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ORIGINAL ARTICLE

Geographic Distribution of Adult Inpatient Surgery Capability in the USA

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Abstract

Introduction Access to timely, quality, and affordable surgical services is an important component of health care systems. A better understanding of the geographic distribution of surgical services in the USA may help identify disparities in access to surgery.

Methods Using the 2015 American Hospital Association Annual Survey, the 2010 Census Bureau Data, and the American Community Survey 5-year estimates from 2011 to 2016, all hospitals with surgical capabilities were geocoded with 30 straight-line mile service areas around each hospital using geospatial analysis. Major surgical hospitals were defined as meeting three of the four following criteria: bed size ≥ 45, ≥ 8600 operations per year, ≥ 12 operating rooms, and academic medical center. The distribution of the US population based on proximity to a hospital capable of performing adult inpatient surgery and a major surgical hospital was then analyzed and compared.

Results Overall, 3409 hospitals were identified that had the capacity to perform adult inpatient surgery of which 1373 were defined as major surgical hospitals. Based on geospatial analysis, 10% of the US population was found to reside outside of a linear 30-mile radius of a surgical hospital. Younger age (OR 0.97, CI 0.96–0.97), female sex (OR 4.6, CI 4.3–5), African-American race (OR = 5.4, CI 4.7–6.2), Hispanic/Latino race (OR 5.5, CI 4.8–6.3), having completed high school or greater (OR = 3.6, CI 3–4.2), being employed (OR 4.8, CI 4.6–4.9), and having any type of health insurance were significantly associated with living in a service area.

Conclusion A significant proportion of the US population lives greater than 30 straight-line miles from a major surgical hospital. Common demographic and socioeconomic factors highlight disparities in access to surgical care.

Keywords Access · Geospatial · Surgery · Location · USA

Introduction

Americans face multiple challenges in accessing health care including insurance status, health literacy, and cost.[1,2] Surgery constitutes a large part of health care that is delivered in the USA with operating room procedures performed during nearly 30% of all hospital stays.[3,4] With increased utilization and centralization of surgical services, access to surgery can, however, be particularly challenging.[4–8] Furthermore, marked changes in health care and delivery of medical services have affected access to hospital-based services for many patients in the USA. For example, 83 rural hospitals have closed across the country since 2010 with another 700 rural hospitals at risk for closure within the next decade.[9,10] At the same time, hospital network participation has increased twofold with the passage of the Patient Protection and Affordable Care Act (ACA).[11] However, access to hospital-based operative services may vary among different patient populations. While

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access to surgical care has been evaluated relative to the role of insurance, race, and health literacy/education, the relationship of geography and travel distance to access has not been well-studied.[12,13]

A consistent volume-outcome relationship has been observed across many surgical procedures, where high-volume centers demonstrate lower morbidity and mortality compared with low-volume centers. Many high-volume centers are often located, however, in urban, metropolitan areas.[14–17] Therefore, timely access to high-quality general surgical care can be challenging for patients in rural areas.[18] A better understanding of the geographic distribution of surgical services may, however, help identify disparities in the access to surgical services. Additionally, understanding the geographic distribution of surgical services may assist in targeting underserved areas. Therefore, the objective of the current study was to define the geographic distribution of access to hospital-based operative services across the USA. In addition, demographic and socioeconomic predictors of geographic distance from hospitals providing inpatient surgery were assessed.

Methods

Data and Study Population

A retrospective cohort analysis was performed using the 2015 American Hospital Association (AHA) Annual Survey, Census Bureau Data for 2010, and the American Community Survey 5-year estimates for 2011 to 2016. Hospitals in the AHA annual survey were included if the hospital reported having an adult inpatient medicine unit and at least one operating room in which surgical operations were performed. Some hospitals reported surgical procedures yet did not report the number of operating rooms; for these hospitals, the authors used direct outreach to hospitals, as well as Internet search information to confirm whether the hospital performed inpatient surgery. Hospitals that were not accessible to the general public such as Veteran's Affairs, Indian Health Services, and hospitals in US territories were excluded (Fig. 1). Overall, 3409 hospitals in the 2015 AHA data were identified that performed adult inpatient surgery.

