for different hospital types on annual and cumulative bases. We did not include occupancy because hospital membership in each occupancy category varied widely from year to year, making graphical interpretation difficult.

In the second part of the analysis, we statistically evaluated the association between hospital characteristics and whether the hospital increased their number of ICU beds. We summarized raw numbers of beds and hospitals in each category in the years 1997 and 2011, and compared the categorical differences using chi-square tests. We then used logistic regression with generalized estimating equations with to model the longitudinal association between hospital characteristics and next-year ICU bed growth. The unit of analysis for this regression was the hospital-year. This approach allowed us to examine year-specific changes while accounting for year-to-year correlations between observations, a condition inherent in our repeated measures study design. The primary dependent variable was whether the hospital increased in number of ICU beds (versus remained unchanged, decreased number of ICU beds or closed). The independent variables of interest were identical to the univariate analysis, but with the addition of occupancy. The final logistic regression model also controlled for geographic region (Northeast, South, Midwest and West by US Census region) and baseline number of total ICU beds.

In addition to a main effects analysis we evaluated whether there were interactions between occupancy and other hospital characteristics (hospital size, hospital teaching status, hospital ownership and urbanicity). We specified these interactions to individually evaluate if different hospital types responded to occupancy differently.

To understand the role of long-term occupancy in addition to immediate past-year occupancy (since hospitals may be able to quickly scale up ICU beds in response to short term changes in demand), we performed a sensitivity analysis using a retrospective three-year moving average of ICU occupancy, limited to hospitals that provided three years or more of data. We performed this analysis to evaluate the possible lagged time effect of occupancy on ICU bed expansion.

We used a lagged autocorrelation matrix and robust standard errors in the generalized estimating equation model. We exponentiated the regression coefficients to produce odds ratios that can be interpreted as the adjusted relative odds of increasing the number of ICU beds in the following year for hospitals with the characteristic in question compared to other hospitals.

We performed data management and statistical analysis using STATA 13.1 (StataCorp, College Station, TX). We used ArcGIS 10.1 (ESRI, Redlands, CA) to geolocate hospitals and assign urban status. Main effects were considered statistically significant at $p<0.05$ and interaction terms were considered statistically significant at $p<0.01$. This research involved analysis of publicly available data at the hospital level and therefore did not meet the University of Pittsburgh Institutional Review Board definition of human subject research.

Results

The analysis included 4,457 individual hospitals and 55,434 individual cost reports (median reports per hospital = 16; IQR: 8 – 16). We interpolated 431 (0.8%) hospital-year records for 220 (4.9%) hospitals with missing cost reports, resulting in a final dataset of 55,865 hospital years. Omitting the first year of the analysis we categorized annual hospital cost reports into the five ICU bed supply categories as follows: 678 new hospital-years (1.3%); 5,142 increased supply hospital-years (9.9%); 41,890 unchanged hospital-years (80.3%); 3,495 decreased supply hospital-years (6.7%) and 992 closed (1.9%) hospital-years.

There was a net increase in ICU beds almost all years. This change was attributable largely to growth in existing hospitals, outweighing shrinkage in existing hospitals, although each year also contained significant numbers of new hospitals with ICU beds and closed hospitals that had contained ICU beds (Figure 1).

As shown in the stratified analyses (Table 1 and Supplemental Figures 1 through 5) this growth predominantly occurred in hospitals with at least 250 hospital beds (n=+18,327 beds; 91.2% of net growth between 1997 and 2011), hospitals with more than 30 ICU beds (n= +25,419 beds; 100% of net growth), teaching hospitals (n=+13,471; 71.2% of net growth), non-profit hospitals (n=+12,801; 68.5% of net growth), hospitals in the highest quartile of ICU occupancy (n+10,157; 54.0% of net growth), urban hospitals (n=+17,665; 94.6% of net growth) and hospitals in the Northeast (n=+9,620; 51.5% of net growth). Taken together, ICU beds were increasingly concentrated in large, urban teaching hospitals. Small, medium and large hospitals decreased in numbers over the study interval, as did small, medium and large ICUs.

