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Defining Vascular Deserts to Describe Access to Care and Identify Sites for Targeted Limb Preservation Outreach

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Abstract

Background—Access to care plays a critical role in limb salvage in chronic limb-threatening ischemia (CLTI). A "medical desert" describes a community lacking access to medical necessities, resulting in increased morbidity and mortality. We sought to describe vascular deserts, which we defined as regions with decreased access to specialty care.

Methods—All California providers performing vascular surgery procedures were identified through online provider and healthcare facility searches. Facility participation in the Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI) lower extremity bypass and peripheral vascular intervention modules was also determined. Addresses were geocoded with a 30-mile surrounding buffer using ArcGIS, creating maps based on care type, including all providers performing vascular procedures, board-certified vascular surgeons, and facilities participating in VQI modules. Public census data overlayed on the maps demonstrated population composition in desert versus non-desert regions. Subsequently, data from the Healthy Places Index (HPI) was overlayed, providing data regarding 25 social factors, comprising an overall HPI score and percent, with lower scores corresponding to poorer health and outcomes.

Results—Maps depicting care regions demonstrated decreased provider coverage with increasing specialty care, with the VQI provider map showing the most prominent "desert" regions. When comparing non-desert versus desert regions by care type, demographics including race, the percentage of the population 200% below the poverty line, and the rate of uninsured residents were described. Social determinants of health were then described for desert and non-desert regions by care type, including the HPI percentage and specific domain factors. The percentage of uninsured residents was significant only in the desert and non-desert areas served by board-certified vascular surgeons (19.6 vs. 16.8%, p <.001). The mean HPI percentile was significantly lower in boardcertified provider and VQI facility deserts than non-deserts (50.48% vs. 40.65%, P<.001 and 52.68% vs. 43.12%, P <.001, respectively). The economic and education factor

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percentiles were significantly lower in all desert populations, while the housing, social, and pollution factors were significantly higher in non-desert regions. Healthcare access, transportation, and neighborhood factor percentiles were significantly lower in board-certified and VQI facility deserts than in the non-desert areas.

Conclusions—Access to vascular care plays a significant role in limb salvage. Through mapping vascular deserts, patient demographics and social factors in desert regions are better understood, and areas that would benefit most from targeted outreach and limb preservation programs for CLTI are identified.

Keywords

health disparities; chronic limb-threatening ischemia; access to care

Introduction

Chronic limb-threatening ischemia (CTLI) affects more than 2 million patients in the United States alone. It is associated with a 20% amputation rate within a year of diagnosis and a mortality rate of up to 40% within 12 months.[1,2] In addition to symptoms of debilitating claudication or rest pain, more than 185,000 patients with peripheral arterial disease and/or diabetes develop wounds and ultimately undergo major lower extremity amputations.[3] With an estimated cost of $17,500 to heal each wound and $30,000 per amputation, treating wounds in these patients currently approaches $25 billion annually. It is expected to double in the next decade.[4,5]

Optimal management of patients with CLTI and tissue loss is best achieved through multidisciplinary teams, including a vascular surgeon able to provide revascularization to promote wound healing.[6] For many patients, access to this specialized care plays a critical role in limb salvage. The technical skills, open and endovascular, within the arsenal of a vascular surgeon, ensures that they are specifically qualified to complete vascular procedures with targeted goals for revascularization. While some geographical regions may have a surgeon (general or cardiothoracic) offering certain vascular procedures, this differs greatly from a board-certified vascular surgeon providing vascular procedures adherent to current data-driven society guidelines.[7]

A “care desert,” also known as a “medical desert” or “hospital desert,” describes a community that does not have adequate access to pharmacies, primary care providers, hospitals, hospital beds, trauma centers, or low-cost health care centers.[8] Other deserts have been described, including food deserts, which denote an area without access to affordable and good-quality fresh food, or maternal care deserts, with limited access to maternity health care services.[9,10] Likewise, literature has demonstrated that patients within a rural community have increased mortality from traumatic injuries owing to delayed or decreased access to care in communities without a trauma center within 30 minutes.[11] Similar gaps in care exist in other surgical fields, with associated disparities in outcomes.[12,13]

Our study sought to describe a “vascular desert” similarly as an area with decreased access to subspecialty-trained vascular surgeons and a potential source of adverse outcomes for patients with CLTI. Identifying these vascular deserts presents an opportunity to improve access to care through a better understanding of population factors and the ability to target regions for specific outreach, ultimately improving CLTI patient outcomes.