Geospatial Analysis

Data were imported into ESRI ArcMap 10.6 for geospatial analysis (ESRI 2018. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute). Hospitals were geocoded using the reported address. Location of the hospitals was initially divided into four regions based on Census Bureau designation (Northeast, Midwest, South, and West). Using the buffer feature, straight-line 30-mile radius service areas were calculated around every hospital. Various distance cutoff values to assess access to care have been used; however, most studies in the USA that have examined access to surgical care had previously used the 30-mile cutoff for analysis.[19–21] The population living within and outside of a 30-mile service area was extrapolated at the block level from census data; the same extrapolation was performed including only major surgical hospitals. Major surgical hospitals were defined as meeting three of the four following criteria: bed size ≥ 45, ≥ 8600 operations per year, ≥ 12 operating rooms, and academic medical center. Criteria for bed size were based on HCUP NIS Description of Data Elements.[22] The criteria for number of procedures and operating rooms were based on the upper bound of the interquartile range for all hospitals included in the analysis.

Statistical Analysis

The distribution of the US population was assessed relative to their proximity to a hospital capable of performing adult inpatient surgery. Demographics of the population living within versus outside a service area of a major surgical hospital were assessed using group *t* tests. Univariate and multivariate logistical regression models that accounted for population demographics, socioeconomic factors, and insurance status were utilized to assess differences among patients living within versus outside a major surgical hospital service area. In addition, the population living within a service area of a major surgical hospital was examined relative to whether their state had expanded Medicaid by January 1, 2015, or not.[23] Although certain states have expanded Medicaid more recently, those states which did so after January 1, 2015, were included in the not expanded group to be consistent with 2015 AHA data. Although Census and ACS data was from 2010 and 2011–2016 respectively, we assumed that the population and demographics did not significantly change during this time period as a response to Medicaid expansion. All statistical analyses were performed using Stata statistical software version 14 (College Station, TX). All tests were two-sided and *P* values of less than 0.01 were considered to indicate statistical significance.

Results

Overall, 3409 hospitals were identified that performed adult inpatient surgical procedures (Table 1). The majority of hospitals were located in the South (37.5%) or Midwest (30.7%), while a smaller subset of hospitals was in the West (18.7%) or the Northeast (13.2%). While the number of hospitals in Northeast was lower, these hospitals had on average a greater number of operating rooms per facility (12.8) versus hospitals in the South,[10] Midwest,[8] or West (7.9) ($P < 0.01$). In addition, hospitals in the Northeast performed on average more surgical procedures per hospital (9909.5, IQR 3337–12,896) versus

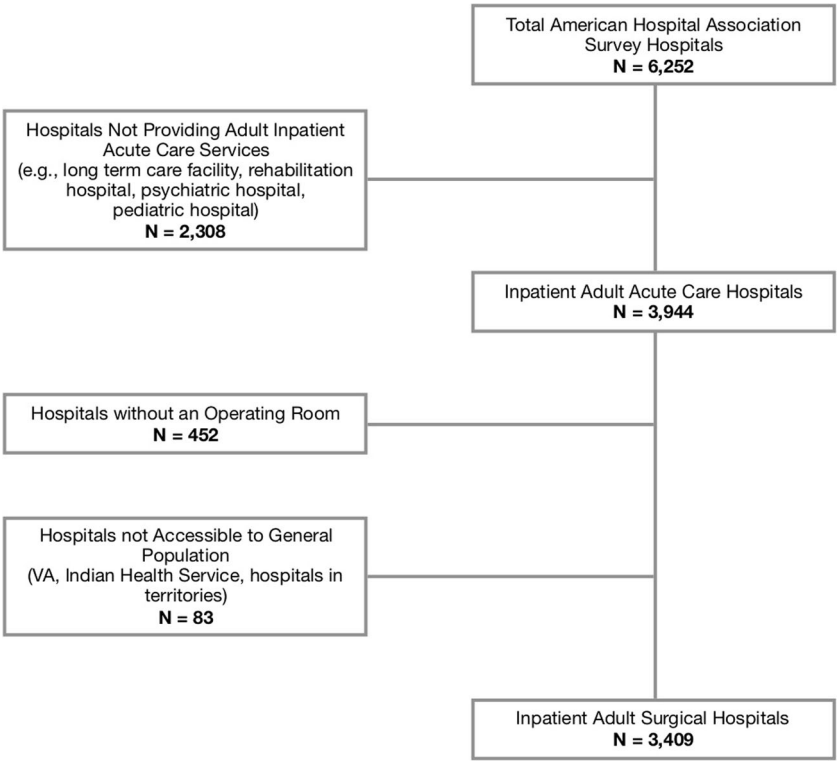

Fig. 1 Flow chart of the exclusion criteria used to create final list of hospitals providing adult inpatient surgery