The longitudinal analyses examining univariate factors associated with next-year growth similarly showed that growth was most likely to occur in hospitals with at least 500 hospital beds (OR for next year growth compared to hospitals with less than 100 beds = 15.82, 95% CI: 12.83 – 18.01, $p<0.01$), hospitals with more than 30 ICU beds (OR for next year growth compared to ICUs with 1 to 5 beds = 8.41, 95% CI: 7.21 – 9.81; $p<0.01$), large teaching hospitals (OR for next year growth compared to non-academic hospitals = 4.29, 95% CI: 3.83 – 4.81, $p<0.01$), hospitals in the highest quartile of occupancy (OR for next year growth compared to hospitals in lowest quartile occupancy = 7.68, 95% CI: 6.75 – 8.73, $p<0.01$) and urban hospitals (OR for next year growth compared to rural hospitals = 2.33, 95% CI: 1.91 – 2.83, $p<0.1$) (Table 2).

In the longitudinal multivariable analysis we identified significant interactions between intensive care occupancy and number of hospital beds and hospital teaching status ($p<0.01$ for each). This analysis showed that the teaching status and hospitals size were independently associated with next-year growth in way that is conditional on occupancy (Table 3): controlling for other factors, large hospitals with high occupancy were most likely to observe next-year growth (adjusted OR: 18.9; 95% CI: 14.0 – 25.5; $p<0.01$; Figure 2); and teaching hospitals with higher occupancy were most likely to observe next-year growth adjusted OR: 7.27; 95% CI: 5.33 – 9.91; $p<0.01$, Figure 3).

Our sensitivity analysis examining three-year moving averages of occupancy produced similar results to the main findings (Supplemental Tables 1 & 2).

Discussion

Growth in the number of ICU beds in the US was previously described at the national level (2, 3). In this analysis we demonstrate, however, that growth is not occurring uniformly across hospitals. Adjusting for other factors, larger hospitals, teaching hospitals, and hospitals with high ICU occupancy were more likely to increase their number of ICU beds compared to other hospitals. In contrast, small hospitals, non-teaching hospitals and hospitals with relatively low ICU occupancy were less likely to add ICU beds in the subsequent year, even after adjusting for other factors.

These findings have important implications for critical care delivery in the United States. Primarily they demonstrate that critical care is not just growing in ever fewer hospitals, but it is predominantly expanding in specific types of hospitals — large and very large academic centers. The result may be a form of *de facto* regionalization, perhaps leading to improvements in the quality of critical care (7). Volume-outcome relationships, in which higher case load is associated with improved quality, are present across many domains of intensive care (7–11). Therefore it is conceivable that as volumes rise, outcomes will improve. At the same time, intensive care expansion in the largest hospitals may have unintended consequences, such as reduced quality in small hospitals that lose their critical care capacity (12) and reduced geographic access in regions served by smaller hospitals (13, 14). In silico simulation studies reveal that the former may be less of concern (15), but the relationship between regionalization and reduced quality at small hospitals awaits empiric investigation. There is recent evidence that intensive care provides measureable benefits to the marginal patient (16), making future research to understand the clinical implications of this expansion and centralization ever more relevant in the current health care landscape (17).

A greater proportion of new ICU beds were added in teaching hospitals during the study period. A shift in care to academic centers could result in higher quality for certain conditions (18–21). However, the expanding intensive care services in academic centers may also come with unintended consequences. Though the number of ICU beds is increasing, the number of American College of Graduate Medical Education residency slots is not comparably growing – and will not meet projected workforce demands (22). It is also unlikely that more resources will be allocated to training slots, either by the Federal government or by hospitals themselves (23). Consequently, a continued shift of intensive care to academic hospitals could result in new workforce strain, perhaps mitigating quality gains that are hypothesized at high volume academic centers.