Methods

Provider Identification

California providers performing open and/or endovascular surgery procedures were identified using a web-based search with the keyword “vascular surgery” and “vascular surgeon.” In addition, online provider and healthcare facility searches were completed, again with the keyword “vascular surgery” or “vascular surgeon.” Providers included were those able to offer the full spectrum of vascular surgery, including both open and endovascular surgery, management of extremity wounds, and amputation if needed.

Providers identified as performing vascular surgery procedures were categorized as either a board-certified vascular surgeon or another type of surgeon (general, cardiothoracic, etc.). To determine if providers were board certified in vascular surgery, the American Board of Surgery’s Certification Checking online tool was used (https://www.absurgery.org/app.jsp?type=vc&id=27). Each provider’s name was entered into the tool to determine the status of the provider’s certification. Surgeons with expired credentials were not included as active providers. In addition to certification, the address where each surgeon practiced was corroborated via an additional online web search. The street address, city, and zip code were recorded.

VQI Participation

The Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI) website maintains a list of provider facilities that currently participate in any of the VQI’s modules; however, the list does not specify which modules are in use at each site. Because the study is concerned solely with CLTI, only sites participating in one or both lower extremity bypass (LEB) and peripheral vascular intervention (PVI) modules were labeled as VQI sites. To determine if sites participated in these modules, quality improvement (QI) personnel at each hospital listed on the VQI website in California were contacted individually. These QI personnel were identified via online web searches to find quality managers or representatives of an equivalent position at each participating site. An email message was sent to the specified person asking for confirmation of module participation. Facility addresses were recorded, including street, city, and zip code.

Mapping & Geospatial Analysis

Geographic Information Systems (GIS) mapping was performed for identified surgeons and facilities. The addresses of all providers and facilities were imported into ArcGIS, and addresses were then geocoded to corresponding latitude and longitude through the ArcGIS World Geocoding Service (Esri, Redlands, CA). Through the California Office of Statewide Health Planning and Development (OSHPD), a base map layer with California Medical Service Study Areas (MSSAs) was imported. MSSAs are sub-city/sub-geographical units that organize population, demographic, and physician data developed to determine areas of unmet medical services needs in accordance with the Song-Brown Act of 1973 and the Garamendi Rural Health Services Act of 1976.[14,15,16] MSSAs are typically comprised of one or more census tracts. When possible, seek to limit travel time from the largest population center to 30 minutes from any location within the designated MSSA. However, this is frequently not possible in more rural census tracts. To each geocoded address, a 30-mile buffer was applied. Buffers were created in a radial milage fashion (as the crow flies) from the point of origin without consideration of roads or site access. To yield the non-desert locations, the area within the 30-mile buffer on the MSSA map was clipped. To produce desert regions, the areas outside the buffer were identified with the erase tool.

2020 census data was overlayed by census tract and corresponding latitude and longitude within the OSHPD MSSA map layer, composed of information on the population within each geographic region, including age breakdown, the racial and ethnic composition of the area, poverty level data, and insurance status. Regarding definitions of poverty included in the analysis, per 2020 census data, a family of 4 was described as living 200% below the poverty line if the annual income was less than $26,200.[17.] Once the desert and non-desert regions were created on the map, the population data was exported as a comma-separated value (csv) file for statistical analysis.

The overlay process was repeated with an overlay of the Healthy Places Index (HPI), a healthy equity data source published by the Public Health Alliance of Southern California.[18] HPI data was overlayed along corresponding census level data and provider locations by aligning census tract and corresponding latitude and longitude data through the ArcGIS World Geocoding Service. The HPI provides data regarding 25 social factors defined under eight domains: economy, education, healthcare access, housing, neighborhoods, clean environment, transportation, and social environment. These factors comprised an overall HPI score and percent, with lower scores corresponding to poorer health and outcomes.