hospitals in the South (6895.7, IQR 1342–8998), Midwest (5296.1, IQR 630–6451), or West (5940.2, IQR 1746.5–8414.5) ($P < 0.01$). A similar pattern was noted regarding average hospital bed number per hospital (mean, Northeast, 255.7 vs. South, 194.5 vs. Midwest 140.9, or West, 169.1) ($P < 0.01$).

Based on geospatial analysis, 2,918,339 (0.9%) individuals in the USA lived outside a straight-line 30-mile service area from any of the 3409 hospitals. Overall, 1373 hospitals met the criteria as major surgical hospitals based on bed size, number of operating rooms, number of operative procedures, and academic medical center status. Geospatial analysis of the US population relative to these major surgical hospitals revealed that 30,921,923 (10%) individuals lived outside a liner 30-mile service (Tables 2 and 3). There was considerable variation in geospatial distance to major surgical hospitals relative to different regions in the country (Fig. 2). Specifically, the Northeast had the lowest percentage of its population living outside the service area of a major surgical hospital (2.6%) versus 10.5% in the South, 11.9% in the West, 13.3% in the Midwest ($P < 0.01$).

Using the 5-year American Community Survey, the demographic profile of individuals living within versus outside a 30-mile service area of major surgical hospitals was examined (Table 4). Individuals who lived within a service area were younger (38.4 years, IQR 33.4–43.5 vs. 40.8 years, IQR 36.6–46.3, $P < 0.01$) and more likely to be female (50.8% vs. 49.6%, respectively) ($P < 0.01$) than individuals who lived > 30 miles from a major surgical hospital. In addition, African-American (14.2% vs. 8.4%), Asian (5% vs. 1%), and Hispanic/Latino (16.2% vs. 10.5%) (all $P < 0.01$) individuals were all more likely to live within rather than beyond a 30-mile radius of a major surgical hospital, whereas Caucasian individuals were more likely to live further than 30-miles away from a major surgical hospital (83.1% vs. 72.4%) ($P < 0.01$).

On univariate logistic regression, younger age (OR 0.97, 95% CI 0.96–0.97) and female sex (OR 4.6, 95% CI 4.3–5) as well as African-American (OR 5.4, 95% CI 4.7–6.2) and Hispanic/Latino (OR 5.5, 95% CI 4.8–6.3) race were associated with living within versus outside a service area with a major surgical hospital (all $P < 0.01$, Table 4). In addition, having at least a high school degree (OR 3.6, 95% CI 3.0–4.2) and being employed (OR 4.8, 95% CI 4.6–4.9) were also associated with living within a major surgical hospital service area (both $P < 0.01$). In contrast, median income was not associated with living distance from a service area (OR 1.00, 95% 1.00–1.00).

On multivariate logistic regression, active employment (OR 9.1, 95% CI 6.2–13.2) and median income below the federal poverty level (OR 4.0, 95% CI 2.5–6.2) were associated with living within a major surgical hospital service area after controlling for other factors. In addition, individuals between the ages of 18–64 years old who were on Medicaid were also more likely to live within a service area (OR 6.0, 95% CI 3.7–9.8) (Table 4).

