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Research Paper

Surgical subspecialist distribution and Social Vulnerability Indices in the inland empire

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HIGHLIGHTS

- There are more male than female surgeons per census tract.
- The number of male surgeons in a census tract is inversely related with minority status/language vulnerability.
- A census tract's social vulnerability and its number of surgical subspecialists are primarily inversely related.
- Fewer surgical subspecialists are linked to minority status/language, transportation, disability, and social vulnerability.

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ABSTRACT

Background: Access to surgical specialty care differs based on geographic location, insurance status, and subspecialty type. This study uses the Inland Empire as a model to determine the relationship between Social Vulnerability Indices (SVIs), surgeon sex, and surgical subspecialty distribution.

Methods: 823 census tracts from the Centers for Disease Control's (CDC) SVI 2018 database were compared against 992 surgeons within 30 distinct subspecialties. This data was retrieved from the American Medical Association's (AMA) 2018 Physician Masterfile. Spearman's bivariate and multiple regression were used to compare the relationship between SVI and number of surgical subspecialists within each census tract.

Results: There were approximately 3.34 male and 0.35 female surgeons per census tract ($t(267) = 7.74$, $p < 0.001$). Significant inverse relationships existed between Cosmetic surgery, Urology and Minority status/language ($\rho = -0.131$ [95 % CI −1.000 to −0.028], $p = 0.016$; $\rho = -0.142$ [95 % CI −1.000 to −0.039], $p = 0.010$, respectively); General surgery, Socioeconomic status ($\rho = -0.118$ [95 % CI −1.000 to −0.014], $p = 0.027$), and Household composition/disability ($\rho = -0.203$ [95 % CI −1.000 to −0.102], $p < 0.001$); Hand surgery and Socioeconomic status ($\rho = -0.114$ [95 % CI −1.000 to −0.010], $p = 0.031$); Otolaryngology, Housing type/transportation ($\rho = -0.102$ [95 % CI −1.000 to 0.001], $p = 0.047$), and Overall Social Vulnerability ($\rho = -0.105$ [95 % CI −1.000 to −0.001], $p = 0.043$). Multiple regression analyses reinforced these findings.

Conclusions: This study concludes that social vulnerability is predictive of, and significantly linked to, differences in distribution of surgical subspecialty and surgeon gender. Future research should investigate recruitment of a diverse surgical workforce, infrastructural barriers to care, and differences in quality of care.

Key message: Our work demonstrates complex relationships between surgical subspecialist distribution, surgeon gender, and a census tract's various Social Vulnerability Indices. Thus, this research can serve to continue educating surgeons and other healthcare providers about the importance of social determinants of health in the construction of healthcare policy and practice, as well as incentivizing equitable recruitment of a diverse population of surgeons.

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Introduction

A significant portion of the United States lacks any surgeons,[1] while others struggle balancing the need of the patient population with surgeon supply.[2] This surgical shortage is particularly pronounced when considering surgical subspecialties. The American Association for Thoracic Surgery anticipates a critical lack of cardiothoracic surgeons by 2035, due to a failure of a proportional increase in residents alongside an increasing surgical workload.[3] Similarly, in pediatric surgery, "average distances to the nearest provider ranged from 27.1 miles for pediatric surgery to 100.9 miles for pediatric cardiothoracic surgery," creating significant barriers for patients to effectively access Pediatric Surgical care.[4] Furthermore, access to surgical specialty care differs significantly based on insurance status, with greater restrictions on patients "with government-funded insurance […] compared with those with commercial insurance".[5] These variations in distance, financial burden, insurance coverage, and equipment access[2] are observed across all surgical subspecialties.[6–8] When coupled with the non-interchangeability of surgeons between specialties, they indicate a troubling lack of surgical access for many.

The Centers for Disease Control (CDC) developed Social Vulnerability Indices (SVIs) as a way to describe and quantify the risk factors experienced by different census tracts across the United States.[9] They are grouped into four major categories: Socioeconomic, Household composition and disability, Minority status and language, and Housing type and transportation, with other sub-characteristics included within each category.

The Inland Empire (IE), an informally designated geographic area in Southern California centering around San Bernardino and Riverside counties, exhibits varied stratifications across nearly every SVI, including transportation access, education level, exposure to pollution, and income.[9,10] San Bernardino County displays poorer levels of prenatal care and food access, and higher rates of hospitalizations and illness for female patients and ethnic minorities compared to not only its neighboring Riverside County, but also the rest of California.[11] As a result, the IE, with its juxtaposition of wealthier cities, such as Loma Linda and Chino Hills, alongside their less socioeconomically advantaged counterparts, such as San Bernardino and Perris, serves as an insightful model for the larger patterns of healthcare disparity found in cities and counties across the larger United States.[10]

Given the marked difference in surgical subspecialty accessibility[12] across different communities, this study builds upon prior analysis of the relationship between surgeons and Social Vulnerability Indices (SVIs) in the Inland Empire.[13] The previous study demonstrates a significant inverse relationship between social vulnerability and number of total surgeons within a census tract. This study delves deeper into this association, using the IE as a model to understand the relationship between surgical subspecialty distribution, and SVIs and their sub characteristics.

