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Leg Amputations Among Texans Remote From Experienced Surgical Care

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ARTICLE INFO

Article history:
Received 14 March 2019
Received in revised form 24 July 2019
Accepted 2 September 2019
Available online 24 December 2019

Keywords:
Disparity
Diabetic foot
Amputation

ABSTRACT

Background: Surgical outcomes may differ between low-volume and experienced hospitals. We sought to identify characteristics of remote patients—those living more than 50 miles from an experienced center—who underwent leg amputations for peripheral artery disease (PAD) and foot complications at low-volume and experienced hospitals and identify regions of Texas where such patients live.

Materials and methods: Publicly available Texas hospitalization data from 2004 through 2009 were used to identify patients with PAD who underwent leg amputation for foot complications, including foot ulcers, foot infections, and gangrene. Geocoding was used to further identify a subset of remote patients and to estimate distances from zip code of residence to hospital in which care was received.

Results: Among all leg amputations, 850 (18.6%) were performed on patients classified as remote, and 3723 (81.4%) were performed on patients classified as nonremote. Compared with nonremote patients, remote patients were more often categorized as white and more frequently received Medicare and/or Medicaid. Of the subset of remote patients, those at low-volume hospitals were older, were less often categorized as Hispanic, more often had Medicaid coverage, were also more frequently admitted through the emergency department, and often had a foot infection compared with those at experienced centers. Geospatial analysis identified five concentrated geographic areas of remote patients who live more than 50 miles from an experienced center.

Conclusions: These findings suggest travel distance may at least influence, if not constrain, the choice of hospital for patients with PAD and foot complications. Efforts to decrease leg amputations among remote patients should be focused on five specific geographic areas of Texas.

Published by Elsevier Inc.

DOI of original article: https://doi.org/10.1016/j.jss.2019.11.026

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0022-4804/$ – see front matter Published by Elsevier Inc.
https://doi.org/10.1016/j.jss.2019.09.074

Better surgical outcomes have been associated with higher case volume in various bariatric,[1] hepatobiliary, cardiac,[2] orthopedic,[3] and vascular operations.[4,5] Despite this, many operations—for example, nearly half of open aortic aneurysm repairs and carotid endarterectomies performed in New York state—are performed by very low-volume surgeons.[6] A previous national cohort analysis of patients who underwent total knee replacements suggests that persons categorized as poor, nonwhite, and nonurban more often use low-volume hospitals.

Our research has previously found that people with peripheral artery disease (PAD) who present with foot complications (such as foot ulcers, foot infections, and gangrene) to low-volume Texas hospitals—hospitals that account for one-quarter of the procedures for this patient population—more often undergo leg amputations and less often undergo revascularization procedures (including lower extremity angioplasty and infrainguinal bypass operations) than people with the same conditions presenting to experienced hospitals.[7] With an interest in ensuring equitable access to experienced surgical care to address the twofold higher rate of leg amputations among persons categorized as black or Hispanic,[7,8] we investigated whether distance from experienced hospitals had a disproportional impact on certain groups within the state. We hypothesized that remote patients might more often be categorized as black or Hispanic than persons categorized as white. We herein describe our use of publicly available data to (1) identify remote geographic areas (i.e., areas ≥50 miles from hospitals experienced in the care of PAD and foot complications) where persons underwent leg amputation at low-volume Texas hospitals and (2) compare characteristics of remote patients who underwent leg amputation at experienced hospitals with the characteristics of remote patients who underwent leg amputation at low-volume hospitals.

Methodology

Study population and hospital data

Publicly available de-identified data were obtained from the Texas Inpatient Public Use Data File. This data set includes data from all nonfederal hospitals in the state. We used quarterly data files from 2004 through 2009. The population of interest was patients aged 18 or older who underwent leg (major or above-ankle) amputation and who had diagnoses of both PAD and foot complications, including foot ulcers, foot infection, and foot gangrene. International Classification of Diseases, 9th revision diagnosis and procedural codes (refer to the previous study[7]) were used to identify the study population. Patients were excluded if International Classification of Diseases, 9th revision diagnosis codes were seen pertaining to trauma, congenital or developmental orthopedic issues, or complications of a previous leg amputation.