On both one- and three-year horizons, we found that high occupancy was associated with expansion of ICU bed supply. High occupancy can produce system strain, albeit with variable effects on quality (24–30). It appears that hospitals may increase beds in part to relieve this pressure. Our results therefore go against the theory of supply-induced demand in critical care, which posits that increases in ICU bed supply are driving ICU utilization, rather than ICU utilization driving demand (31–36). This finding is important because it suggests that at least *initial* ICU bed expansion is responsive to increased demand in some hospitals. However, future work should evaluate on what timeline and at what threshold hospitals decrease their ICU bed supply when experiencing reduced ICU demand. Hospitals may add ICU beds in the face of transient capacity strain, resulting too many beds when demand normalizes. In these centers, ICU beds will either go unused or will be used for patients that are not likely to benefit from intensive care (37).

We observed a marked increase in numbers of ICU beds from 2009 to 2011. One possibility for this accelerated growth is the economic recovery that occurred after then end of a well-described economic recession in the United States (2007–2009) (38). However, the Office of the Actuary in the Centers for Medicare and Medicaid Services reported low health care growth rates between 2009 and 2011, calling this hypothesis into question (39). These patterns extend back to 2005 and extend through at least 2012 (40). Therefore it is more likely that these changes simply reflect changing spending priorities for individual hospitals, a hypothesis that deserves further study.

