OPEN

Characteristics of U.S. Acute Care Hospitals That Have Implemented Telemedicine Critical Care

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OBJECTIVES: Telemedicine critical care is associated with improved efficiency, quality, and cost-effectiveness. As of 2010, fewer than 5% of U.S. hospitals had telemedicine critical care, and fewer than 10% of ICU beds were covered. We evaluated recent telemedicine critical care implementation and bed coverage rates in the United States and compared characteristics of hospitals with and without telemedicine critical care.

DESIGN: Cross-sectional study of 2018 American Hospital Association Annual Survey Database.

SETTING: U.S. hospitals.

PATIENTS: None.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: We obtained data regarding telemedicine critical care implementation, ICU capability (defined as ≥ 1 ICU bed), other hospital characteristics, and the Herfindahl-Hirschman Index, a measure of ICU market competition based on hospital referral regions. Among 4,396 hospitals (response rate 71%), 788 (17.9%) had telemedicine critical care, providing potential coverage to 27,624 (28% of total) ICU beds. Among 306 hospital referral regions, 197 (64%) had a respondent hospital with telemedicine critical care. Telemedicine critical care implementation was associated with being a nonprofit (odds ratio, 7.75; 95% CI, 5.18–11.58) or public (odds ratio, 4.16 [2.57–6.73]) compared with for-profit hospital; membership in a health system (odds ratio, 3.83 [2.89–5.08]; stroke telemedicine presence (odds ratio, 6.87 [5.35–8.81]); ICU capability (odds ratio, 1.68 [1.25–2.26]); and more competitive ICU markets (odds ratio per 1,000-point decrease in Herfindahl-Hirschman Index 1.11 [1.01–1.22]). Notably, rural critical access hospitals had lower odds of telemedicine critical care implementation (odds ratio, 0.49 [0.34–0.70]). Teaching status, geographic region, and rurality were not associated with telemedicine critical care implementation.

CONCLUSIONS: About one fifth of respondent hospitals had telemedicine critical care by 2018, providing potential coverage of nearly one third of reported ICU beds. This represents a substantial increase in telemedicine critical care implementation over the last decade. Future expansion to include more rural hospitals that could benefit most may be aided by addressing hospital financial and market barriers to telemedicine critical care implementation.

KEY WORDS: electronic intensive care unit; intensive care unit organization; telemedicine; tele-critical care; tele-intensive care unit

Telemedicine critical care (TCC) involves live, interactive video, and audio interactions with remotely located critically ill patients and bedside providers, along with remote access to real-time patient data. Although TCC programs vary widely in implementation methods and care delivery models, TCC has been shown to improve efficiency and quality of

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ICU care, as well as cost-effectiveness and satisfaction among patients and care providers (1, 2).

Broad adoption of TCC has been proposed to address critical care physician shortages especially in small rural hospitals (3). As of 2010, only 4.6% of U.S. hospitals had implemented TCC, and only 7.9% of ICU beds were covered by the technology (4). However, with changes in the U.S. healthcare system over the past decade, implementation rates as well as factors affecting implementation may have changed substantially. TCC was originally conceived to increase access to critical care specialists for critically ill and injured patients, and its implementation thus typically required physical ICU beds. However, as of 2015, only 60% of U.S. registered hospitals reported at least one ICU bed (5), and technology-enabled TCC has been increasingly deployed beyond the physical confines of the ICU to support emergent needs and triage of critically ill patients in hospitals with no physical ICU beds (6).

The objectives of this study were two-fold: first, to determine the number of U.S. acute care hospitals (with and without ICU capabilities) that have implemented TCC and the proportion of ICU beds (among hospitals with ICU capability) with potential TCC coverage and second, to determine hospital and market characteristics associated with TCC implementation.

MATERIALS AND METHODS

Data Sources

We obtained data regarding TCC implementation, ICU capabilities, and other hospital characteristics from the fiscal year (FY) 2018 American Hospital Association (AHA) Annual Survey Database (7). This dataset is derived from the annual surveys sent to all AHA-registered U.S. hospitals and voluntarily completed. Survey data from respondent hospitals are merged into one master dataset each year. We also obtained and linked metropolitan statistical area (MSA) household income data from the 2018 American Community Survey to the AHA survey data using hospital core-based statistical area (CBSA) codes.