Statistical Analysis

Descriptive statistics were performed. Categorical variables were described using frequencies and percentages. Parametric continuous variables were described by mean and standard deviation. Non-parametric continuous variables were described using the median and interquartile range. Significance testing was completed using the Chi-squared test for categorical variables. T-testing was used to analyze parametric continuous variables, and non-parametric variables were analyzed using the Kruskal-Wallis test. A P-value <0.05 conferred significance. All statistical analyses were completed in R Studio (RStudio, PBC, Boston, MA).

Results

From web-based searching, 104 physicians who perform vascular procedures were identified. Upon checking certifications with the ABS’s public site, 44 surgeons were general/cardiothoracic surgeons, and 60 were board-certified vascular surgeons. A total of 10 facilities participated in VQI modules. A total of 8 facilities participated in the LEB module, ten participated in the PVI module, and eight participated in both modules. (Figure

1) These providers were mapped by practice address and geocoded onto respective maps. (Figure 2)

The total California state population in 2020 described 23,532,471 residents. 22,136,171 residents lived within 30 miles of a surgeon offering vascular procedures, and 1,396,300 lived in a vascular desert. The number of residents who lived within 30 miles of a board-certified vascular surgeon was 21,580,226, with 1,952,245 living in a desert region. Finally, the population with access to a VQI surgeon for lower extremity bypass or peripheral vascular intervention was even lower, with only 17,108,189 living within 30 miles and 6,424,282 in a desert region. (Figure 2) There was a significant difference in the mean size of the MSSA in square miles for all vascular deserts compared to the non-desert areas, confirming that MSSAs in deserts were more frequently composed of larger and more rural census tracts. (All-surgeons non-desert 5 miles, vs. desert 271 miles, p = <0.002, Board-certified non-desert 3.8 miles vs. desert 203 miles p<0.001, VQI non-desert 1.9 miles vs. desert 68.4 miles p<0.001).

Census-Level Population Factors

There were significant differences when looking at the demographic breakdown of residents in the desert and non-desert areas. (Table1) There were more residents with household income below 200% of the poverty line in any vascular care desert (non-desert = 36.3%, desert = 37.5%, p <0.001) or a board-certified vascular surgeon desert (non-desert = 36.1%, desert = 39.7%, p<0.001). However, the difference was insignificant when comparing VQI deserts and non-deserts (non-desert = 35.2, desert = 39.6%, p=0.16).

The racial and ethnic breakdown also showed significant differences between desert and non-desert regions. White persons were significantly higher in all the vascular desert regions. (Table 1) Asian, black, and Hispanic residents were more likely to live in a non-desert area. There was no significant difference in the number of Hispanic residents who resided in VQI vascular deserts versus non-desert (36% vs. 37%, p=0.08).

The number of residents over 65 was also higher in all desert regions compared to the non-desert areas. In the all-provider care group in non-desert regions, the percentage of people over 65 is 13% versus 16% in desert regions (p<0.001). In board-certified vascular deserts, the number of people over 65 was 15% versus 13% in non-desert regions (p<0.001). Finally, in VQI desert areas, the number of people over 65 was 14% versus 12% in non-desert areas (p<0.001). The percentage of uninsured residents was significant only in the desert and non-desert populations served by board-certified vascular surgeons (19.6 vs. 16.8%, p <.001). In the VQI and the all-vascular care areas, the percentage of uninsured was not significantly different. (Table 1).