Our study has several limitations. The data were obtained from HCRIS, a self-reported annual summary that is subject to potential errors from inaccurate information, data miscoding or missing annual submissions. However, we performed value range checking and interpolated annual summary data when missing data was present. While we found a strong indication that ICU occupancy is associated with subsequent ICU bed changes, we did not simultaneously evaluate the effect of hospital occupancy. Hospital occupancy represents an additional system strain, which could impact hospital decisions regarding bed expansion. We also could not study the effect of hospital networks, wherein ICU bed supply is changed in a coordinated fashion between groups of hospitals (41, 42). Although system level effects are of interest, network relationship information is not available from HCRIS. Finally, we could not measure other hospital level responses to capacity strain – such as throughput management (43), elective surgery scheduling (44–46) or patient transfers.

Our study provides convincing evidence that the expansion of intensive care in the US is increasingly occurring in larger academic hospitals, at least in part, driven by high ICU occupancy. Whether these changes result in improved patient outcomes and lower costs is unknown.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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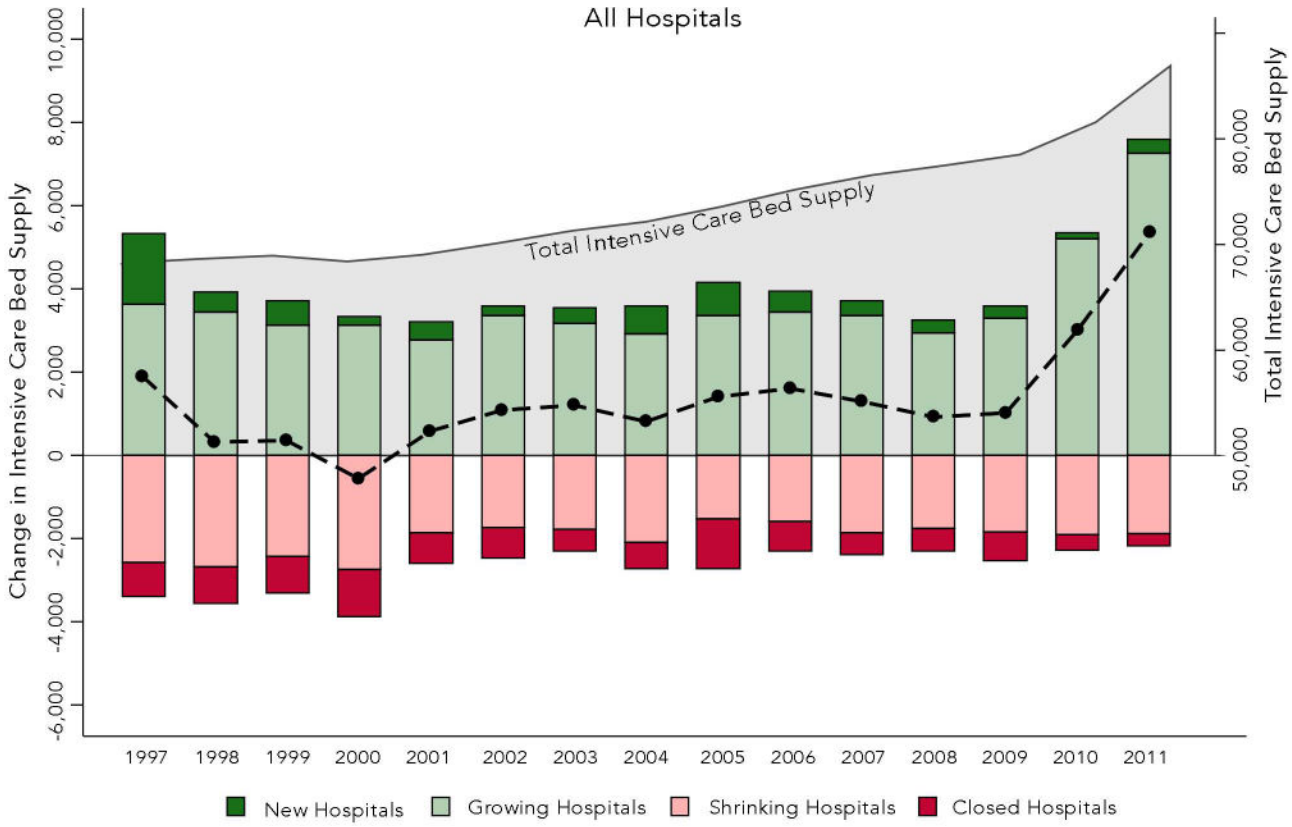