Hospital and Market Characteristics

Hospital characteristics included ownership status, teaching status, geographic region, membership in a health system, total hospital beds, ICU capability (defined as ≥ 1 ICU bed), and ICU bed counts. To determine market characteristics, we evaluated three aspects that can potentially influence a hospital's investment in TCC: rurality, intensivist staffing, and market competitiveness.

To determine rurality, we used the AHA's CBSA categorization of hospitals as metropolitan, micropolitan, or rural. We evaluated intensivist staffing using the number of privileged and full-time equivalent (FTE) intensivists reported in the AHA survey. A privileged intensivist is defined by the AHA as a physician with special training to work with critically ill patients and generally provides medical-surgical, cardiac, pediatric, neonatal, and other types of intensive care services (7). Physicians with courtesy, honorary, or provisional privileges or who provide only nonclinical service are excluded. FTE values are calculated as the total number of hours worked by physicians over the full 12-month reporting period divided by the normal number of hours worked by a full-time employee for that same period. Market competitiveness was determined using the Herfindahl-Hirschman Index (HHI)—the sum of squares of market shares within a market which ranges from 0 (perfectly competitive) to 10,000 (perfectly concentrated) (8). We defined regional ICU markets using the Dartmouth Atlas of hospital referral regions (HRRs) and calculated market share by estimating a hospital's ICU bed count as the proportion of total ICU beds in each hospital's HRR.

We also studied hospitals' technology-related measures (other telehealth use, e.g., for stroke) and designation as a critical access hospital (CAH). CAH designation is determined by Centers for Medicare and Medicaid Services and requires that hospitals have fewer than 25 beds, be located more than 35 miles from the nearest hospital, and maintain average length of stay of less than 96 hours (9).

Telemedicine Capability

The 2018 AHA survey included a question on "electronic ICU (eICU)" as a hospital facility or service. Responding hospitals indicated whether the service was owned or provided by the hospital, by their health system, or through a formal contractual arrangement or joint venture with another provider that was not part of the health system. We categorized a hospital as having TCC if they responded yes to any of these three modalities for eICU implementation.

Statistical Analysis

Hospital characteristics for continuous variables were summarized using medians and interquartile ranges (IQRs). Frequency counts with percentages were used to describe categorical variables. We estimated the number of hospitals with TCC as a proportion of all responding hospitals. We used these data to estimate the total number of ICU beds potentially covered by TCC as well as the proportion of total ICU beds with potential TCC coverage among respondent hospitals with ICU capability. Comparisons were made between TCC implementing and nonimplementing hospitals using two-sample *t* tests and the Mann-Whitney-Wilcoxon rank-sum test for continuous variables and chi-square tests for categorical variables.

To determine characteristics associated with TCC implementation, we estimated a multivariable generalized additive mixed regression model, accounting for clustering of hospitals at the ICU market level. We considered all variables for inclusion, with the exception of ICU bed count, FTE intensivists, and privileged intensivists (due to their correlation with ICU capability) and MSA income (due to absence of rural income data). We tested for linearity of relationships between our outcome variable (TCC implementation) and the continuous explanatory variables and found that total bed count showed significant nonlinear ($p < 0.05$) relationships, whereas the Herfindahl-Hirschman Index had a striking linear relationship (**Supplemental Fig. 1**, http://links.lww.com/CCX/A694 and **Supplemental Fig. 2**, http://links.lww.com/CCX/A695). Total bed count was therefore included in the model as restricted splines and subsequently as piecewise linear functions at appropriate cut points. To mitigate the effect of outliers, the upper and lower values of total bed count were trimmed at 10 and 1,631, respectively. The model therefore included the following categorical variables: hospital ownership structure (nonprofit, public, and for-profit), teaching status, geographic region, rurality, health system membership, ICU capability, stroke telemedicine presence, CAH designation and two continuous variables: total bed count and the HHI.