Differences in access to major surgical hospitals were observed among states based on Medicaid expansion

Table 1 Characteristics of hospitals included in geospatial analysis

	Northeast	South	Midwest	West	Total
Total (% of total)	449 (13.2)	1278 (37.5)	1045 (30.7)	637 (18.7)	3409
Operating rooms (mean, range)	5769 (12.8, 0–103)	12,743 (10, 0–105)	8407 (8, 0–173)	5030 (7.9, 0–56)	31,949
Procedures (mean, range)	4,449,375 (9909.5, 152–131,999)	8,812,644 (6895.7, 4–79,107)	5,534,457 (5296.1, 6–128,968)	3,783,925 (5940.2, 25–37,719)	22,580,401
Total beds (mean, range)	114,797 (255.7, 4–2381)	248,583 (194.5, 6–2654)	147,229 (140.9, 3–1390)	107,706 (169.1, 6–885)	618,315
AMC (% of total)	215 (47.9)	321 (25.1)	296 (28.3)	180 (28.1)	1012
Trauma center (I–III) (% of total)	150 (33.4)	410 (32.1)	383 (36.7)	235 (36.9)	1178

(Supplemental table). Specifically, among states that expanded Medicaid, 90.6% of the population lived within a service area versus only 83.6% of individuals who lived in states that did not expand Medicaid ($P < 0.01$). Notably, the population living within a service area in a state that expanded Medicaid was more likely to be insured at every age range versus individuals living in states that did not expand Medicaid (< 18: 95.0% vs. 92.1%, 18–64: 80.6% vs. 71.5%, > 65: 98.8% vs. 98.6%) (all $P < 0.01$).

Discussion

Access to high-quality inpatient surgical services is a major population health priority. In fact, Dr. George Sheldon highlighted the problem of "surgical deserts" over a decade ago when he reported in 2006 that 30% of counties in the USA did not have an active surgeon.[24] The current study expands on this previous work by characterizing the geographic distribution of adult inpatient hospitals providing surgery and identified gaps in the availability of surgical services to certain populations in the USA. While 99% of Americans resided within 30 linear miles of a hospital that had surgical capabilities, approximately 10% lived greater than 30 linear miles from a major surgical hospital. In addition, significant geographic differences were observed in travel distance to major surgical hospitals across the USA with the lowest percentage of individuals living outside a straight-line 30-mile radius occurring in the Northeast. Individuals who lived greater than 30 miles from a major surgical hospital were significantly more likely to be older, male, Caucasian, below the federal poverty level, unemployed, and less likely to have insurance. Of note, these disparities in access to surgical services appeared greater among states without Medicaid expansion.

Few studies have previously evaluated disparities in access to surgical services in the USA based on geospatial factors. In general, rural counties with a greater percentage of black, Hispanic, uninsured, and low-education individuals disproportionately tend to lack access to emergency general surgery care.[25] Analyzing use of medical care more broadly, Towne reported that racial/ethnic minority working-age adults as well as individuals with lower incomes, lower education, and those individuals who reside in the South and states that failed to participate in Medicaid Expansion in 2014 were more likely to forgo medical care.[26] The current study was novel in that it used geospatial information systems (GIS) to analyze the geographic distribution of adult inpatient operating rooms in the USA. While other investigators had used similar technologies, these studies focused on access to surgical care in other countries outside of the USA.[27–29] For example, Esquivel et al. reported that 66% of the population in Zambia lived greater than 2 h from a surgical facility.[29] In a study of seven African countries, Knowlton et al. noted that catchment areas, defined as the

Table 2 Population living outside of hospital service areas

	Northeast	South	Midwest	West	Total
Total population	55,317,240	114,555,744	66,927,001	71,945,553	308,745,538
Population living > 30 M from any hospital (%)	27,681 (0.1)	765,041 (0.7)	528,106 (0.8)	1,597,511 (2.2)	2,918,339 (0.9)
Population living > 30 M from large hospital (%)	1,459,127 (2.6)	11,992,040 (10.5)	8,896,483 (13.3)	8,574,273 (11.9)	30,921,923(10)

*Large hospital defined as meeting three of the four following criteria: bed size > 45beds, performing ≥ 8600/year, having ≥ 12 operating rooms, and an academic medical center

area that could reach a surgical hospital via a vehicle in less than two hours, varied vastly between countries.[27]