Figure 1.

Change in intensive care bed supply by year attributable to new hospitals, growing hospitals, shrinking hospitals and closed hospitals in the United States between 1997 and 2011 (left axis scale). The black dashed line shows the net annual change in intensive care bed supply. The light grey region shows the national intensive care bed supply (right axis scale). Note: Intensive care beds from hospitals with no change in a given year (compared to the prior year) *are* included in the right axis summary count.

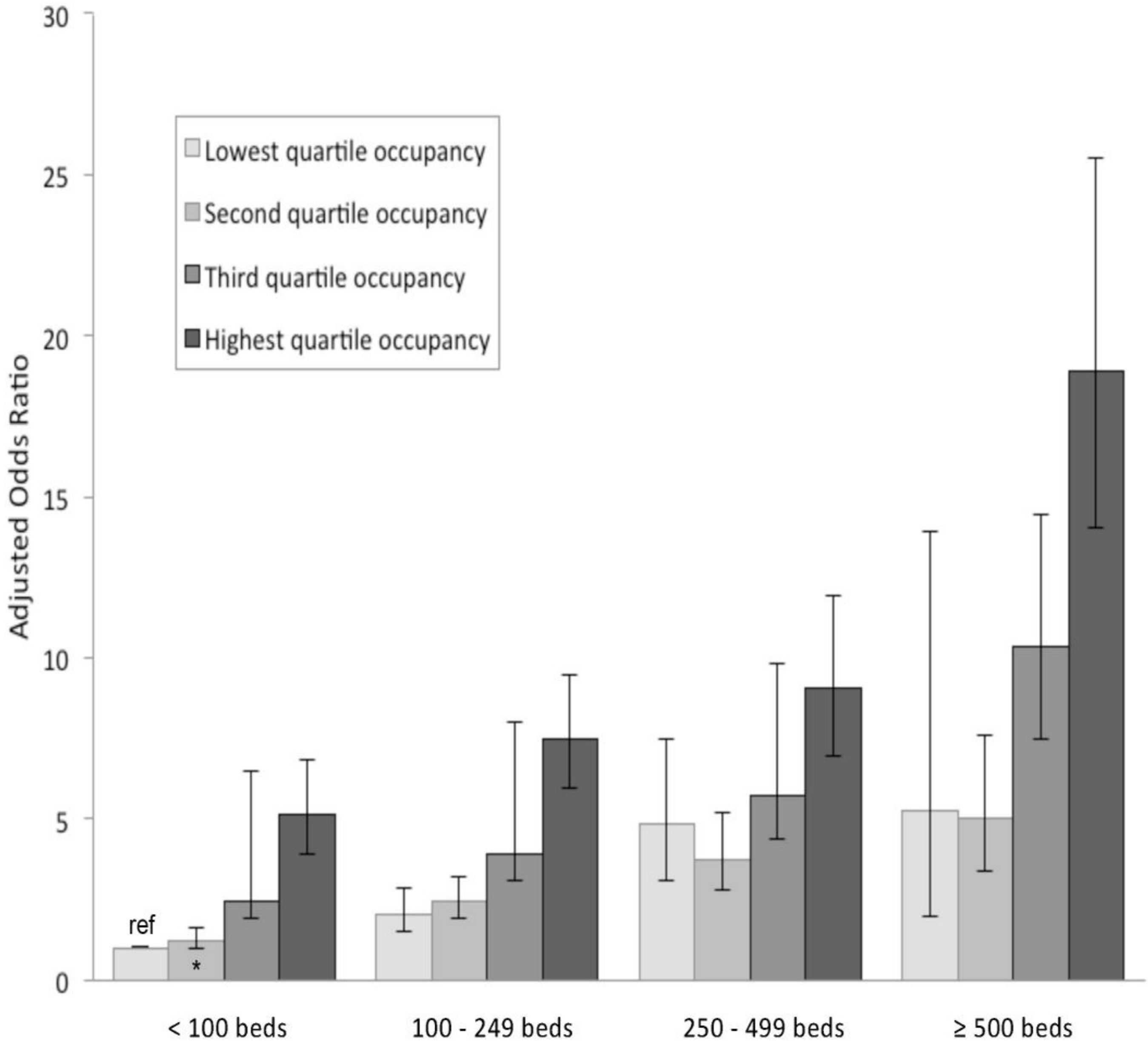

Figure 2.

Odds of increasing intensive care beds in subsequent year by hospital size and quartile of occupancy. Model adjusts for baseline number of intensive care beds, hospital academic status, hospital ownership, geographic region and urbancity. The reference category for comparisons is lowest quartile of intensive care occupancy and less than one hundred hospital beds. All comparisons have p-values <0.01, with exception of the comparison marked with an asterisk.