Table 1 – Comparison of characteristics of patients with PAD in Texas who underwent leg amputation for foot complications that were considered remote (more than 50 miles from an experienced center) or nonremote.

Variable	Overall (4573)	Remote (n = 850)	Nonremote (3723)	P-value
Male	2652 (58.0)	502 (59.1)	2150 (57.7)	0.49
Age				
18-44 y	93 (2.0)	15 (1.8)	78 (2.1)	0.54
45-64 y	1172 (25.6)	232 (27.3)	940 (25.2)	0.22
65-74 y	1157 (25.3)	218 (25.6)	939 (25.2)	0.80
75 + y	2151 (47.0)	385 (45.3)	1766 (47.4)	0.26
Black	1015 (22.2)	148 (17.4)	867 (23.3)	0.0002†
Hispanic	1388 (30.4)	198 (23.3)	1190 (32.0)	<0.0001†
Medicare	3385 (74.0)	691 (81.3)	2694 (72.4)	<0.0001†
Medicaid	1525 (33.3)	322 (37.9)	1204 (32.3)	0.002†
ER admission	2468 (54.0)	460 (54.1)	2008 (53.9)	0.92
Diabetes	2481 (54.3)	412 (48.5)	2069 (55.6)	0.0002*
Foot infection	2023 (44.2)	346 (40.7)	1677 (45.0)	0.02*
Foot osteomyelitis	534 (11.7)	82 (9.6)	452 (12.1)	0.04*
ESRD	93 (2.0)	14 (1.6)	79 (2.1)	0.38
Median poverty prevalence, % (25%-75% IQR)	14.5 (8.5-23.1)	14.2 (10.5-18.1)	15.3 (8.0-24.8)	0.133
Median distance to closest experienced center, miles (25%-75% IQR)	14.1 (5.7-40.5)	74.3 (61.3-87.4)	11.0 (5.0-21.1)	<0.0001†
Median distance to hospital used, miles (25%-75% IQR)	12.1 (5.8-22.4)	62.4 (28.4-83.7)	14.0 (6.6-34.0)	<0.0001†

Numbers in parenthesis represent percentages unless otherwise indicated.
ER = emergency room; ESRD = end-stage renal disease; IQR = interquartile range.
* P-value of ≤0.05.
† P-value of ≤0.01.

The previous study has demonstrated that patients with PAD and foot complications treated at hospitals, whose average total number of leg amputations plus leg revascularizations (open surgical or endovascular) is fewer than 15 per year, have a 1.8-fold higher risk-adjusted rate of leg amputation than that of revascularization.[7] We therefore defined an experienced center as any of the 77 Texas hospitals reporting an average of 15 or more total leg amputations plus leg revascularization procedures during the study period. In contrast, the remaining 271 Texas hospitals that performed at least one such procedure but averaged fewer than 15 per year during the study period were classified as low-volume centers.

Distance calculations

Cartesian coordinates for the 77 experienced centers in Texas were obtained using Google Maps. Cartesian coordinates for the center of 1855 Texas zip codes were obtained from a Google Maps geocoding function. The straightline distance from the center of each patient's zip code of residence to each of the 76 experienced centers was then calculated using the Haversine formula with signed decimal degrees without compass direction (e.g., latitude 29.7102907310004, longitude -95.4002913439997). The minimum distance from every Texas zip code to an experienced center was then defined as the lowest of these 77 distances. Median distances and 25%-75% interquartile ranges (IQRs) were then calculated for each zip code to the closest hospital in each of three categories: very high-volume centers only; high- or very high-volume centers only; and moderate-, high-, or very high-volume centers. Distance calculations were performed using Microsoft Excel and LibreOffice Calc.