Methods

Unlike other legally delineated areas, such as counties and cities, "'Inland Empire' is a made-up term and the areas to which it applies have been argued over for a century".[14] Thus, this study applied a more conservative definition, incorporating only the areas most often agreed upon: San Bernardino and Riverside counties[15,16] (Fig. 1).

To investigate whether the IE has a lower number of surgeons in locations with higher SVIs compared to locations with lower SVIs, two major resources were utilized. The first was the CDC SVI database for California. The CDC provides a series of calculated SVIs which quantify social vulnerability within counties and communities in a number, based on statistics such as the median number of people in a household, the number of languages other than English spoken, the risk of becoming unhoused, a household's median income, etc.[11] This information is then sorted by census tract, providing a numerical insight into a particular geographic region's social vulnerability, with higher SVI numbers equating to higher vulnerability. San Bernardino County's 2018 SVIs were utilized in this project, to ensure that information corresponded to the information in the second resource, the American Medical Association's Physician Masterfile.[12] This provided information about physician specialty, gender (binary), residency location, and importantly, census tract of practice. From this database, we created individual totals for each subspecialty of practicing surgeons who resided in San Bernardino and Riverside County, excluding those who were deceased or no longer practicing, as these individuals are not impacting a community's access to specialty surgical care; this yielded total 1007 surgeons. 15 surgeons were removed from this total due to inappropriate census tract or absent gender labeling, yielding 992 surgeons. Amongst these 992 surgeons, there were 30 distinct subspecialties: Adult reconstructive orthopedics, Cardiovascular disease, Colon and rectal surgery, Cosmetic surgery, Facial plastic surgery, Female pelvic medicine (urology), Foot and ankle orthopedics, General surgery, Hand surgery, Hand surgery (orthopedics), Hand surgery (plastics), Neurological surgery, Oral and maxillofacial surgery, Orthopedic surgery, Orthopedic surgery of the spine, Otolaryngology-head and neck surgery, Pediatric cardiothoracic surgery, Pediatric surgery (orthopedics), Pediatric surgery (neurology), Pediatric surgery (surgery), Pediatric urology, Plastic surgery, Sports medicine (orthopedic surgery), Trauma/critical care (surgery), Surgical oncology, Surgical oncology (urology), Thoracic surgery, Transplant surgery, Urology, and Vascular surgery.

The number of each surgical subspecialty in a census tract was compared to the various SVIs in their respective census tract, thus focusing on determining whether or not there lies a relationship between a census tract's social vulnerability and the number of subspecialty surgeons within that census tract. This allowed for a careful examination of how socioeconomic status, household composition, minority status, and housing type affects one's ability to readily access subspecialty surgery in the IE. Census tracts not listed in the Physician Masterfile were assumed to have zero surgeons and were not included in the analysis, in order to isolate the impact of SVIs on the presence or absence of surgical subspecialists.

Data analysis was conducted via SPSS in two stages. First, a Spearman's bivariate analysis was used to demonstrate the relationship between the four major SVI categories and the number of surgical subspecialists per census tract. Significance was set at $p < 0.05$. The SVIs utilized in this analysis were imported from the CDC's list of measured SVIs for each census tract. Following the Spearman's analysis, a multiple regression analysis plotted the same SVIs utilized in the Spearman's model, with surgeon number serving as the independent variable, to determine which of the previously investigated census tract characteristics was most associated with surgeon number. Utilizing the same SVIs across both analytical methodologies allowed us to investigate the relationships in a consistent manner.

Results

This investigation studied a total of 992 surgeons. Of those 992, 896 were male, and 96 were female. On average, there were approximately 3.34 male and 0.35 female surgeons per census tract ($t(267) = 7.74$, $p < 0.001$, Table 1), with the number of male surgeons demonstrating a significantly inverse relationship with minority status/language ($\rho = -0.149$ [95 % CI −1.000 to −0.047], $p = 0.007$). The total numbers of each surgical subspecialty can be found in Table 1.