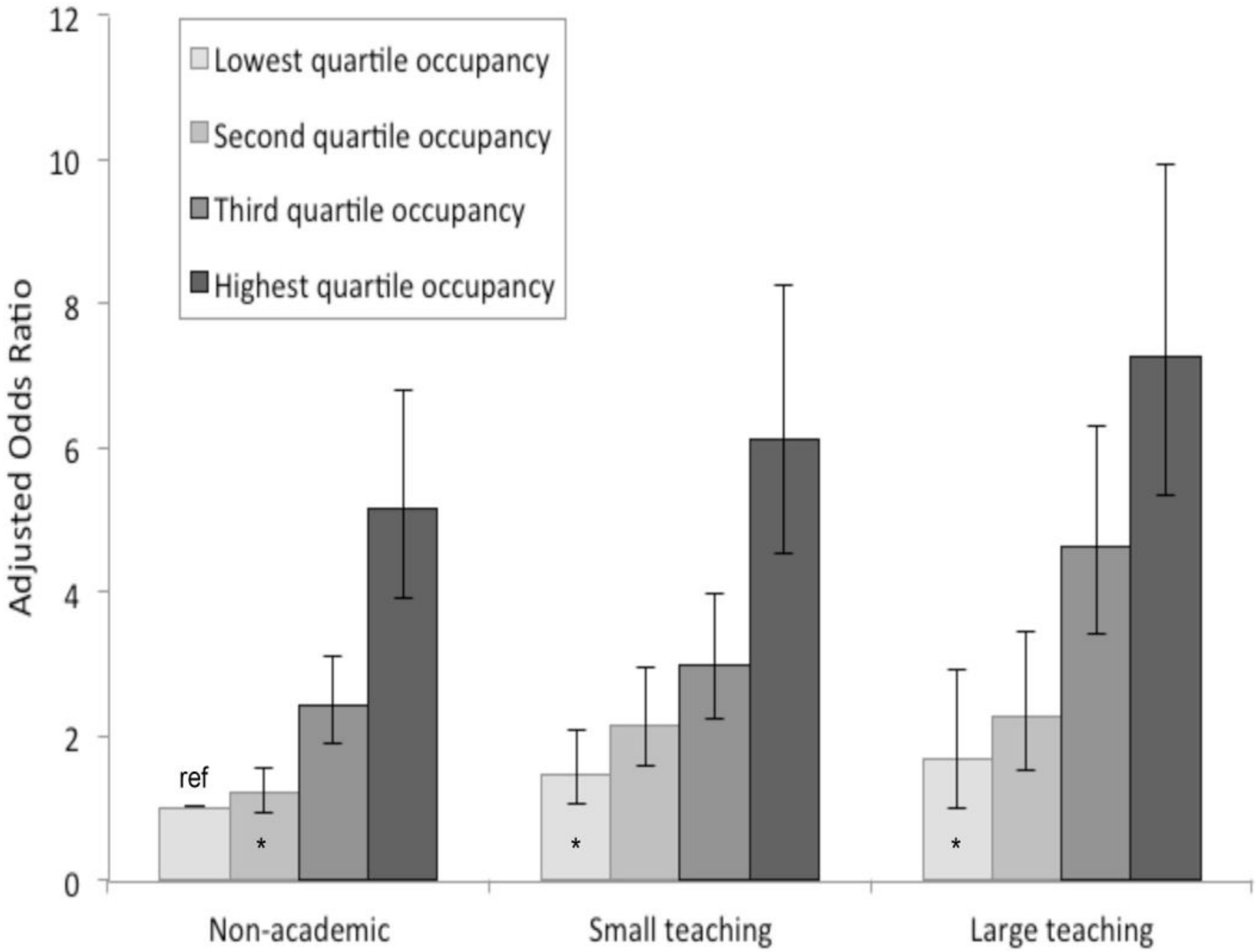

Figure 3.

Odds of increasing intensive care beds in subsequent year by teaching status and quartile of occupancy. Model adjusts for baseline number of intensive care beds, total hospital beds, hospital ownership, geographic region and urbancity. The reference category for comparisons is lowest quartile of intensive care occupancy and non-teaching status. All comparisons have p-values <0.01, with exception of comparisons marked with asterisks.

Table 1

Intensive care bed supply and hospital characteristics in the United States between 1997 and 2011