Geospatial analysis

The aforementioned minimum distance estimates were used to identify patients with PAD and foot complications who underwent leg amputation and live 50 or more miles from an experienced center. These patients were classified as "remote," and those living less than 50 miles from an experienced center were classified as "nonremote." (It is to be noted that we avoided using the rural-urban dichotomy to avoid assuming that all experienced centers were within 50 miles of all zip codes classified as urban or that the only zip codes located more than 50 miles from an experienced center would be rural.) Geospatial mapping was performed using the Rstudio, version 1.0.143, with *ggmap* and *ggplot2* packages to visualize the density of such persons.

Table 2 – Characteristics of remote patients (those living more than 50 miles from an experienced center) who underwent amputation at an experienced hospital or a low-volume hospital.

Variable	All remote ($n = 850$)	Remote patients who went to an experienced center ($n = 441$)	Remote patients who went to a low-volume center ($n = 409$)	P-value
Male	502 (59.1)	254 (57.6)	248 (60.6)	0.37
Age				
18-44 y	15 (1.8)	13 (2.1)	2 (0.5)	0.007*
45-64 y	232 (27.3)	149 (33.8)	83 (20.3)	<0.0001*
65-74 y	218 (25.6)	116 (26.3)	102 (24.9)	0.65
75 + y	385 (45.3)	163 (37.0)	222 (54.3)	<0.0001*
Black	148 (17.4)	74 (16.8)	74 (18.1)	0.61
Hispanic	198 (23.3)	122 (27.7)	76 (18.6)	<0.002*
Medicare	691 (81.3)	353 (80.0)	338 (82.6)	0.33
Medicaid	322 (37.9)	149 (33.2)	173 (42.3)	0.01*
ER admission	460 (54.1)	212 (48.1)	248 (60.6)	0.0002*
Diabetes	412 (48.5)	211 (47.8)	201 (49.1)	0.70
Foot osteomyelitis	82 (9.6)	43 (9.8)	39 (9.5)	0.92
Foot infection	346 (40.7)	149 (33.8)	197 (48.2)	<0.0001*
ESRD	14 (1.6)	7 (1.6)	7 (1.7)	0.89
Median poverty prevalence, % (25%-75% IQR)	14.2 (10.5-18.2)	14.3 (11.2-18.5)	13.7 (9.7-18.3)	0.09
Distance to closest experienced center, miles (25%-75% IQR)	74.3 (61.3-87.9)	71.7 (60.1-85.5)	77.2 (63.6-94.7)	0.0005*
Distance traveled to hospital used, miles (25%-75% IQR)	62.4 (28.4-83.7)	75.9 (62.4-98.4)	27.5 (8.0-55.8)	<0.0001*

Numbers in parenthesis represent percentages unless otherwise indicated.
ER = emergency room; ESRD = end-stage renal disease; IQR = interquartile range.
*P-value of ≤0.01.

