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Geographical Imbalance of Anesthesia Providers and its Impact On the Uninsured and Vulnerable Populations

Executive Summary

- The purpose of this study was to determine if there is a relationship between socioeconomic factors related to geography and insurance type and the distribution of anesthesia provider type.
- Using the 2012 Area Resource File, the correlation analyses illustrates county median income is a key factor in distinguishing anesthesia provider distribution.
- Certified registered nurse anesthetists (CRNAs) correlated with lower-income populations where anesthesiologists correlated with higher-income populations.
- Furthermore, CRNAs correlated more with vulnerable populations such as the Medicaid-eligible population, uninsured population, and the unemployed.
- Access to health care is multifactorial; however, assuring the population has adequate insurance is one of the hallmark achievements of the Affordable Care Act.
- Removing barriers to CRNA scope of practice to maximize CRNA services will facilitate meeting the demand by vulnerable populations after full implementation of the Affordable Care Act.

The Affordable Care Act (ACA) will place increasing demands on the health care workforce. According to the Kaiser Commission on Medicaid and the Uninsured (2013), in 2012 nearly 47 million nonelderly Americans were uninsured. The ACA will expand Medicaid coverage to nonelderly adults with incomes below 138% the federal poverty level ($15,856 for an individual). Based on an Urban Institute analysis, approximately 22.3 million uninsured individuals will qualify for Medicaid under the new provisions of the ACA (Kenney, Dubay, Zuckerman, & Huntress, 2012). These provisions of insurance to the uninsured will likely increase demand for health care and thereby increase the need for health care providers.

In particular, special attention to issues concerning the anesthesia workforce is critical because of the direct effect on access to surgical, anesthesia, and pain management services. Anesthesia providers (certified registered nurse anesthetists [CRNAs] and anesthesiologists) practice in every setting where anesthesia is delivered. Research regarding the anesthesia workforce has attempted to demonstrate shortages or geographic maldistribution (Daugherty, Fonseca, Kumar, & Michaud, 2010; Fallacaro & Ruiz-Law, 2004; Schubert, Eckhout, Ngo, Tremper, & Peterson, 2012). However, such research has fallen short in outlining the complex relationships between geography, population density, provider density, and key ACA factors such as income, insurance, and unemployment.

State and county governments are challenged by health care workforce geographical imbalances. Population density reflects both population number and population access to health providers. Based on this concept, one may ask, "Does access to CRNAs and anesthesiologists differ based on factors other than population den-

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sity?" To address this question advanced correlation analyses was used. These analyses have been applied previously to workforce analysis (De Costa, Al-Muniri, Diwan, & Eriksson, 2009; Mayer, Beil, & von Allmen, 2009; Roche, Duffield, & White, 2011; Rosenthal, Zaslavsky, & Newhouse, 2005) and spatial studies (Chernew, Sabik, Chandra, Gibson, & Newhouse, 2010; Nash & Chaloud, 2002; Titeux, Dufrene, Jacob, Paquay, & Defourny, 2004). Based on the literature review, this is the first spatial study to use correlation analyses to assess the relationship between socioeconomic factors related to geography and insurance type while also assessing the distribution of two anesthesia providers.

This study implements an experimental approach to (a) identify and assess whether CRNAs and anesthesiologists are evenly distributed among geographic regions based on population density; (b) determine whether economic conditions (socioeconomic factors related to geography and insurance amid other variables) among populations are associated with the distribution of anesthesia provider type; and (c) assess to what extent anesthesia providers differ among populations of varied socioeconomic conditions.

Data and Methodology

The study used data from the 2012 U.S. Health Resources and Services Administration Area Resource File (ARF) data file. The ARF provided information pertaining to anesthesia provider, household income, Medicare, Medicaid, health insurance, operating rooms, employment, and poverty at the county level (U.S. Department of Health and Human Services, 2012). The 2013 Rural-Urban Continuum Codes (RUCC) were used to determine the degree of urbanization and adjacency to a metropolitan area (U.S. Department of Agriculture, 2013).