All analyses were performed using R Studio Version 3.6.2 and SAS Version 9.4 for Windows (SAS Institute, Cary, NC). All hypothesis tests were two sided with a significance level of 0.05. The Washington University Human Research Protection Office deemed this study (IRB number 202101113) exempt due to its use of hospital-level data.

RESULTS

Hospital Characteristics

In FY 2018, of 6,218 registered hospitals, 4,400 (71%) responded to the AHA survey (**Fig. 1**). Among respondent hospitals overall (**Table 1**), most (81.9%) were located in nonrural areas, and two thirds (68.4%) were part of an established health system. Approximately one in five were for profit (21.2%) or designated as CAHs (23%). The median (IQR) hospital and ICU bed counts were 93 (32–219) and 6 (0–25), respectively, whereas the median (IQR) FTE and privileged intensivist counts were 9 (4–21) and 0 (0–11), respectively.

Among responding hospitals, 2,763 (62.9%) had ICU capability with a total of 98,610 ICU beds; 788 hospitals (17.9%) reported TCC implementation, providing potential coverage to 27,624 ICU beds (28% of total). Approximately one quarter of hospitals (24%) with ICU capability and nearly one tenth of hospitals (7.6%) without ICU capability reported TCC implementation.

Hospital and Market Characteristics by TCC Implementation

There was geographic variability in the use of TCC. Of 306 HRRs in the United States, 197 (64.4%) had at least one respondent hospital with TCC, whereas 188 (61.4%) had a hospital with ICU capability and TCC coverage (**Fig. 2**). Hospital and market characteristics by TCC implementation status are summarized in Table 1. Compared with nonimplementing hospitals, hospitals that implemented TCC were more likely to be large (in terms of total and ICU bed counts), nonprofit, teaching hospitals, located in nonrural areas, members of a health system, with ICU and stroke telemedicine capabilities, and more intensivists. Implementing hospitals were equally likely to be located across the four U.S. regions, less likely to be designated as CAHs, but more likely to be in more competitive ICU markets and in metro areas with higher household incomes.

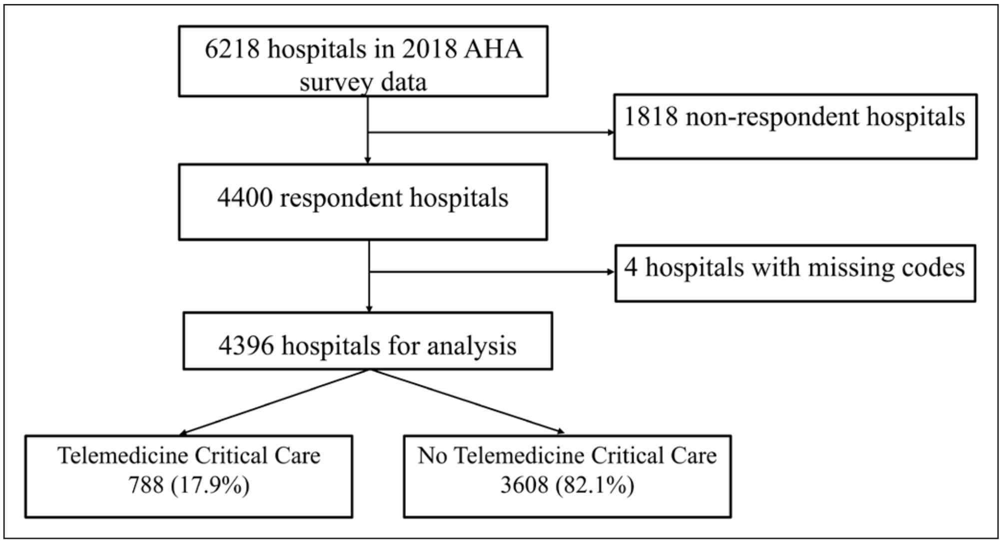

Figure 1. Study flow chart. AHA = American Hospital Association.