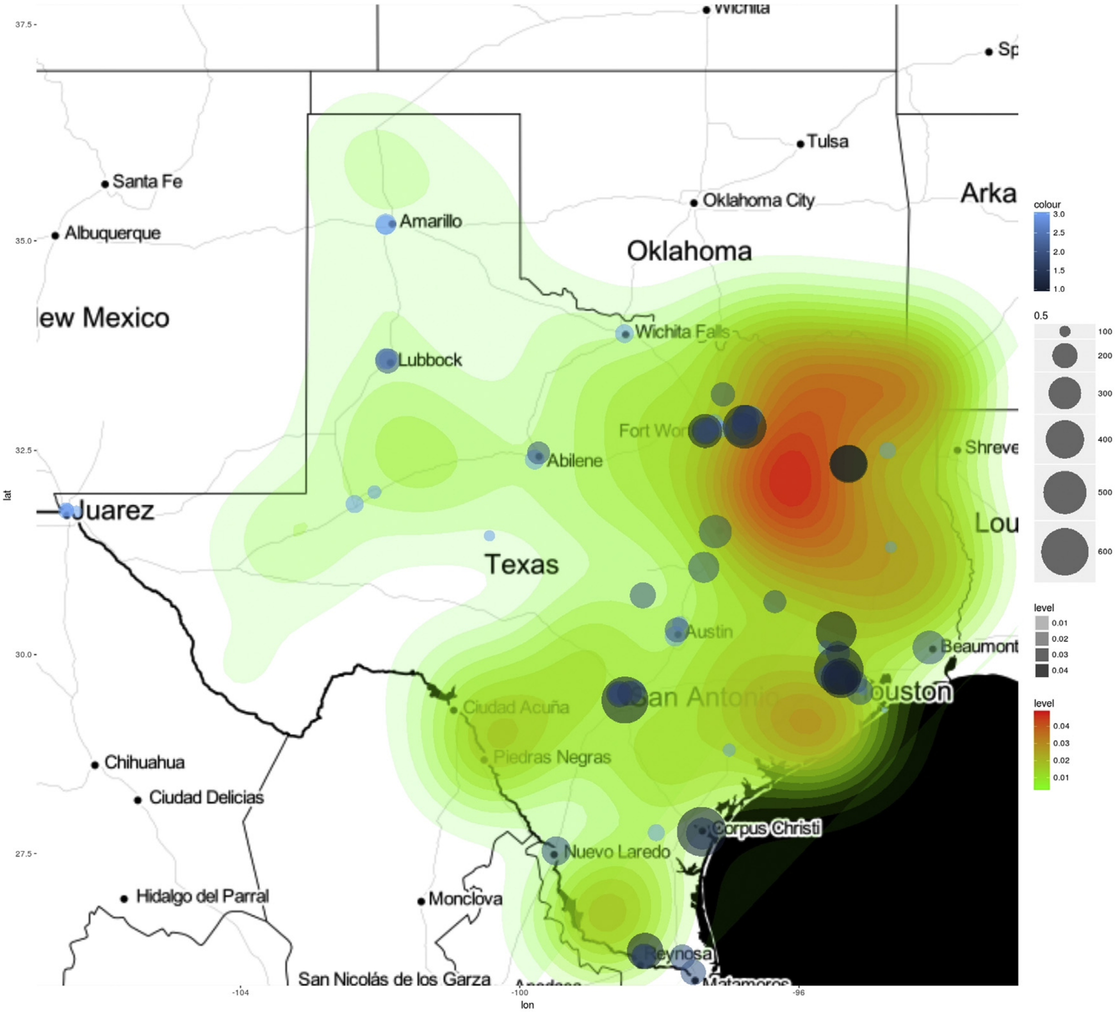

Fig. 1 – Density map showing zip code of residence for all patients with PAD who underwent leg amputation for foot complications and who live more than 50 miles from an experienced hospital. Four geographic clusters of remote patients were seen: (1) in northeast Texas in between Dallas and Tyler; (2) in the central Gulf Coast near El Campo; (3) near Brackettville in rural southwest Texas; and (4) near Big Spring along the Texas–Mexico border. Circles represent experienced medical centers in Texas, circle size corresponding to annual volume for revascularization and leg amputation procedures performed for this patient population. (Color version of figure is available online.)

Results

Study population and distance estimates

During the study period, 4573 leg amputations were performed on patients with PAD and foot ulcers, foot gangrene, or foot infections who live in Texas. Of these, 2978 (65.1%) of leg amputations were performed at 77 experienced hospitals, and 1595 (34.9%) were performed at 271 low-volume centers. Among all leg amputations, 850 (18.6%) were performed on patients classified as "remote" (living more than 50 miles from an experienced center), and 3723 (81.4%) were performed on patients classified as nonremote. Compared with nonremote patients, patients classified as remote more frequently received Medicare (81.3% *versus* 72.4%, respectively) and/or Medicaid (37.9% *versus* 32.3%, respectively) as one of their two payers but were less frequently categorized as black (17.4% *versus* 23.3%, respectively) or Hispanic (23.3% *versus* 32.0%, respectively) and less frequently had diabetes (48.5% *versus* 55.6%, respectively), foot infections (40.7% *versus* 45.0%), or foot osteomyelitis (9.6% *versus* 12.1%; Table 1).