Anesthesia providers. For the purpose of this study, anesthesia providers are defined as either CRNAs or anesthesiologists. Certified registered nurse anesthetists were identified using the 2010 National Provider Identification file from the Centers for Medicaid & Medicare Services and nonfederal anesthesiologists were identified using the 2010 American Medical Association Physician Masterfile, maintained in the 2012 ARF. Provider-to-population ratio was calculated as the number of anesthesia providers (CRNAs or anesthesiologists respectively) per 10,000 people.

County-population variables. Variables pertaining to anesthesia access were identified as the number of operating rooms, number of anesthesia providers, and the presence of insurance (Medicaid, Medicare, and individuals with or without insurance) as identified in the ARF. These variables were chosen as a proxy for anesthesia access because surgery requires a high concentration of anesthesia services and insurance status lends to greater accessibility to these services. Economic factors that affect access or eligibility to insurance were identified as median household income, poverty, and employment. The importance of these variables were based on the fundamental foundation of the ACA and its implications on improving access to insurance by expanding Medicaid eligibility and opening the health insurance marketplace for the uninsured. Together these variables represent a set of interrelated socioeconomic factors that affect health care access to anesthesia services and resources.

Geo-spatial factors. Two important geo-spatial factors in addressing population access to anesthesia care are total population size within a defined population (e.g., Medicaid, uninsured, unemployment, poverty status) and a defined area range. All variables were analyzed in conjunction with geographic factors for spatial distribution as defined by the 2013 RUCC classification in addition to county and population size. Counties were used as the unit of analysis, because health referral regions (HRR) are too large a geographical unit to analyze a combination of populations within a HRR as having the same anesthesia provider density (provider per 10,000 population ratio). Population density was calculated by normalizing the population within those counties where anesthesia providers reside. The size for a typical county ranged from 329 sq. miles (10th percentile) to 2,056 sq. miles (90th percentile) with a median of 657 sq. miles (50th percentile). By converting county size into an approximate radius, a radius range from 10.2 miles to 25.6 miles (10th-90th percentile converting range respectively) was calculated for those counties where anesthesia providers reside.

Statistical analysis. Descriptive analysis and two advanced correlation analyses, partial least square correlation and Pearson partial correlation, were used in this study. To explore whether anesthesia providers were evenly distributed in the United States, the distribution of anesthesia providers among RUCC were compared and the county median household income by percentiles were calculated. Counties were grouped into metropolitan counties (RUCC 1-3), nonmetropolitan/urban adjacent counties (RUCC 4-5), and rural counties (RUCC 7-9). Median household income was categorized by the 10th, 25th, 50th, 75th, and 90th median income percentiles by county as illustrated in Table 1.

Partial least square correlation (PLS) was used to identify the factors that influence CRNA and anesthesiologist distribution. As an exploratory process, PLS is a variance-based correlation method used to capture maximal information of two multidimensional variables (Abdi & Williams, 2013; Borga, 2001; Rosipal & Kramer, 2006) allowing the researcher to

Table 1.
Descriptive Characteristics of Population and Anesthesia Provider by RUCC and Median Household Income