	Intensive Care Beds							Hospitals						
	1997 (n=68,264)		2011 (n=86,945)		Change between 1997 and 2011		p-value	1997 (n=3,680)		2011 (n=3,179)		Change between 1997 and 2011		p-value
Hospital size, n (%)														
Small (<100 beds)	8,828	(12.9)	7,537	(8.7)	−1,291	(−4.2)	<0.01	1,391	(37.8)	1,100	(34.6)	−291	(−20.9)	0.01
Medium (100–249 beds)	22,221	(32.6)	23,866	(27.4)	+1,645	(+5.2)		1,392	(37.8)	1,211	(38.1)	−181	(−13.0)	
Large (250–499 beds)	23,227	(34.0)	31,711	(36.5)	+8,484	(+2.5)		680	(18.5)	649	(20.4)	−31	(−4.6)	
Very large (≥ 500 beds)	13,988	(20.5)	23,831	(27.4)	+9,843	(+6.9)		217	(5.9)	219	(6.9)	+2	(+0.9)	
Intensive care size, n (%)														
Small (1–5 beds)	1,811	(2.7)	1,200	(1.4)	−611	(−1.3)	<0.01	511	(13.9)	334	(10.5)	−177	(−34.6)	<0.01
Medium (6–15 beds)	14,458	(21.2)	10,805	(12.4)	−3,653	(−8.8)		1,665	(45.2)	1,222	(38.4)	−443	(−26.6)	
Large (16–30 beds)	16,845	(24.7)	14,371	(16.5)	−2,474	(−8.2)		818	(22.2)	691	(21.7)	−127	(−15.5)	
Very large (>30 beds)	35,150	(51.5)	60,569	(69.7)	+25,419	(+18.2)		686	(18.6)	932	(29.3)	+246	(+35.9)	
Hospital teaching status, n (%)														
Nonteaching	29,569	(43.3)	34,779	(40.0)	+5,210	(−3.3)	<0.01	2,525	(68.6)	2,150	(67.6)	−375	(−14.9)	0.57
Small teaching	20,990	(30.7)	27,411	(31.5)	+6,421	(+0.8)		744	(20.2)	650	(20.4)	−94	(−12.6)	
Large teaching	17,705	(25.9)	24,755	(28.5)	+7,050	(+2.6)		411	(11.2)	379	(11.9)	−32	(−7.8)	
Hospital ownership, n (%)														
Nonprofit	46,435	(68.0)	59,236	(68.1)	+12,801	(+0.1)	<0.01	2,315	(62.9)	2,010	(63.2)	−305	(−13.2)	0.83
For profit	12,181	(17.8)	14,570	(16.8)	+2,389	(−1.0)		769	(20.9)	671	(21.1)	−98	(−12.7)	
Government	9,648	(14.1)	13,139	(15.1)	+3,491	(+1.0)		596	(16.2)	498	(15.7)	−98	(−16.4)	
Intensive care occupancy, n (%)														
Lowest quartile (≤40.4%)	8,909	(13.1)	8,793	(10.1)	−116	(−2.9)	<0.01	986	(26.8)	807	(25.4)	−179	(−18.2)	<0.01
2nd quartile (>40.4% to 57.5%)	15,049	(22.0)	18,547	(21.3)	+3,498	(−1.5)		1,005	(27.3)	851	(26.8)	−154	(−15.3)	
3rd quartile (>57.5% to 71.8%)	23,582	(34.5)	28,724	(33.0)	+5,142	(−0.4)		991	(26.9)	813	(25.6)	−178	(−18.0)	
Highest quartile (>71.8%)	20,724	(30.4)	30,881	(35.5)	+10,157	(+4.9)		698	(19.0)	708	(22.3)	+10	(+1.4)	

	Intensive Care Beds							Hospitals						
	1997 (n=68,264)		2011 (n=86,945)		Change between 1997 and 2011		p-value	1997 (n=3,680)		2011 (n=3,179)		Change between 1997 and 2011		p-value
Urbanicity, n (%)														
Rural location	1,993	(2.9)	3,009	(3.5)	+1,016	(+0.6)	<0.01	284	(7.7)	290	(9.1)	+6	(+2.1)	0.04
Urban location	66,271	(97.1)	83,936	(96.5)	+17,665	(−0.6)		3,396	(92.3)	2,889	(90.9)	−507	(−14.9)	
Region, n (%)														
Northeast	27,309	(40.0)	36,929	(42.5)	+9,620	(+35.2)	<0.01	1,470	(39.9)	1,318	(41.5)	−152	(−10.3)	0.35
South	12,735	(18.7)	14,092	(16.2)	+1,357	(+10.7)		635	(17.3)	517	(16.3)	−118	(−18.6)	
Midwest	14,937	(21.9)	18,262	(21.0)	+3,325	(+22.3)		872	(23.7)	717	(22.6)	−155	(−17.8)	
West	13,283	(19.5)	17,662	(20.3)	+4,379	(+33.0)		703	(19.1)	627	(19.7)	−76	(−10.8)	

* Intensive care bed and hospital counts include interpolation in years with missing cost reports

Table 2

Univariate associations between annual increase in intensive care beds and hospital characteristics in the United States between 1997 and 2011