Access to surgical care and travel distance to surgical facilities is important, both in the USA and abroad, because delays in accessing surgical services may lead to worse health outcomes. For example, patients with acute appendicitis from rural areas have higher rates of perforation versus matched patients from urban areas.[30] Perforation rates are also higher in areas with lower surgeon density, another important determinant of access to surgical care not assessed in the current study.[30] In addition, the incidence of hospital readmission has been reported to be higher, particularly to non-index hospitals, among patients who live furthest away from hospitals where the index surgery was performed.[31,32] For both elective colorectal and pancreatic procedures, increased travel distance from a patient's residence to the surgical hospital has been associated with an increase in length of stay [33,34]. Data on travel distance relative to outcomes among patients undergoing other elective procedures such as hernia repairs, antireflux surgery, and cholecystectomy are, however, scant. In addition, patient preferences around travel and outcomes for surgery are poorly understood. For example, in the USA, many patients prefer to undergo surgery locally even when travel to a regional center may result in a lower operative mortality risk.[35] In contrast, data from Japan suggested that patients who needed non-emergency, relatively complicated surgical interventions tended to be admitted to distant hospitals, thus suggesting that this population of patients may prefer to travel further to obtain care at higher volume hospitals for elective, technically demanding surgeries.[36]

The current study noted that approximately 10% of Americans did not have 30-mile access to hospitals with high-volume surgical services. Efforts in recent years to

Table 3 Demographics of study population

	Within service area	95% CI	Outside of service area	95% CI	*$p < 0.001$
Median age	38.4	38.4–38.5	40.8	40.6–40.9	< 0.01
Female (%)	50.8	50.8–50.9	49.6	49.5–49.7	< 0.01
Race/ethnicity (%)					
Caucasian	72.4	72.2–72.6	83.1	82.7–83.5	< 0.01
African American	14.2	14–14.4	8.4	8.1–8.7	< 0.01
All other	4.6	4.5–4.7	2.3	2.2–2.4	< 0.01
Hispanic/Latino	16.2	16–16.3	10.5	10.2–10.9	< 0.01
Completed high school or greater	86.1	86–86.2	84.4	84.2–84.6	< 0.01
Employed	63.5	63.4–63.6	57.6	57.4–57.8	< 0.01
Poverty	16.5	16.4–16.6	18.4	18.1–18.6	< 0.01
Median income (USD)	69,192.06	68,915.4–69,468.73	52,963.52	52,621.92 53,305.12	< 0.01
Insurance					
< 18 years old w/ any insurance	94	93.7–94	92	91.9–92.2	< 0.01
< 18 years old w/ Medicare	0.27	0.25–0.28	0.27	0.25–0.3	0.5898
< 18 years old w/ Medicaid	33.9	33.8–34.1	38.4	38.1–38.8	< 0.01
18–64 years old w/ any insurance	77.4	77.3–77.5	73.6	73.3–73.9	< 0.01
18–64 years old w/ Medicare	3.3	3.3–3.4	4.7	4.6–4.8	< 0.01
18–64 years old w/ Medicaid	11.2	11.1–11.3	11.9	11.8–12.1	< 0.01
> 65 years old w/ any insurance	98.8	98.7–98.8	99.4	99.4–99.4	< 0.01
> 65 years old w/ Medicare	74.4	74.3–74.5	74	73.9–74.2	< 0.01
> 65 years old w/ Medicaid	10.1	10–10.2	8.5	8.3–8.7	< 0.01