The zip code of residence was available for analysis for 4322 of these 4573 patients in the study sample (94.5%). The median calculated distance traveled was 15 miles overall (25%-75% IQR of 7-38 miles): 17 miles (25%-75% IQR of 8 to 43 miles) for patients who underwent surgery at an experienced center *versus* 12 miles (25%-75% IQR of 6-28 miles) who underwent surgery at a low-volume center ($P < 0.0001$, Table 1).

Further analyses focused exclusively on remote patients. Compared with remote patients who underwent leg amputation at experienced centers, remote patients who

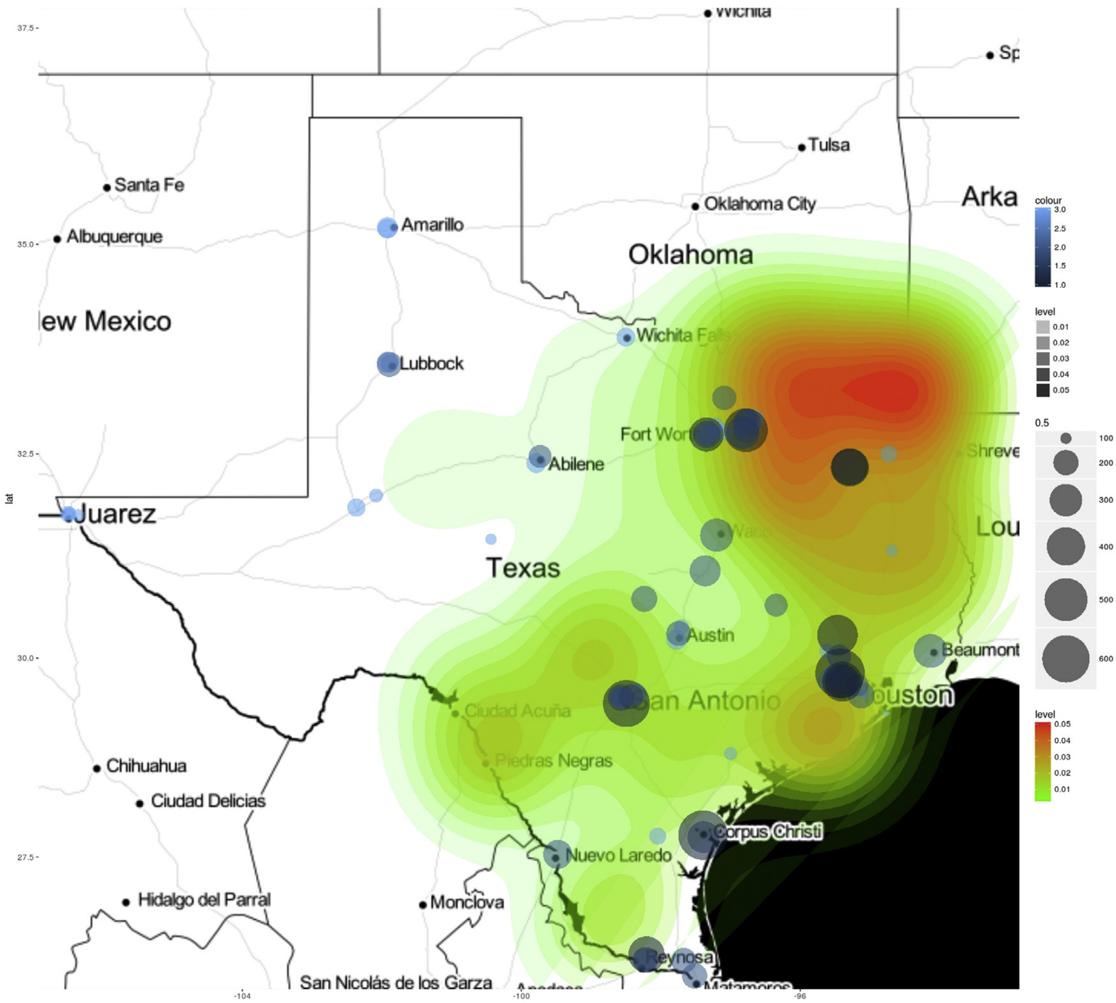

Fig. 2 – **Density map showing zip codes of residence for all patients with PAD who underwent leg amputation for foot complications and who live more than 50 miles from an experienced hospital but underwent amputation at a low-volume hospital. This shows some small differences compared with Fig. 1, including a northern shift of the highest concentration and an additional concentration near Kerrville northwest of San Antonio. (Color version of figure is available online.)**

underwent leg amputation at low-volume hospitals were more often aged 75 y or older (54.3% *versus* 37.0%), more often had Medicaid as one of two primary payers (42.3% *versus* 33.2%), were more frequently admitted through the emergency department (60.6% *versus* 48.1%), and more often had a foot infection (48.2% *versus* 33.8%), but they were less often <65 y old (20.8% *versus* 35.9%) and less often categorized as Hispanic (18.6% *versus* 27.7%; Table 2). Although the difference between the median experienced hospital-to-home distances reached significance, the magnitude of difference was relatively small (72 *versus* 77 miles for those undergoing surgery and experienced *versus* low-volume hospitals, respectively) compared with the estimated distances traveled to the hospital at which care was received (76 *versus* 28 miles for those undergoing surgery and experienced *versus* low-volume hospitals, respectively). Of remote patients who underwent leg amputation at a low-volume hospital, 313 (76.5%) received care at a hospital that was closer to their zip code of residence than the closest experienced center.