Characteristic	OR	95% CI	*P* value
Hospital size			
Small (<100 beds)	ref		
Medium (100–249 beds)	3.07	(2.75 – 3.43)	< 0.01
Large (250–499 beds)	6.48	(5.79 – 7.25)	< 0.01
Very large (≥ 500 beds)	15.82	(13.83 – 18.01)	< 0.01
Intensive care size			
Small (1–5 beds)	ref		
Medium (6–15 beds)	1.74	(1.49 – 2.03)	< 0.01
Large (16–30 beds)	3.70	(3.16 – 4.32)	< 0.01
Very large (>30 beds)	8.41	(7.21 – 9.81)	< 0.01
Hospital teaching status			
Non-academic	ref		
Small teaching	2.55	(2.32 – 2.80)	< 0.01
Large teaching	4.29	(3.83 – 4.81)	< 0.01
Hospital ownership			
Non-profit	ref		
For-profit	0.87	(0.78 – 0.96)	< 0.01
Government	0.87	(0.76 – 1.00)	0.04
Intensive care occupancy			
Lowest quartile (≤40.4%)	ref		
2nd quartile (>40.4% to 57.5%)	1.76	(1.53 – 2.02)	< 0.01
3rd quartile (>57.5% to 71.8%)	3.73	(3.27 – 4.26)	< 0.01
Highest quartile (>71.8%)	7.68	(6.75 – 8.73)	< 0.01
Urbanicity			
Rural	ref		
Urban	2.33	(1.91 – 2.83)	< 0.01
Region			
Northeast	ref		
South	0.72	(0.63 – 0.83)	< 0.01
Midwest	0.80	(0.71 – 0.91)	< 0.01
West	0.94	(0.84 – 1.06)	0.31

Table 3

Fully adjusted multivariable model for hospital characteristics and annual increase in intensive care beds in the United States between 1997 and 2011

Characteristic	OR	95% CI	*P* value	Interaction term P value
Hospital size				< 0.01
Small (<100 beds)				
Lowest occupancy	ref			
2nd quartile occupancy	1.21	(0.95 – 1.55)	0.12	
3rd quartile occupancy	2.42	(1.90 – 3.09)	< 0.01	
Highest occupancy	5.16	(3.92 – 6.79)	< 0.01	
Medium (100–249 beds)				
Lowest occupancy	2.04	(1.49 – 2.78)	< 0.01	
2nd quartile occupancy	2.46	(1.90 – 3.18)	< 0.01	
3rd quartile occupancy	3.91	(3.07 – 4.98)	< 0.01	
Highest occupancy	7.48	(5.93 – 9.43)	< 0.01	
Large (250–499 beds)				
Lowest occupancy	4.82	(3.11 – 7.46)	< 0.01	
2nd quartile occupancy	3.76	(2.75 – 5.15)	< 0.01	
3rd quartile occupancy	5.71	(4.32 – 7.54)	< 0.01	
Highest occupancy	9.08	(6.93 – 11.90)	< 0.01	
Very large (≥ 500 beds)				
Lowest occupancy	5.25	(1.98 – 13.89)	< 0.01	
2nd quartile occupancy	5.03	(3.35 – 7.54)	< 0.01	
3rd quartile occupancy	10.38	(7.47 – 14.42)	< 0.01	
Highest occupancy	18.92	(14.03 – 25.50)	< 0.01	
Hospital teaching status				< 0.01
Non-academic				
Lowest occupancy	ref			
2nd quartile occupancy	1.21	(0.95 – 1.54)	0.12	
3rd quartile occupancy	2.42	(1.90 – 3.09)	< 0.01	
Highest occupancy	5.16	(3.92 – 6.79)	< 0.01	
Small teaching				
Lowest occupancy	1.46	(1.04 – 2.05)	0.03	
2nd quartile occupancy	2.14	(1.57 – 2.92)	< 0.01	
3rd quartile occupancy	2.98	(2.25 – 3.96)	< 0.01	
Highest occupancy	6.11	(4.53 – 8.25)	< 0.01	
Large teaching				
Lowest occupancy	1.68	(0.98 – 2.89)	0.06	
2nd quartile occupancy	2.29	(1.53 – 3.44)	< 0.01	
3rd quartile occupancy	4.62	(3.40 – 6.28)	< 0.01	
Highest occupancy	7.27	(5.33 – 9.91)	< 0.01	

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Characteristic	OR	95% CI	*P* value	Interaction term P value
Hospital ownership				–
Non-profit	ref			
For-profit	1.00	(0.90 – 1.10)	0.97	
Government	0.95	(0.85 – 1.06)	0.34	
Urbanicity				–
Rural	ref			
Urban	0.90	(0.74 – 1.09)	0.29	

Model controls for baseline number intensive care beds and geographic region.