Healthy Places Index- Social Determinants of Health Factors

When comparing the HPI percentile, the score was significantly lower in board-certified vascular deserts and VQI facility deserts (40.65±23.19 versus 50.48±29.02%, p<.001 and 43.12±26.17 versus 52.6829.27%, p<.001, respectively). (Table 2) However, it was higher in the all-provider desert region (53.22±26.96 versus 50.26±29.0%, p=.007). Within domains comprising the overall HPI score, education factors and the overall education domain percentile were significantly lower in all desert populations (45.66±31.45 versus 49.05±29.69%, p=.005 in all provider regions, 34.60±25.07 versus 49.34±29.69%, p<.001 in board-certified vascular provider regions, and 38.46±26.33 versus 52.10±29.88%, p<.001 in VQI facility regions), corresponding to a less educated population living in all desert regions compared to the non-desert areas. This finding was mirrored in the economic domain, with all desert regions reporting a lower mean income percentile and overall economic percentile (42.62±31.04 versus 49.13±29.61%, p<.001 in all provider regions, 32.22±25.27 versus 49.44±29.61%, p<.001 in board-certified vascular areas, and 38.35±27.85 versus 52.31±29.41%, p<.001 in VQI facility regions). The healthcare access percentile was significantly lower in the board-certified vascular and VQI facility desert regions (43.03±40.99 versus 48.87±48.20%, p<.001 and 46.00±26.95 versus 49.86±30.53%, p<.001, respectively). The housing, neighborhood, pollution, and social domain percentiles tended to be higher in desert regions. However, the transportation percentile was significantly lower in board-certified vascular and VQI facility desert regions (41.06±28.40 versus 49.06±29.58%, p<.001 and 39.92±28.05 versus 51.65±29.51%, p<.001). The transportation percentile did not significantly differ in all provider regions.

Discussion

Using OSHPD data files, we used ArcGIS to describe access to vascular care for CLTI on a population level with census and HPI data points allowing for evaluation of populations living in the desert and non-desert areas. Analysis of population-level statistics revealed that patients residing in desert areas with all vascular providers and board-certified vascular providers had a higher rate of poverty than non-desert areas, a finding confirmed by multiple factors in census-level data and the Healthy Places Index. Additionally, we observed that non-white patients were more likely to reside in urban areas, closer to vascular providers and VQI facilities. In contrast, more elderly and white patients lived within desert regions, and being insured was not significantly different among desert and non-desert populations. Other social determinants of health identified by the HPI indicated less education and transportation access in desert regions despite improved housing and pollution measures.

Poverty has long been described as a population-level factor associated with poorer education and overall socioeconomic status.[19, 20] Knowing these complex interwoven factors, poverty has been identified as a surrogate and an independent risk factor for the increased prevalence of peripheral arterial disease (PAD).[21] When comparing desert versus non-desert populations in regions with all provider types and board-certified vascular surgeons, we noted a significantly higher percentage of people living 200% below the poverty line in desert regions. This finding was not significant in VQI regions, despite a similar disparity between desert and non-desert regions, suggesting a similar ongoing phenomenon. The HPI also confirmed this finding, with a lower mean income and overall economic percentile in desert versus non-desert regions. We noted that desert regions are generally synonymous with more rural areas, and historically poverty is more pronounced in rural areas.[22] Our current findings affirm these prior population-level observations. In the setting of known association with increased prevalence of PAD, our data support the association between poverty and access to adequate vascular care. When offering care to patients from desert regions, care should be taken to minimize out-of-pocket expenses for this population. One option to reduce the patient's financial burden is further incorporating telehealth into existing practices. By partnering with primary care providers in rural desert regions, providers may work to establish care pathways that limit in-person appointments.

For all groups, the population residing in desert areas comprised a significantly higher proportion of patients over 65 years than residents in non-desert areas. These findings correspond to census-level data that has previously demonstrated a higher proportion of the population between 65 and 85 years of age residing in more rural areas.[23] For many of these patients who have reached retirement, proximity to urban areas is typically unnecessary. Rural regions may offer a lower cost of living that is more compatible with the fixed incomes on which many elderly patients subsist. The limitations associated with a fixed or low income present a primary source for decreased access to care through reduced funds for travel to larger facilities and specialized care in more urban regions. The financial limitations combined with the increased prevalence of chronic diseases in a more elderly population present substantial barriers to adequate care.

Another potential barrier includes access to transportation. While patients in urban areas may also experience significant poverty, proximity to a provider and availability of public transit eases some of the burden associated with travel for a specialty care appointment. For populations in more rural regions, longer travel times for specialty care combined with a lack of public transportation can create a significant barrier for many patients, especially compounded by increased poverty rates. Appreciating this burden allows providers to adjust care models to limit these burdens. One method to address this burden includes incorporating remote telehealth visits into provider practice patterns to limit the barrier to care posed by travel.