Geospatial analysis

Of all 1858 Texas zip codes, 476 (25.6%) are located more than 50 miles away from an experienced center, 75 (4%) are located more than 100 miles away, 29 (1.5%) are located more than 150 miles away, and 10 (0.5%) are located more than 200 miles away. The median distance for all patients to an experienced center of any level was 27.7 miles (25%-75% IQR of 10.1 to 58.9 miles).

Geospatial analysis and mapping identified four regions with concentrations of remote patients with PAD and foot complications who underwent leg amputation (Fig. 1). The densest area was centered in northeast Texas, in between the cities of Tyler and Dallas (Fig. 1). Two moderately dense concentrations were identified: one in the central Gulf Coast centered near El Campo (approximately 70 miles south of Houston) and another in rural southwest Texas, centered near Brackettville and approximately 170 miles southwest of San Antonio. Two additional, less-concentrated areas were identified near Big Spring in west Texas and in the Rio Grande Valley.

Mapping was repeated with a subset of only remote patients who underwent surgery at a low-volume hospital (Fig. 2). Findings differed from the previously described map of all remote patients in some notable respects. First, the highest density region shifted further north, centered instead between Texarkana and Paris, Texas. An additional, less-concentrated area was seen centered approximately 66 miles northwest of San Antonio. The density of remote patients identified in the Rio Grande Valley and near Big Spring decreased when restricted to low-volume hospitals. The Gulf Coast concentration centered at El Campo appeared unchanged.