Many of the surgical subspecialties did not demonstrate significant relationships with the various SVIs. Of those that did: Cosmetic surgery and urology had significantly inverse relationships with Minority status/language ($\rho = -0.131$ [95 % CI −1.000 to −0.028], $p = 0.016$; $\rho = -0.142$ [95 % CI −1.000 to −0.039], $p = 0.010$, respectively). General surgery exhibited significantly inverse relationships with both Socioeconomic status ($\rho = -0.118$ [95 % CI −1.000 to −0.014], $p = 0.027$) and Household composition/disability ($\rho = -0.203$ [95 % CI −1.000 to −0.102], $p < 0.001$). Hand surgery also had an inverse relationship with

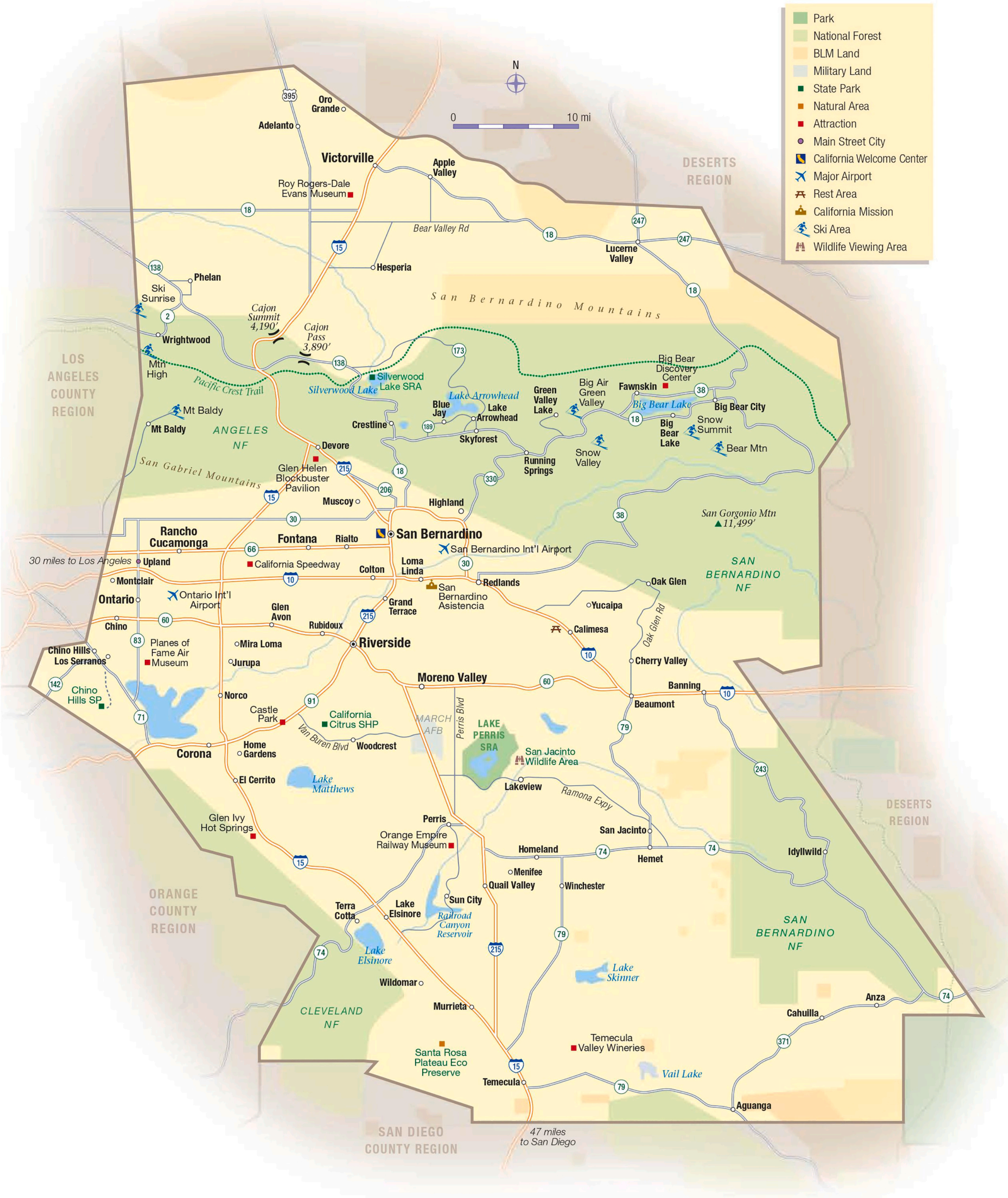

Fig. 1. Map of the Inland Empire [52].
Accessed from popumaps.blogspot.com [site removed].

Table 1
Individual counts of the number of each surgical subspecialty within the Inland Empire divided by gender.

Total surgeon numbers		
Specialty	Count	
	Male	Female
Adult reconstructive orthopedics	3	0
Cardiovascular disease	2	0
Colon and rectal surgery	18	2
Cosmetic surgery	2	0
Facial plastic surgery	4	0
Female pelvic medicine (urology)	2	1
Foot and ankle orthopedics	2	0
General surgery	215	40
Hand surgery	16	4
Hand surgery (orthopedics)	11	0
Hand surgery (plastics)	5	2
Neurological surgery	56	4
Oral and maxillofacial surgery	7	0
Orthopedic surgery	191	10
Orthopedic surgery of the spine	11	0
Otolaryngology-head and neck surgery	3	0
Pediatric cardiothoracic surgery	1	0
Pediatric surgery (orthopedics)	8	2
Pediatric surgery (neurology)	1	0
Pediatric surgery (surgery)	4	1
Pediatric urology	2	1
Plastic surgery	47	11
Sports medicine (orthopedic surgery)	33	0
Trauma/critical care (surgery)	29	5
Surgical oncology	10	2
Surgical oncology (urology)	1	0
Thoracic surgery	52	1
Transplant surgery	4	0
Urology	99	7
Vascular surgery	56	6
Mean number of surgeons per census tract*	3.34	0.35

* $t(267) = 7.745$, $p < 0.001$.