Multivariable Associations With TCC Implementation

Multivariable analyses showed higher TCC implementation among nonprofit hospitals (odds ratio [OR], 7.75; 95% CI, 5.18–11.58) and public hospitals (OR, 4.16 [2.57–6.73]) compared with for-profit hospitals (**Table 2**). TCC was also significantly associated with membership in a health system (OR, 3.83 [2.89–5.08]), presence of an ICU (OR, 1.68 [1.25–2.26]), and stroke telemedicine presence (OR, 6.87 [5.35–8.81]). CAHs were less likely to have TCC compared with non-CAHs (OR, 0.49 [0.34–0.70]). Above a cut off of 373 beds, larger hospital size was associated with higher odds of TCC implementation (OR per additional 25 hospital beds 1.11 [1.06–1.16]) (Supplemental Fig. 1, http://links.lww.com/CCX/A694). Lower regional ICU market concentration (more competition) was associated with higher TCC implementation (OR 1.11 per 1,000-point decrease in HHI [1.01–1.22]). Teaching status (OR vs nonteaching 1.12 [0.87–1.43]), geographic region (OR Midwest vs Northeast 1.19 [0.66–2.15]), and rurality (OR rural vs nonrural 0.88 [0.61–1.29]) were not significantly associated with TCC implementation.

DISCUSSION

In this cross-sectional study of 4,396 acute care hospitals that responded to the AHA survey for FY 2018, roughly one fifth of U.S. acute hospitals had TCC, representing potential coverage of nearly one third of ICU beds reported by these hospitals in the same calendar year. TCC implementation was strongly associated with a hospital's profit status, health system membership, ICU capability, and stroke telemedicine presence. Notably, CAHs were significantly less likely to have this advanced technology.

In a previous study of TCC adoption in the United States between 2003 and 2010, Kahn et al (4) reported increased adoption from 16 hospitals (0.4%) to 213 hospitals (4.6%), with a corresponding increase in ICU bed coverage of 598 (0.9%) to 5,799 (7.9%). In that same study, only three of 306 HRRs (1.0%) in the United States had a hospital with TCC in 2003, which increased to 204 (66.7%) in 2009. Our study suggests that there has been a significant increase in TCC implementation by U.S. acute hospitals in the past decade, representing more than a three-fold (from 213 to 788) increase in implementing hospitals and a nearly five-fold (from 5,799 to 27,624) increase in ICU bed coverage.

What factors are driving this marked increase in uptake of TCC? Although high technological and staffing costs remain a significant barrier (10, 11), improved finances following the end of the 2008 recession may have better positioned hospitals to implement technologies that require capital investments such as TCC (4). However, another plausible explanation is the consolidation of hospitals into health systems over the past 2 decades, including a surge in hospital mergers and acquisitions beginning in 2010 (12, 13). This is supported by our finding that hospitals that were part of a health system were four times as likely to have TCC compared with those that were not—possibly through economies of scale brought about by shared spending and investments when TCC "spokes" are implemented at smaller hospitals and added to the "hub" of established hospitals (1). Such arrangements may even have salutary effects for the hub hospitals, who may gain complex referrals and other benefits from these relationships (11).

TABLE 1.
Characteristics of Hospitals by Telemedicine Critical Care Implementation Status