Discussion

Our previous study compared rates of revascularization and leg amputation among persons with PAD and foot complications. We focused this current investigation exclusively on persons who underwent a leg amputation with the intent of finding populations whose outcome could be most improved through improving access to experienced surgical care. Our findings suggest that travel distance may constrain the choice of hospital for patients in Texas who undergo leg amputations for the combination of PAD and foot pathology and are remote (living more than 50 miles from an experienced center). Patients who receive care at low-volume hospitals are more often elderly, on Medicaid, have a foot infection, and are admitted to the hospital through the emergency room.

Contrary to expectations, we found that remote patients were more often categorized as white than black or Hispanic. We also found that remote Hispanic patients were less likely to use low-volume hospitals than those categorized as white. Although addressing a racial disparity in leg amputation rates that has existed for more than 20 y[7,8] remains our priority, we would still acknowledge that reducing the travel burden to the remote populations which we have identified would also provide value. Patients generally view travel to a distant hospital as a burden to themselves and their support network,[9] and efforts to minimize the need for such travel may therefore provide value to patients irrespective of an impact on clinical outcomes. In addition, decreased travel burdens may improve the number of patients receiving specialty care[10]—a positive impact that is not readily reflected in patient-level studies that include only patients who underwent specialized evaluation and treatment (rather than all patients with a disease) as a denominator.

Geospatial analysis may provide many benefits to the clinical and public health communities. Viewing clusters on a map allows for large amounts of very granular data to be visually aggregated, providing observations that might be difficult to make when reviewing such data in tabular form. In this study, geospatial analysis using publicly available data helped us identify four geographic areas that represent the residence of large but remote groups of patients who underwent leg amputations in Texas. Observations made through the direct clinical care of patients who come to our hospitals in Houston had led us to anticipate clustering in northeast Texas, but centered near Lufkin rather than Texarkana. We had some suspicion that there might be a cluster near the southern Gulf Coast, but not as near to Houston as we found. Similarly, these clusters were not identified when reviewing zip code–level data in tabular form, perhaps because of the nonlogical ordering of zip codes and a more limited ability to aggregate data from multiple zip codes. We intend to use findings from this geospatial analysis to design teleconsultation service and/or outreach clinics in Texas, although many other approaches may provide benefit.

This study has a few limitations. Straightline distances were used because these can be calculated using two geographic locations. This may have underestimated distances traveled by road. Although the location of hospitals within our data set was accurate to within meters, the location of residence was estimated using the geographic center of each of the 2595 Texas zip codes. Given a mean zip code area in Texas of 104 square miles, our distance calculations may therefore be up to 10 miles off actual straightline distances if place of residence data had a degree of precision similar to that of hospitals. In addition, it is possible that patients living near the northeast Texas border seek care in neighboring states. Although possible, we do not anticipate that this would shorten the distance to an experienced center, as the travel distances from the city of Texarkana are 72 miles to Shreveport, Louisiana, and 142 miles to Little Rock, Arkansas. In addition, we are calculating distances; in actuality, a patient's travel burden is a complex interaction of distance and resources, including access to transportation, money, time, and social support. Nevertheless, we feel that our choice of a 50-mile travel distance threshold for the binary definition of remote populations is relatively conservative (shorter distance than the Veterans Healthcare Administration's Choice Act based on a 40-mile travel distance). Finally, we did not have access to longitudinal data. We consider variations in the rates of leg amputation among various groups problematic regardless, but we cannot comment on the extent to which patients included in this study underwent revascularization attempts.

In summary, publicly available geospatial analysis of health-care data can provide actionable findings that may help identify regions where patients have high travel burdens. We recommend that more clinicians, public health practitioners, and health-care systems engage in such analyses in an effort to improve access to high-quality care. Such efforts would be likely to provide value to patients and may improve health outcomes, especially in the context of patients with PAD and foot complications.

Acknowledgment

The study received no funding (unfunded research). N.R.B. was involved in all aspects of the study. A.U.G. collected data and assisted with the data analysis. S.S. assisted with the data analysis and manuscript writing. J.L.M. and S.R.O. critically reviewed the manuscript and provided important input on the final manuscript.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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