Socioeconomic status (ρ = −0.114 [95 % CI −1.000 to −0.010], p = 0.031). Otolaryngology demonstrated a significantly inverse relationship with Housing type/transportation (ρ = −0.102 [95 % CI −1.000 to 0.001], p = 0.047) as well as Overall Social Vulnerability (ρ = −0.105 [95 % CI −1.000 to −0.001], p = 0.043). Table 2 provides further information on Spearman rho values for each surgical subspecialty and their relationship with the four primary SVIs.

Multiple regression analysis revealed the following relationships between SVI subcategories and surgical subspecialties: increased Housing type/transportation vulnerability was associated with a greater number of Adult reconstructive orthopedic surgeons (B = 0.381 [95 % CI 0.052 to 0.710]; $t(266) = 2.290$, $p < 0.023$),@@@ Orthopedic surgeons (B = 6.022 [95 % CI 0.580 to 11.463]; $t(266) = 2.185$, $p < 0.030$), and Colon and rectal surgeons (B = 1.449 [95 % CI 0.249 to 2.649]; $t(266) = 2.385$, $p < 0.018$; Table 3). A larger percentage of persons in group quarters was associated with more Foot and Ankle Orthopedic Surgeons (B = 0.038 [95 % CI 0.013 to 0.063]; $t(266) = 2.946$, $p < 0.004$) and Surgical Oncologists (B = −0.080 [95 % CI −0.155 to −0.004]; $t(266) = -2.091$, $p < 0.038$), and a larger percentage of housing in multi-unit structures (>10 units) was associated with more Orthopedic Surgeons of the Spine (B = 0.019 [95 % CI 0.003 to 0.035]; $t(266) = 2.312$, $p < 0.022$). A greater total number of households was associated with more Hand Surgeons (B = 0.001 [95 % CI 0.0003 to 0.001]; $t(266) = 3.134$, $p < 0.002$). A larger daytime population, defined as the number of people (including residents and commuters) present in an area during normal business hours, was associated with greater numbers of Pediatric Surgeons (B = 5.10E−6 [95 % CI 3.873E−8 to 1.017E−5]; $t(266) = 1.990$, $p < 0.048$).

A greater number of households with no vehicle available was associated with fewer Cosmetic Surgeons (B = 0.002 [95 % CI 0.000 to 0.003]; $t(266) = 2.656$, $p < 0.009$), and a greater percentage of persons 25 years or older with no high school diploma was associated with fewer numbers of both General Surgeons (B = 0.278 [95 % CI 0.038 to 0.519]; $t(266) = 2.284$, $p < 0.024$) and Neurosurgeons (B = 0.114 [95 % CI 0.013 to 0.215]; $t(266) = 2.227$, $p < 0.027$). Greater Overall Social Vulnerability was associated with fewer Otolaryngologists (B = 1.752 [95 % CI 0.871 to 2.632]; $t(266) = 3.928$, $p < 0.001$). Finally, a greater percentage of minority (defined as all persons except white, non-Hispanic) was associated with fewer Urologists (B = 0.217 [95 % CI 0.008 to 0.427]; $t(266) = 2.049$, $p < 0.042$).

Discussion

Amid evolving patterns of surgical care, our study investigates the relationship between surgical subspecialties and the communities they serve. While prior studies have focused on the distribution of primary care physicians,[17] the present study found that there are significantly inverse relationships between most surgical subspecialists and the SVIs of the census tracts they serve. Furthermore, our results demonstrate that there is significant variability in both the number of surgeons within each surgical subspecialty, as well as the distribution of these subspecialists across different census tracts.

In addition, the majority of census tracts surveyed within the IE had zero surgeons, thus reinforcing the notion that many communities are without surgeons at all.[1,2] Within those communities that had surgeons, many were concentrated in areas with high Housing type/Transportation Indices, but not in areas with high Minority Status/Language or Socioeconomic indices. This consistent elevation in Transportation vulnerability may reflect the IE's significant deficits in public transportation infrastructure[18] throughout all census tracts, ensuring that surgeons will inevitably practice in an area with poor transportation indices. However, the differences in income between neighboring cities such as Loma Linda and San Bernardino also provide greater opportunities for selective employment away from areas with higher socioeconomic vulnerabilities.[9] Thus, the inverse relationship between the number of Cosmetic surgeons, Otolaryngologists, and Transportation may thus mirror similar patterns of wealth disparity. Furthermore, the inverse relationship between Cosmetic surgeons, Urologists, and Minority status/language, coupled with the inverse relationship between General surgeons, Hand surgeons, and Socioeconomic status, further emphasizes that these differences in economic wealth are often drawn across racial lines.