Our analysis of racial and ethnic groups confirmed findings consistent with prior census data. Within all non-white and non-ethnic groups, a significantly larger proportion of patients resided in urban and non-desert areas. Despite nearness to specialty providers and facilities, there has been a noted and persistent disparity in outcomes, with African Americans having a rate of amputation 2 to 4 times higher than white patients.[24] Such findings demonstrate that access to care is a complex problem, and proximity to providers is one of many barriers to care. Further investigation is warranted to explore additional factors unique to these populations and methods to improve access to care.

There were multiple limitations in our study. Providers included were those offering comprehensive vascular care described as both open and endovascular surgery, thus interventional radiologists, cardiologists, and others providing isolated peripheral endovascular intervention were not included for analysis; therefore, this does not represent an exhaustive map of all providers able to offer some form of vascular intervention, as the complexity of CLTI is best managed by those providers able to address all aspects of related care. By choosing the VQI as our QI program to denote quality care, we are potentially excluding other high-quality care facilities participating in other QI programs and biasing our results accordingly. The included analysis is drawn from census-level data, providing a limited retrospective snapshot of population-level data subject to sampling errors, among other traditional limitations of retrospective data review. Additionally, spatial analysis was accomplished with 30-mile radius buffers surrounding providers and facilities. These buffers, measured as the crow flies, do not account for actual transit time and may underestimate the true burden of travel experienced by many patients. The decision to set the boundary at 30 miles arises from the expectation that transit time can dramatically vary by region, with 30 miles sometimes representing an hour or more commute each way. Prior literature suggests there is a linear relationship with an increasing rate of loss to follow-up with increasing transit time, and our own institutional experience demonstrates the additional burden that many patients experience when forced to travel long distances for care.[25]Our findings also show that multiple complex factors interplay to determine individual patient access to care. A population-level study can only partially capture these complex factors, though it may help provide some guidance for further research and targeted limb preservation outreach efforts.

Conclusion

Access to specialty vascular care as part of a multidisciplinary management approach plays a significant role in limb salvage. The characteristics of at-risk patients in these areas are better understood through spatial analysis of vascular deserts and evaluation of census data and traditional social determinants of health. In addition, areas that have the most potential for benefit from targeted limb preservation outreach programs and changes in practice patterns in CLTI are identified.

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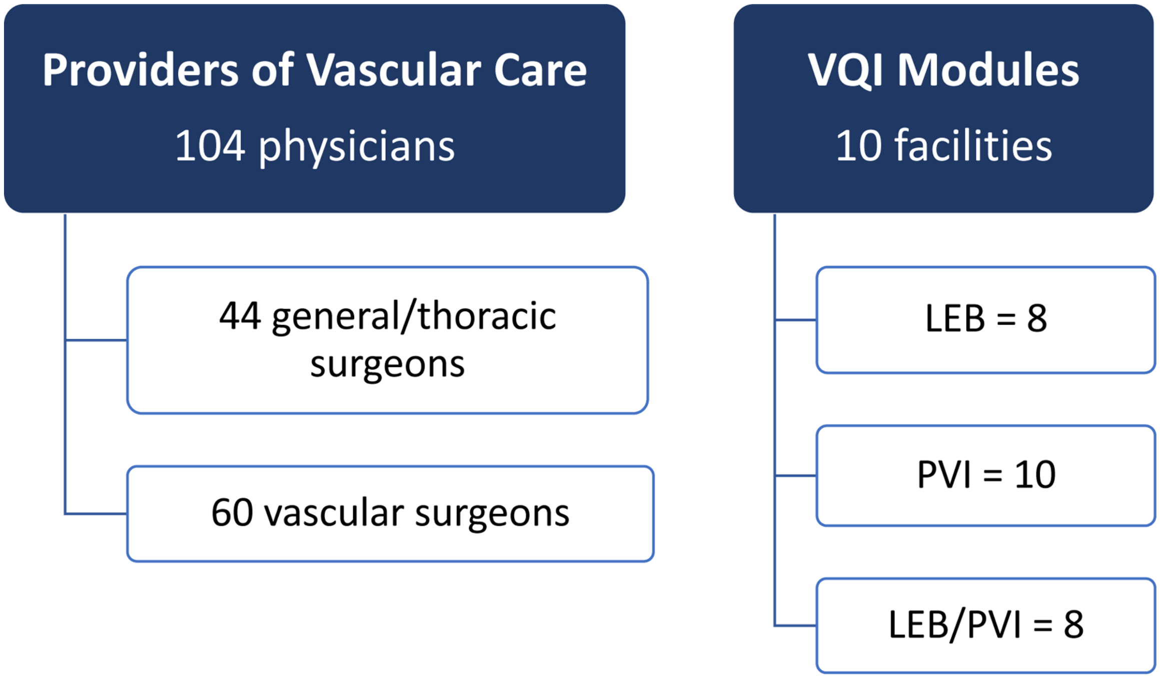