Characteristics	Combined, N = 4,396	Implementers, N = 788	Nonimplementers, N = 3,608	p
Ownership, n (%)				< 0.0001
For profit	932 (21.2)	38 (4.1)	894 (95.9)	
Nonprofit	2,564 (58.3)	671 (26.2)	1,893 (73.8)	
Public	900 (20.5)	79 (8.8)	821 (91.2)	
Teaching status, n (%)				< 0.0001
Teaching	1,877 (42.7)	451 (24.0)	1,426 (76.0)	
Nonteaching	2,519 (57.3)	337 (13.4)	2,182 (86.6)	
Region, n (%)				0.78
Northeast	583 (13.3)	137 (23.5)	446 (76.8)	
Midwest	900 (20.5)	147 (16.3)	753 (83.7)	
South	2,154 (48.9)	357 (16.6)	1,797 (83.4)	
West	759 (17.3)	147 (19.4)	612 (80.6)	
Location, n (%)				< 0.0001
Rural	796 (18.1)	76 (9.5)	720 (90.5)	
Nonrural	3,600 (81.9)	712 (19.8)	2,888 (80.2)	
Part of a health system, n (%)				< 0.0001
Yes	3,006 (68.4)	696 (23.2)	2,310 (76.8)	
No	1,390 (31.6)	92 (6.6)	1,298 (93.4)	
ICU capability, n (%)				< 0.0001
Yes	2,763 (62.9)	664 (24.0)	2,099 (76.0)	
No	1,633 (37.1)	124 (7.6)	1,509 (92.4)	
Stroke telemedicine, n (%)				< 0.0001
Yes	2,025 (46.1)	663 (32.7)	1,362 (67.3)	
No	2,371 (53.9)	125 (5.3)	2,246 (94.7)	
Critical access hospital, n (%)				< 0.0001
Yes	1,011 (23)	102 (10.1)	909 (89.9)	
No	3,385 (77)	686 (20.3)	2,699 (79.7)	
Total bed, median (interquartile range)	93 (32–219)	142 (58–292)	82 (28–208)	< 0.0001
ICU beds, median (interquartile range)	6 (0–25)	14 (5–39)	5 (0–22)	< 0.0001
Full-time equivalent intensivists, median (interquartile range)[a]	9 (4–21)	11 (4–34)	8 (3–18)	< 0.0001
Privileged intensivists, median (interquartile range)[b]	0 (0–11)	16 (13–37)	0 (0–7)	< 0.0001
Herfindahl-Hirschman Index, median (interquartile range)[c]	2,147 (1,006–3,411)	1,892 (977–3,065)	2,212 (1,008–3,578)	< 0.0001
Income metropolitan statistical area (1,000 U.S. dollars), median (interquartile range)[d]	58.0 (51.1–67.0)	61.0 (53.0–69.4)	57.1 (50.7–65.4)	< 0.0001

[a] $n = 1,494$ for comparisons.
[b] $n = 3,613$ for comparisons.
[c] The Herfindahl-Hirschman Index (range, 0–10,000) is a measure of market concentration used to determine market competitiveness. Higher values indicate higher market concentration.
[d] $n = 3,419$ for comparisons and only includes nonrural data.
Proportions for categorical variables are represented as column percentages for the combined column and as row percentages for the comparison columns.