The positive relationship between a larger daytime population and Pediatric surgeons may reflect the continued increase in concentration of Pediatric surgeons in urban, population dense areas as the number of pediatric inpatient units continues to decrease nationally.[19] Finally, there was a marked disproportion between the numbers of male and female surgeons in the IE, mirroring the pattern of gender distribution across the larger United States.[20] Thus, our findings warrant further discussion.

A recent study estimated that health disparities cost $1.24 trillion from 2003 to 2006 in direct medical costs, premature death, and lost productivity, creating a strong economic incentive for the study and elimination of health disparities.[21] In the current surgical environment, vulnerable patients are more likely to receive care by low-volume surgeons at lower-volume hospitals, despite evidence that volume is significantly related to improved surgical outcomes.[22,23] Subsequently, patient mortality continues to differ significantly based on socioeconomic status and racial identity. Ethnic minorities and patients in lower socioeconomic quartiles demonstrate higher rates of operative mortality and post-operative complications compared to their white or wealthier counterparts.[24,25] Some surgeons suggest that "this disparity is related to excessive administrative burdens and low monetary reimbursement" involved in practicing in lower-income communities.[5] This is reflected in our demonstration of the inverse association between Overall Social Vulnerability and Otolaryngologists, as well as percentage of minorities and Urologists (Table 3).

Table 2
Table detailing the Spearman rho values for the four major categories of social vulnerability, as well as the sum of the categories, when compared with number of surgical subspecialists per census tract.