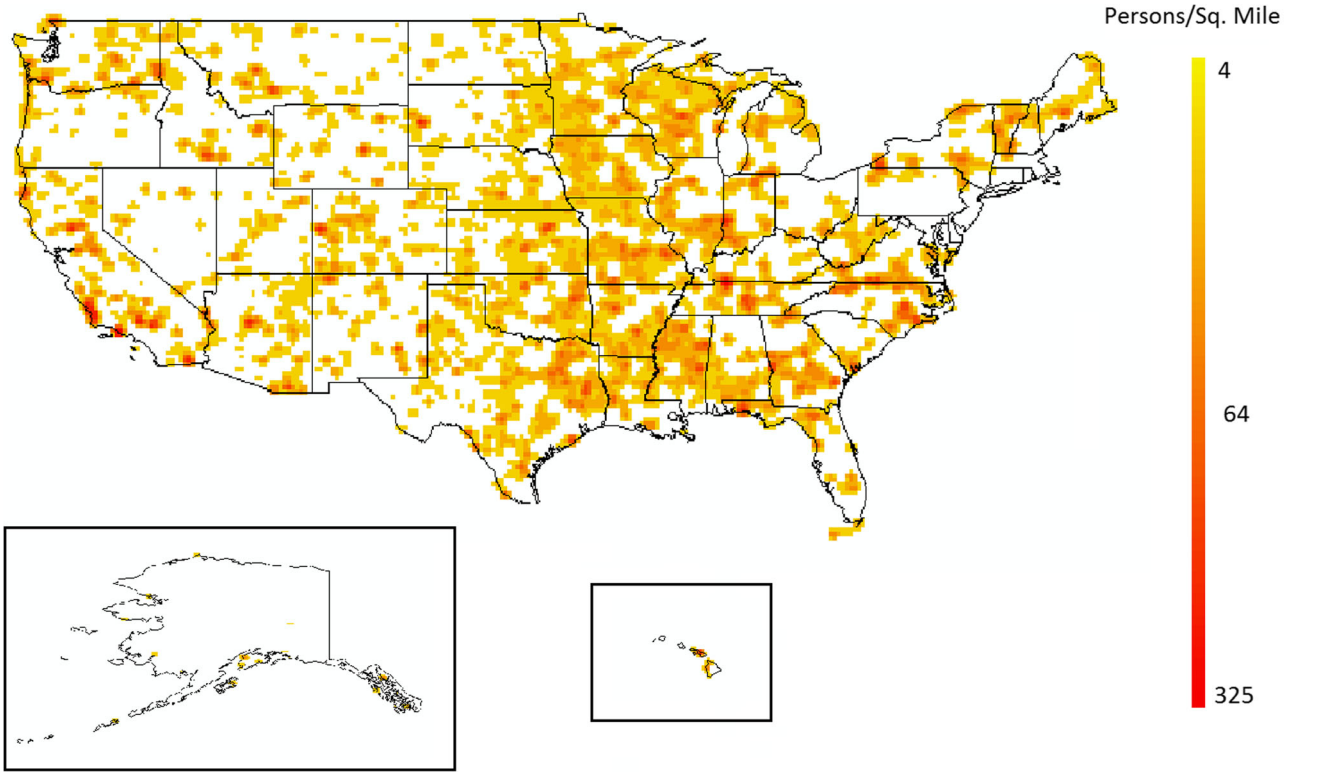

Fig. 2 Heat map depicting population of USA relative to distance from a major surgical hospital offering surgical services (Major surgical hospitals were defined as meeting three of the four following criteria: bed size ≥ 45, ≥ 8600 operations per year, ≥ 12 operating rooms, and academic medical center)

regionalize surgical care further may serve only to exacerbate disparities in access to surgical facilities. Two recent studies demonstrated that the operative mortality with high-risk surgery decreased substantially at high-volume hospitals and with high-volume surgeons.[14,15] Although increased market concentration and hospital volume have contributed to declining mortality with some high-risk operations, declines in mortality with other procedures have been largely attributable to other factors, such as changes in surgical management of certain diseases,[37] public reporting,[38] and quality improvement initiatives.[39] While patients may certainly benefit from regionalization for certain complex procedures, patient outcomes for less complex procedures may be just as good—or even better—with local surgical treatment.[40] As such, a thoughtful approach to regionalization should be adopted that reduces the risk of more complex procedures, while assuring local options for less complex, lower risk surgery.[8]

Interestingly, despite the importance of hospital and surgeon volume on outcomes, recent evidence suggests that these factors may be less important to patients in their selection of surgical facilities. Rather, travel distance remains a critical determinant in patient choice. For example, in a study of California cancer patients undergoing gastrectomy, the majority of patients underwent gastrectomy at hospitals nearest to home, reflecting little regionalization of gastrectomy in California.[41] In addition, the importance of travel distance (and therefore the burden of regionalization) appears to be greatest among certain vulnerable populations. For instance, among patients undergoing pancreatectomy, the elderly, racial minorities, and patients with self-pay or Medicaid payer status were most sensitive to travel burden, suggesting this vulnerable cohort may be affected disproportionately by a minimum-volume policy.[42] In states that did not expand Medicaid, hospital closures have increased while states that have expanded Medicaid have experienced lower hospital closures.[43] The finding that fewer individuals in non-Medicaid expansion states lived within 30-miles of a major surgical hospital may very well be influenced by this trend. Alarmingly, one analysis suggested that without intervention, an estimated 673 hospitals in the United States may also close over the next 5 years.[44] Further closures of smaller regional hospitals may only exacerbate the problem of access to surgical care, especially among states that have chosen not to expand access to Medicaid.