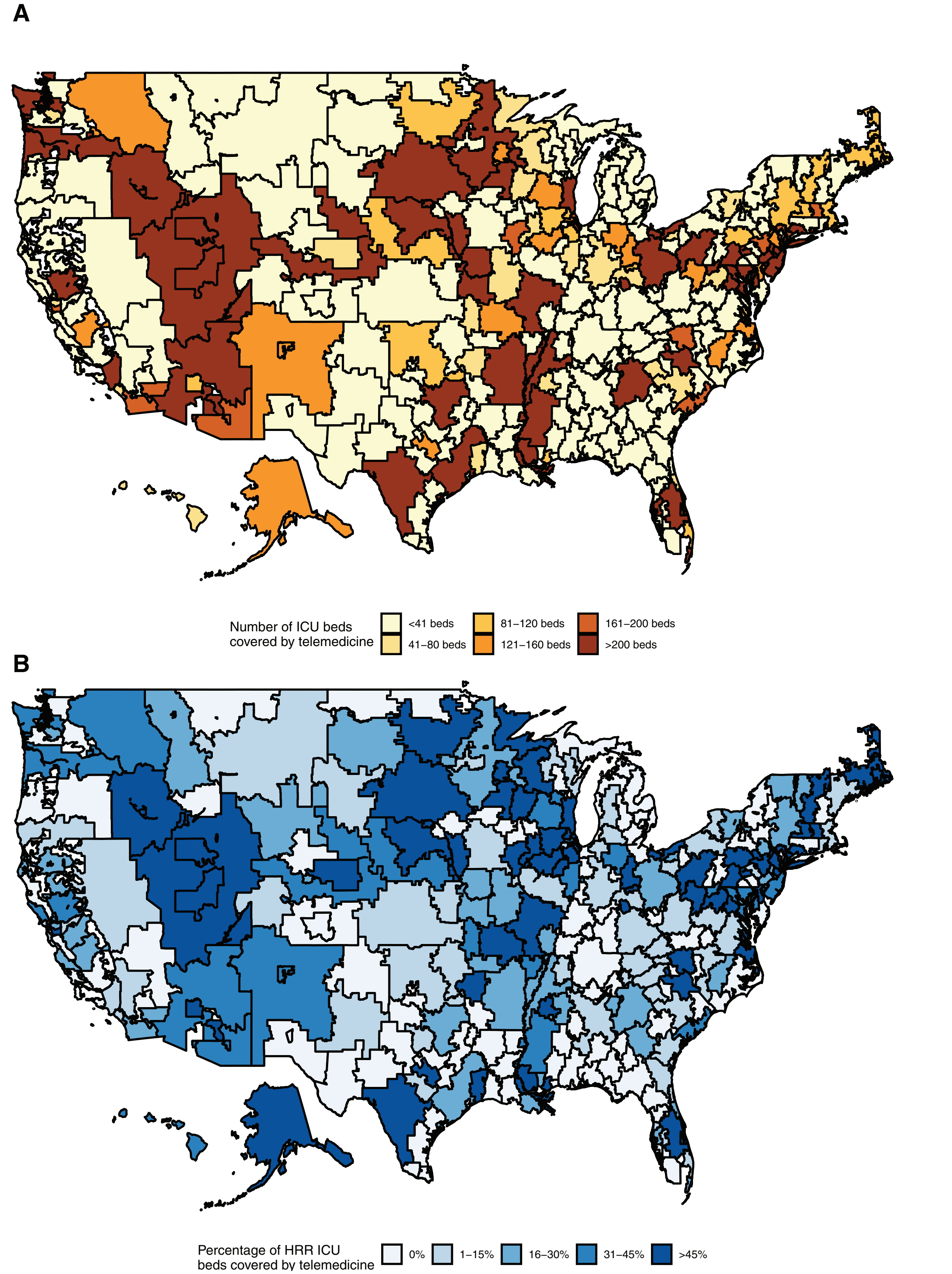

Figure 2. Geographic distribution of telemedicine critical care by hospital referral region (HRR) in 2018 showing number of ICU beds covered by telemedicine (**A**), and proportion of HRR ICU beds covered by telemedicine (**B**).

TABLE 2.
Hospital and Market Characteristics and Odds of Telemedicine Critical Care Implementation

Characteristics	OR	95% CI	*p*
Ownership			
For profit	Reference	Reference	Reference
Nonprofit	7.75	5.18–11.58	< 0.0001
Public	4.16	2.57–6.73	< 0.0001
Teaching status	1.12	0.87–1.43	0.39
Region			
Northeast	Reference	Reference	Reference
Midwest	1.19	0.66–2.15	0.55
South	0.83	0.50–1.36	0.45
West	1.04	0.58–1.87	0.90
Rural location	0.88	0.61–1.29	0.52
Part of a health system	3.83	2.89–5.08	< 0.0001
ICU presence	1.68	1.25–2.26	0.0007
Stroke telemedicine presence	6.87	5.35–8.81	0.0001
Critical access hospital	0.49	0.34–0.70	0.01
Total beds (per 25 increase above 373)	1.11	1.06–1.16	< 0.0001
Herfindahl-Hirschman Index (per 1,000 decrease)	1.11	1.01–1.22	0.03

OR = odds ratio.

Our study also suggests that current TCC implementation appears to be significantly shaped by other hospital structural and financial factors. Nonprofit and public hospitals had eight and four times higher odds, respectively, of implementing TCC compared with for-profit hospitals. The reasons for this are unclear; it is possible that there is not yet a business case for TCC that resonates with the for-profit hospital industry or that for-profit hospitals systematically lack other key infrastructural needs that would make this technology cost-effective (10, 14, 15). We also found that hospitals with stroke telemedicine capability were seven times more likely to have TCC. These hospitals may have already addressed barriers related to telemedicine implementation including capital investments in infrastructure and regulatory obstacles (16, 17). It is also possible that a more broad commitment to telemedicine may have facilitated both stroke telemedicine and TCC uptake (18).