Spearman rho values										
Surgical subspecialty/gender	Socioeconomic status theme		Household composition/disability theme		Minority status/language theme		Housing type/transportation theme		Overall social vulnerability	
	Spearman's ρ (95 % CI)	*p*	Spearman's ρ (95 % CI)	*p*	Spearman's ρ (95 % CI)	*p*	Spearman's ρ (95 % CI)	*p*	Spearman's ρ (95 % CI)	*p*
Adult reconstructive orthopedics	0.031 (−0.073, 1.000)	0.307	0.013 (−0.091, 1.000)	0.419	0.006 (−0.098, 1.000)	0.463	0.108 (0.005, 1.000)	0.038	0.065 (−0.039, 1.000)	0.145
Cardiovascular disease	−0.112 (−1.000, −0.009)	0.033	−0.002 (−1.000, 0.101)	0.485	−0.109 (−1.000, −0.005)	0.038	−0.102 (−1.000, 0.002)	0.048	−0.108 (−1.000, −0.005)	0.039
Colon and rectal surgery	−0.007 (−1.000, 0.097)	0.454	0.008 (−0.096, 1.000)	0.447	−0.036 (−1.000. 0.068)	0.280	0.101 (−0.002, 1.000)	0.049	0.032 (−0.072, 1.000)	0.301
Cosmetic surgery	−0.050 (−1.000, 0.053)	0.205	0.029 (−0.075, 1.000)	0.317	−0.131 (−1.000, −0.028)	0.016	0.096 (−0.007, 1.000)	0.058	0.004 (−0.100, 1.000)	0.475
Facial plastic surgery	0.015 (−0.089, 1.000)	0.405	0.012 (−0.091, 1.000)	0.420	−0.013 (−1.000, 0.091)	0.418	0.074 (−0.030, 1.000)	0.112	0.036 (−0.068, 1.000)	0.280
Female pelvic medicine (urology)	−0.015 (−1.000, 0.088)	0.401	−0.070 (−1.000, 0.034)	0.125	−0.011 (−1.000, 0.093)	0.430	−0.037 (−1.000, 0.067)	0.274	−0.037 (−1.000, 0.067)	0.274
Foot and ankle orthopedics	0.015 (−0.089, 1.000)	0.406	−0.061 (−1.000, 0.043)	0.160	−0.039 (−1.000, 0.065)	0.261	0.095 (−0.009, 1.000)	0.061	0.025 (−0.079, 1.000)	0.341
General surgery	−0.118 (−1.000, −0.014)	0.027	−0.203 (−1.000, −0.102)	< 0.001	−0.045 (−1.000, 0.059)	0.231	0.016 (−0.088, 1.000)	0.400	−0.085 (−1.000, 0.019)	0.082
Hand surgery	−0.114 (−1.000, −0.010)	0.031	−0.081 (−1.000, 0.023)	0.093	−0.073 (−1.000, 0.031)	0.118	0.027 (−0.077, 1.000)	0.329	−0.061 (−1.000, 0.043)	0.161
Hand surgery (orthopedics)	−0.031 (−1.000, 0.073)	0.307	0.027 (−0.076, 1.000)	0.327	−0.072 (−1.000, 0.032)	0.121	0.031 (−0.073, 1.000)	0.305	−0.002 (−1.000, 0.102)	0.488
Hand surgery (plastics)	0.054 (−0.049, 1.000)	0.187	0.109 (0.005, 1.000)	0.038	0.068 (−0.036, 1.000)	0.134	0.091 (−0.013, 1.000)	0.069	0.093 (−0.011, 1.000)	0.064
Neurological surgery	−0.099 (−1.000, 0.004)	0.052	−0.011 (−1.000, 0.092)	0.427	−0.102 (−1.000, 0.001)	0.047	0.034 (−0.070, 1.000)	0.289	−0.041 (−1.000, 0.062)	0.249
Oral and maxillofacial surgery	−0.016 (−1.000, 0.088)	0.396	−0.020 (−1.000, 0.084)	0.375	0.004 (−0.100, 1.000)	0.473	0.065 (−0.038, 1.000)	0.143	0.019 (−0.085, 1.000)	0.377
Orthopedic surgery	−0.013 (−1.000, 0.091)	0.417	−0.016 (−1.000, 0.087)	0.395	−0.038 (−1.000, 0.066)	0.269	0.129 (0.026, 1.000)	0.017	0.034 (−0.070, 1.000)	0.288
Orthopedic surgery of the spine	0.050 (−0.054, 1.000)	0.207	−0.025 (−1.000, 0.079)	0.345	0.010 (−0.094, 1.000)	0.435	0.062 (−0.042, 1.000)	0.155	0.034 (−0.070, 1.000)	0.290
Otolaryngology-head and neck surgery	−0.097 (−1.000, 0.007)	0.057	−0.034 (−1.000, 0.070)	0.292	−0.100 (−1.000, 0.004)	0.051	−0.102 (−1.000, 0.001)	0.047	−0.105 (−1.000, −0.001)	0.043
Pediatric cardiothoracic surgery	0.065 (−0.039, 1.000)	0.144	−0.020 (−1.000, 0.084)	0.371	0.061 (−0.043, 1.000)	0.159	0.102 (−0.001, 1.000)	0.047	0.082 (−0.022, 1.000)	0.091
Pediatric surgery (orthopedics)	−0.058 (−1.000, 0.046)	0.173	0.074 (−0.030, 1.000)	0.113	−0.053 (−1.000, 0.051)	0.193	−0.020 (−1.000, 0.084)	0.374	−0.026 (−1.000, 0.077)	0.334
Pediatric surgery (neurology)	0.095 (−0.008, 1.000)	0.060	0.065 (−0.039, 1.000)	0.144	0.094 (−0.010, 1.000)	0.063	0.061 (−0.043, 1.000)	0.162	0.090 (−0.014, 1.000)	0.071
Pediatric surgery (surgery)	−0.028 (−1.000, 0.076)	0.325	−0.055 (−1.000, 0.049)	0.185	−0.034 (−1.000, 0.070)	0.288	0.082 (−0.022, 1.000)	0.092	0.010 (−0.094, 1.000)	0.437
Pediatric urology	−0.009 (−1.000, 0.094)	0.439	−0.040 (−1.000, 0.064)	0.259	0.041 (−0.063, 1.000)	0.252	0.021 (−0.083, 1.000)	0.364	0.009 (−0.095, 1.000)	0.442
Plastic surgery	−0.012 (−1.000, 0.092)	0.423	−0.067 (−1.000, 0.037)	0.138	−0.024 (−1.000, 0.080)	0.348	0.140 (0.037, 1.000)	0.011	0.034 (−0.070, 1.000)	0.288
Sports medicine (orthopedic surgery)	0.016 (−0.087, 1.000)	0.394	0.050 (−0.054, 1.000)	0.209	−0.025 (−1.000, 0.079)	0.342	0.114 (0.010, 1.000)	0.031	0.058 (−0.046, 1.000)	0.173
Trauma/critical care (surgery)	−0.033 (−1.000, 0.071)	0.296	−0.081 (−1.000, 0.023)	0.092	0.037 (−0.067, 1.000)	0.273	0.003 (−0.101, 1.000)	0.480	−0.029 (−1.000, 0.075)	0.318
Surgical oncology	0.080 (−0.024, 1.000)	0.097	0.053 (−0.051, 1.000)	0.194	0.097 (−0.007, 1.000)	0.057	0.115 (0.011, 1.000)	0.030	0.122 (0.018, 1.000)	0.023
Surgical oncology (urology)	−0.020 (−1.000, 0.084)	0.371	−0.059 (−1.000, 0.045)	0.168	−0.061 (−1.000, 0.043)	0.162	0.012 (−0.092, 1.000)	0.421	−0.022 (−1.000, 0.082)	0.361
Thoracic surgery	0.085 (−0.019, 1.000)	0.083	0.093 (−0.011, 1.000)	0.065	0.020 (−0.084, 1.000)	0.373	0.169 (0.066, 1.000)	0.003	0.126 (0.023, 1.000)	0.020
Transplant surgery	−0.030 (−1.000, 0.074)	0.314	0.025 (−0.079, 1.000)	0.342	−0.024 (−1.000, 0.079)	0.345	0.012 (−0.092, 1.000)	0.421	−0.006 (−1.000, 0.098)	0.463
Urology	−0.065 (−1.000, 0.039)	0.144	0.024 (−0.080, 1.000)	0.350	−0.142 (−1.000, −0.039)	0.010	0.120 (0.016, 1.000)	0.025	0.002 (−0.102, 1.000)	0.486
Vascular surgery	−0.009 (−1.000, 0.094)	0.439	0.046 (−0.058, 1.000)	0.228	−0.057 (−1.000, 0.047)	0.177	0.069 (−0.035, 1.000)	0.132	0.027 (−0.077, 1.000)	0.331
Female	−0.043 (−1.000, 0.061)	0.244	−0.103 (−1.000, 0.000)	0.046	0.051 (−0.053, 1.000)	0.205	0.045 (−0.058, 1.000)	0.229	−0.006 (−1.000, 0.098)	0.460
Male	−0.099 (−1.000, 0.004)	0.052	−0.051 (−1.000, 0.053)	0.201	−0.149 (−1.000, −0.047)	0.007	0.201 (0.099, 1.000)	<0.001	0.007 (−0.097, 1.000)	0.456