Figure 1:
Breakdown of providers and facilities present within desert maps. 104 physicians (60 vascular surgeons and 44 general/thoracic surgeons) comprised the all-provider map, while 60 vascular surgeons comprised the board-certified vascular surgeon map. A total of 10 facilities participated in VQI extremity modules. Eight facilities participated in both the peripheral vascular intervention and lower extremity bypass modules, and two facilites in only the peripheral vascular intervention module.

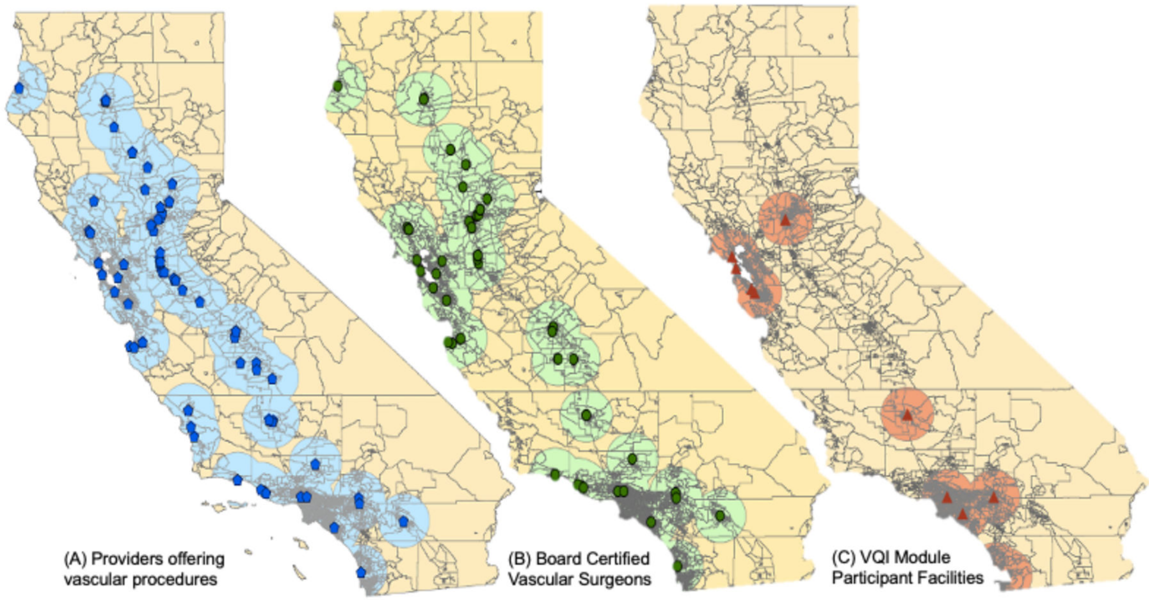

Figure 2.

Maps demonstrating the types of vascular care across California MSSAs with a 30-mile zone around each provider or facility to demonstrate desert (yellow) vs. non-desert (colored) communities. A represents any surgeon that performs vascular procedures (blue), B. represents Board Certified Vascular Surgeons (green), and C represents sites that participate in the VQI LEB/PVI modules (orange).