Several limitations should be considered when interpreting the results of the current study. The geospatial analysis of service areas was performed using straight-line distance rather driving miles; however, previous studies have validated that for non-emergency travel to hospitals, the added precision offered by the substitution of travel distance, travel time, or both for straight-line distance is largely inconsequential.[45] In fact, it is likely that this analysis underestimated true driving distance and therefore the proportion of the population living

Table 4 Univariate and multivariate logistic regression of indicators of living within a major surgical hospital service area versus living outside of a service area

	Univariate			Multivariate		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Age	0.97	0.96–0.97	< 0.01	0.98	0.98–0.99	< 0.01
Female	4.6	4.3–5	< 0.01	4.9	4.3–5.5	< 0.01
Race/ethnicity						
Caucasian	0.1	0.09–0.11	< 0.01	0.27	0.21–0.36	< 0.01
African American	5.4	4.7–6.2	< 0.01	3.8	2.9–5.2	< 0.01
Hispanic/Latino	5.5	4.8–6.3	< 0.01	13.2	10.5–16.6	< 0.01
Completed high school or greater	3.6	3–4.2	< 0.01	5	3.1–8.1	< 0.01
Employment	4.8	4.6–4.9	< 0.01	9.1	6.2–13.2	< 0.01
Below FPL	0.34	0.28–0.4	< 0.01	4	2.5–6.2	< 0.01
Median income	1	1.0–1.0	< 0.01	1	1.0–1.0	< 0.01
Insurance						
< 18 years old w/ any insurance	3.2	3–3.5	< 0.01	6.1	4.1–9.1	< 0.01
<18 years old w/ Medicare	0.66	0.14–3	0.6	0.96	0.12–7.5	0.97
< 18 years old w/ Medicaid	0.43	0.39–0.47	< 0.01	0.62	0.49–0.79	< 0.01
18–64 years old w/ any insurance	3.3	3–3.7	< 0.01	1.1	0.79–1.4	0.67
18–64 years old w/ Medicaid	0.46	0.38–0.57	< 0.01	6	3.7–9.8	< 0.01
> 65 years old w/ Medicare	1.4	1.1–1.7	< 0.01	1.4	1–1.9	0.03
> 65 years old w/ Medicaid	3.8	3.1–4.7	< 0.01	1.6	1.1–2.3	0.01

outside of a major surgical hospital service area. The definition of a major surgical hospital was also poorly defined. While minimum volume of specific procedures exists in the literature, there is no consensus on the total number of operations performed in a hospital. Furthermore, it was not possible from the dataset to distinguish the volume of specific procedures performed in each hospital. Therefore, we acknowledge that the assumption that a relationship exists between the totality of operations and outcomes may be limited. While the Annual Survey of Hospitals of the American Hospital Association is considered a comprehensive database of US hospitals, the data is self-reported and its accuracy cannot be guaranteed. An additional limitation of the Annual Survey of Hospitals of the American Hospital Association is the lack of information regarding which hospitals had around the clock operating room access. The presence of an operating room does not necessarily mean that it is always staffed by a surgeon. Indeed, there may be more considerations to surgical care access beyond simply having an operating room. As such, data from the current study may underestimate access to surgical care. Finally, although the American community survey is the principal source of high-resolution geographic information about the US population, the data contains a certain level of uncertainty due to sampling error.[46]

In conclusion, approximately 10% of the US population lives greater than 30 linear miles from a major surgical hospital with significant variation observed among geographic locations in the country, among demographic and socioeconomic groups, and among states that did and did not expand Medicaid. These findings have important implications for the regionalization of surgical care and health policy decision making with the goal of providing safe, accessible surgical services to all. In a rapidly changing health care environment, the impact of regionalization, hospital mergers, and urbanization of hospitals and their impacts on outcomes need further clarification. Additionally, the role ambulatory surgical centers and other innovative health care delivery models relative to surgical care access require further study. Ultimately, a better understanding of patient preferences and perceptions of geography based on disease and intervention as well as socioeconomics should be elucidated so that as providers we may deliver more patient centered care.

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