Interestingly, our finding that there was at least one hospital with TCC capabilities in only 197 of 306 HRRs (64.4%) in the United States is essentially unchanged since 2009 despite the increase in the number of sites and beds this represents (4). This suggests that the increase in TCC implementation may not be fueled by expansion into new markets but by adding services in established markets. We demonstrated a linear and significant relationship between lower HHI (less market concentration or more competition) and higher odds of TCC implementation. With overall consolidation in the hospital industry, hospital markets have also become increasingly concentrated (12), and hospitals in more competitive ICU markets may see TCC as a way to distinguish and competitively position themselves (19). This is in contrast to the state of regional ICU markets in 2006 (4), when there appeared to be no difference in the competitiveness of ICU markets in which hospitals with and without TCC were located.

TCC was originally conceived to address critical manpower shortages in small and rural hospitals by extending the reach of intensivists (3, 20, 21). We found that 124 hospitals (7.6% of respondents) without ICU capability reported having TCC services—probably representing the use of this technology outside of the ICU setting, including in step-down units (22), and emergency departments (23, 24). Our finding that rural hospitals were equally as likely as nonrural hospitals to have TCC suggests that telemedicine may not be fully meeting its potential to extend the benefits of intensivists to rural U.S. hospitals. Our observation that CAHs (a subset of rural hospitals) were much less likely to have TCC is particularly noteworthy in this regard. With fewer hospital and ICU beds, less specialized medical and surgical capabilities (25), requirement to maintain short average lengths of stay, and thin operating margins, it is possible that CAHs have primarily relied on interhospital transfers of their more critically ill patients to larger referral hospitals, rather than investing in the TCC technology that allows for remote comanagement by tele-intensivists (26). The need for TCC access for rural hospitals has been brought into sharp focus by the ongoing coronavirus disease 2019 (COVID-19) pandemic, with expanded TCC utilization proposed to support smaller hospitals lacking on-site critical care expertise, particularly when such facilities are unable to transfer their critically ill patients to overwhelmed large urban centers (27, 28).

Our study has several limitations. First, due to incomplete response, our study may have underreported TCC implementation, thereby affecting national estimates of use and regional market penetration. Second, because respondent and nonrespondent hospitals differed by many characteristics (**Supplemental Table**, http://links.lww.com/CCX/A696), the possibility of nonresponse bias remains, and our study lacked the data to apply hospital-level sampling weights to adjust for nonresponse bias. Third, the manner in which the AHA survey question regarding TCC implementation was structured may have led to misclassification of our primary exposure variable. Hospitals may have responded on the basis of whether their TCC installation was "eICU"—a term which for many years has been a trademarked brand name for a specific fixed-installation continuous monitoring product. Fourth, our study may have overestimated bed coverage by TCC because of the possibility that this technology may not be extended to all ICU beds in hospitals with TCC. Fifth, our study is cross-sectional in nature and represents a snapshot of TCC implementation in 2018. We were therefore only able to characterize factors associated with TCC implementation and could not explicitly determine why a hospital or health system implemented TCC or how implementation trends may have changed over time.

CONCLUSIONS

About one fifth of respondent U.S. hospitals reported TCC in 2018, providing coverage to nearly one third of reported ICU beds. Despite the increase in implementation and bed coverage, there remains significant room for expansion and coverage, particularly for rural and CAHs. As more hospitals consolidate and direct reimbursement for tele-ICU services increase, adoption is expected to continue to increase particularly with the advent of federal legislation changing the landscape for tele-ICU encounter billing and with the COVID-19 pandemic highlighting the importance of telemedicine for extending scarce clinician resources to traditionally underresourced areas. Future studies evaluating national and regional patterns of TCC implementation, as well as optimal organizational structure and staffing models employing TCC, are essential to further our understanding of the value of TCC and to spur further adoption in rural and small hospitals where TCC is not already established.

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