Table 3
Table displaying the significant coefficient values for the multiple regression analysis, with surgeon subspecialty number serving as the dependent variable.

Multiple regression (df = 266)				
Surgeon subspecialty	SVI subcategory	B (95 % CI)	*p* (significance)	Beta
Adult reconstructive orthopedics	Housing type/transportation Theme	0.381 (0.052, 0.710)	0.023	1.070
Colon and rectal surgery	Housing type/transportation Theme	1.449 (0.249, 2.649)	0.018	1.269
Cosmetic	Number of households with no vehicle available	0.002 (0.000, 0.003)	0.009	1.453
Foot and ankle orthopedics	Percentage of persons in group quarters	0.038 (0.013, 0.063)	0.004	1.407
General surgery	Percentage of persons (age 25+) with no high school diploma	0.278 (0.038, 0.519)	0.024	1.499
Hand surgery	Number of households	0.001 (0.0003, 0.001)	0.002	1.928
Neurological surgery	Percentage of persons (age 25+) with no high school diploma	0.114 (0.013, 0.215)	0.027	1.433
Orthopedic surgery	Housing type/transportation theme	6.022 (0.58, 11.463)	0.030	1.052
Orthopedic surgery of the spine	Percentage of housing in structures with 10 or more units	0.019 (0.003, 0.035)	0.022	1.142
Otolaryngology — head and neck surgery	Overall social vulnerability	1.752 (0.871, 2.632)	0.0001	7.763
Pediatric surgery (surgery)	Estimated daytime population	5.100E−6 (3.873E−8, 1.017E−5)	0.048	0.186
Surgical oncology	Percentage of persons in group quarters	−0.080 (−0.155, −0.004)	0.038	−1.135
Urology	Percentage minority (all persons except white, non-Hispanic)	0.217 (0.008, 0.427)	0.042	4.344

Other literature emphasizes that there are multifactorial reasons for these disparities beyond socioeconomic factors, including geographic/physical access to hospitals and sociocultural differences.[26] Sociologic investigation has proposed that "SES embodies an array of resources, such as money, knowledge, prestige, power and beneficial social connections that protect health no matter what mechanisms are relevant at any given time".[27] Socioeconomic status in particular can directly preclude a patient from appropriately accessing the transportation and financial resources that would allow them to receive care at higher volume, advanced centers. For instance, in a cohort of patients undergoing thyroid surgery, ethnic minorities, lower income, and Medicare patients were more likely to be treated by low volume surgeons at low volume centers, with subsequently longer lengths of stay and rate of complications.[28] Sosa et al.[29] were the first to explore this issue as they related to thyroidectomy; however, further research has demonstrated that these patterns persist across specialty and procedure type.[30–32] Thus, future research must consider ways to incentivize surgical subspecialists to practice in underserved communities, whether via motivating currently practicing surgeons, or motivating engaging with interested students and residents.