Table 1:

A depiction of population level factors in desert versus non-desert regions based on type of specialty care provided.

Table 1: Population composition of residents in desert versus non-desert communities									
	All Providers			**Board-certified Vascular Surgeons**			**VQI Facilities**		
	Non-Desert (%)	**Desert (%)**	**P value**	**Non-Desert (%)**	**Desert (%)**	**P value**	**Non-Desert(%)**	**Desert (%)**	**P value**
200% below poverty level	36.3	37.5	<.001	36.1	39.7	<.001	35.2	39.6	0.16
White	59.2	82.2	<.001	58.8	81.3	<.001	55.0	75.6	<.001
Asian	22.1	4.48	<.001	22.4	6.1	<.001	25.0	10.3	<.001
Hispanic	37.3	28.2	<.01	37.2	31.7	<.001	37.1	36.0	0.08
Black	12.2	5.5	<.001	12.4	5.4	<.001	13.4	7.4	<.001
Uninsured	17.9	17.6	0.71	19.6	16.8	<.001	17.1	17.2	0.93

Table 2:

Social determinants of health factors of residents in desert versus non-desert communities.

	All Providers			Board-certified Vascular Surgeons			VQI Facilities		
	Non-Desert (%±STD)	**Desert (% ±STD)**	**P value**	**Non-Desert (%±STD)**	**Desert (% ±STD)**	**P value**	**Non-Desert (%±STD)**	**Desert (% ±STD)**	**P value**
Healthy Places Index Factors (Mean Percentile)									
Overall HPI Percentile *	50.26±29.00	53.22±26.96	.007	50.48±29.03	40.65±23.19	<.001	52.68±29.27	43.12±41.99	<.001
HPI Domains (Economic, Education, Healthcare Access, Housing, Neighborhood, Polution, Transportation, Social)									
Economic Percentile	49.13±29.61	42.62±31.04	<.001	49.44±29.61	32.22±25.27	<.001	52.31±29.41	38.35±27.85	<.001
-Mean Income Percentile	49.10±29.61	44.53±30.55	<.001	49.41±29.66	35.07±25.29	<.001	51.67±29.80	40.62±27.68	<.001
Education Percentile	49.05±29.69	45.66±31.45	.005	49.34±29.69	34.60±25.07	<.001	52.10±29.88	38.46±26.33	<.001
-Percent high school aged in high school	74.23±40.13	70.23±43.09	.014	74.41±40.04	66.91±43.43	<.001	75.21±39.74	70.44±41.64	<.001
-Percentage >25 years completed college	48.99±29.78	47.93±29.67	.347	49.27±29.82	35.29±22.18	<.001	52.25±30.10	38.22±25.26	<.001
Healthcare Access Percentile	48.73±29.72	50.12±29.24	.209	48.87±29.80	43.03±26.11	<.001	49.86±30.53	46.00±26.95	<.001
Housing Percentile	48.45±29.64	53.71±28.80	<.001	48.35±29.70	54.90±28.16	<.001	47.38±30.20	53.65±27.77	<.001
Neighborhood Percentile	48.59±29.49	46.66±33.81	.130	48.87±29.50	40.69±22.03	<.001	50.09±29.07	43.28±31.07	<.001
Pollution Percentile	48.15±29.50	63.01±31.62	<.001	47.93±29.30	57.00±33.06	<.001	47.32±28.12	52.77±33.25	<.001
Transportation Percentile	48.87±29.60	50.16±32.26	.291	49.06±29.58	41.0628.40	<.001	51.65±29.51	39.92±28.05	<.001
Social Percentile	48.64±29.62	53.62±31.34	<.001	48.61±29.60	50.61±30.04	.106	48.53±29.76	50.28±29.67	.019

* The HPI percent is derived from a score composed of 25 individual factors organized in 8 domains: economy, education, healthcare access, housing, neighborhoods, clean environment, transportation, and social environment. A higher percentile corresponds to healthier community conditions.