In addition, while this study limited its exploration of surgeon gender-based distribution to within the United States, these patterns persist on an international scale. For instance, within Australia and New Zealand, female general surgeons made up <20 % of the specialty[33] while both the European Society of Thoracic Surgeons and the Brazilian College of Surgeons demonstrate similarly marked differences between total and thoracic surgeons, respectively.[34,35] Other international studies suggest that these patterns persist across surgical subspecialty, as well as within academic institutions.[36–39] Although some studies have hypothesized that this difference may be due to positive intrinsic motivators, such as personal satisfaction and work-life balance,[40,41] other literature adeptly proposes that this disparity may be due to negative pressures, such as a lack of mentorship,[42] or "discrimination, differences in compensation, and job promotion".[38]

Within the United States, prior literature demonstrates that amongst medical students interested in surgery, female, Black, Hispanic, and Indian/Pakistani students, as well as those who received scholarships or had significant debt burden, were more likely "to intend to practice in underserved areas" compared to their peers.[43] However, within this population, female, low-income, and ethnic minority students, were less likely to have a sustained path in surgery,[44] and students with lower median family incomes are significantly less likely to match into a surgical specialty, even after adjusting for STEP scores.[45] Although The Match is multifactorial, "an accumulation of barriers including lack of mentorship, limited exposure to surgical fields, need for paid work instead of shadowing or unpaid internships, responsibility to care and provide for family members, decreased research opportunities, and decreased access to test preparation resources" may influence this discrepancy.[45] Future investigations should explore ways to foster mentorship and engagement in underserved surgery for motivated medical students. Thus, as demonstrated by prior literature, important considerations for increasing access to care must engage in a multifaceted approach, including diversification of resources, such as transportation or interpreter services, broadened patient insurance acceptance, including publicly and privately insured patients, and engagement and mentorship with interested trainees.[6]

Limitations and future investigations

Similarly to the study which inspired this research, this project utilized the Inland Empire as a model system for the larger United States. However, this study was restricted in its sample size, leading to the demonstration of various correlations between specialties and SVIs at the level of $p < 0.05$, but with Confidence Intervals which included 1. This was seen in the relationships between Adult reconstructive orthopedics, Urology, Orthopedic surgery, Plastic surgery, Surgical oncology, Thoracic surgery, male surgeons and Housing type/transportation (Table 2). It was also seen in the relationship between Surgical oncology, Thoracic surgery and Overall Social Vulnerability, as well as Orthopedic surgeons, Colon and rectal surgeons, and increased Housing type/transportation vulnerability (Table 2). The relationships between Surgical oncology, Otolaryngology, Thoracic surgery, and Overall Social Vulnerability may reflect the higher rates of chronic diseases, such as cancer, in marginalized populations.[46] The positive relationships between Surgical Oncologists and percentage of persons in group quarters, and Colon and Rectal Surgeons and Housing type/Transportation Vulnerability, lends further credence to this hypothesis. Thus, further research would benefit from expanding our exploration to a larger population to determine, as we would expect, whether these patterns persist across larger samples.

This study also relied on surgeon self-survey of primary specialty, potentially leading to variability in the reported results. For example, the 2018 Medical Board of California voted against "allowing the American Board of Cosmetic Surgery to advertise as 'board certified' cosmetic surgeons" in an effort to prevent misleading advertisements and scope confusion amongst patients.[47] In our investigation, two individuals self-identified as "cosmetic surgeons," while two others self-identified as specialists in "cardiovascular disease," lending further credence to the limitation of specialty self-identification when measuring a census tract's population of surgeons.

While our study demonstrates significant relationships between surgical subspecialty distribution and Housing type/transportation vulnerability, it fails to elucidate how specific differences in distance from major medical institutions, or the nearest surgical subspecialist, directly impacts surgical outcomes. Thus, other studies may benefit from exploring specifics in geographic distance. Future research must also consider the rural population. While poverty, overall mortality, and socioeconomic disparity is greater in urban communities, rural populations are often composed of older, uninsured, less educated individuals, thus superimposing further barriers to appropriate access to care.[48] Specifically, specific barriers to transportation should be explored, such as the role of infrastructure in larger cities versus rural communities.

Somewhat surprising was the inverse relationship between the percentage of persons without a high school diploma and both General and Neurosurgeons. While this relationship may reflect the relationship between socioeconomic status and education,[49] future research may benefit from investigating how distribution of surgical centers relates to overall education level. Our demonstration of the positive relationship between population and number of hand surgeons departs from prior studies which have failed to show a correlation with population proportions[50]; however, this may be due to the decreased population sampled in this study. Finally, similarly to previous work, our investigation does "not allow us to […] examine potential differences in *quality* of care" — potential differences which may drastically influence or exacerbate the already existing disparities in access.[51]

Conclusion

This study demonstrates the presence of statistically significant inverse relationships between surgical subspecialties and various SVIs within the Inland Empire. Thus, it establishes a foundation for exploring patterns of surgical subspecialty distribution, surgical recruitment, and infrastructural barriers to care across the larger United States.

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Ethical approval

This is an observational study. The Loma Linda University IRB has confirmed that no ethical approval is required.

CRediT authorship contribution statement

Brandon Shin: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **David Shin:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Yasmine Siagian:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Jairo Campos:** Writing – review & editing, Investigation, Formal analysis, Data curation. **M. Daniel Wongworawat:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Marti F. Baum:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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