Rural Urban Continuum Codes (RUCC)	Median Income by Percentile	Total U.S. Population		Anesthesiologists (MD/DO)					Certified Registered Nurse Anesthetists (CRNAs)				
		County *n*	Population *n*	County *n*	Population *n* (%)	MD/DO *n*	Average MD/DO Ratio per 10,000 Population	Average Number of MD/DO per County	County *n*	Population *n* (%)	CRNAs *n*	Average CRNA Ratio per 10,000 Population	Average Number of CRNAs per County
Total	-	3,143	308,745,538	1,433	280,036,700 (90.7)	41,236	0.73	20	1,854	283,858,137 (91.9)	35,570	1.25	17
Metro: (RUCC 1-3)	90th pctl	260	86,759,500	232	85,870,328 (99.0)	14,907	1.48	64.3	213	82,816,076 (95.5)	7,288	0.88	34.22
	75-90th pctl	301	79,943,960	225	77,674,878 (97.2)	10,972	1.12	48.8	222	76,801,158 (96.1)	7,304	1.11	32.9
	50-75th pctl	290	63,374,227	219	61,483,370 (97.0)	9,526	1.21	43.5	227	61,303,537 (96.7)	10,998	1.92	48.45
	25-50th pctl	219	25,753,212	145	24,060,744 (93.4)	3,371	1.17	23.3	140	23,142,619 (89.9)	4,838	1.97	34.56
	10-25th pctl	73	5,056,688	28	4,039,871 (79.9)	582	1.31	20.8	36	4,387,900 (86.8)	705	1.61	19.58
	10th pctl	24	1,564,545	4	1,298,631 (83.0)	69	0.64	17.3	7	1,353,050 (86.5)	126	1.09	18
Non-Metro: (RUCC 4-6)	90th pctl	20	1,075,841	16	966,076 (89.8)	140	1.61	8.8	14	793,633 (73.8)	76	1	5.43
	75-90th pctl	84	3,798,544	44	2,644,758 (69.6)	237	0.85	5.4	61	3,099,411 (81.6)	311	1.16	5.1
	50-75th pctl	247	9,269,856	126	6,160,061 (66.5)	417	0.65	3.3	168	7,092,862 (76.5)	820	1.24	4.88
	25-50th pctl	285	11,441,920	160	8,046,699 (70.3)	452	0.57	2.8	224	9,865,309 (86.2)	1,260	1.31	5.63
	10-25th pctl	159	5,037,098	54	2,634,680 (52.3)	158	0.61	2.9	102	3,915,027 (77.7)	508	1.23	4.98
	10th pctl	104	2,653,849	31	1,325,051 (49.9)	58	0.53	1.9	60	1,954,286 (73.6)	221	1.11	3.68
Rural: (RUCC 7-9)	90th pctl	35	428,378	8	173,175 (40.4)	31	2.44	3.9	15	291,715 (68.1)	42	1.72	2.8
	75-90th pctl	86	995,336	16	403,389 (40.5)	61	1.5	3.8	27	528,701 (53.1)	82	1.59	3.04
	50-75th pctl	248	2,843,709	36	932,343 (32.8)	86	0.97	2.4	85	1,591,363 (56.0)	276	1.82	3.25
	25-50th pctl	282	3,330,949	39	980,329 (29.4)	77	1.27	2	114	2,052,585 (61.6)	293	1.7	2.57
	10-25th pctl	239	3,183,092	36	984,157 (30.9)	69	0.82	1.9	95	1,959,968 (61.6)	301	1.72	3.17
	10th pctl	187	2,234,834	14	358,160 (16.0)	23	0.69	1.6	44	908,937 (40.7)	121	1.33	2.75

NOTE: The average 2009 median household income was $42,951 for all counties (*n*=3,143) with $31,233 -$56,239 being the 10th-90th percentile range. For those counties where anesthesia providers are present (*n*=2,098), the average 2009 median household income was $44,980 with $32,888-$59,456 being the 10th-90th percentile range. Data regarding provider ratio per 10,000 population and provider per county is based on those counties where a provider is present. There are 1,045 counties where neither anesthesiologist nor CRNA reside.

pctl = percentile

minimize Type I error (Sherry & Henson, 2005). More importantly, as a component analysis method, PLS can identify the most influential variation related to county and population characteristics for provider distributions (Abdi & Williams, 2013; Borga, 2001; Nash & Chaloud, 2002; Rosipal & Kramer, 2006).

The PLS analysis indicated provider distribution significantly correlated with county median income among a variety of investigated variables found in the ARF. Many of the variables identified in this paper are multi-collinear (e.g., Medicaid eligible and median income) and were determined to be important for further analysis using Pearson partial correlation.

The Pearson partial correlation was used to analyze those *closely related* but *distinct* variables associated with anesthesia access. In the Pearson partial correlation, three common geographical factors (county size, RUCC, and county population) were controlled for all counties where anesthesia providers reside (n=2,098). An analysis that does not control for county location or type (e.g., RUCC) results in treating poorly defined areas similarly (Hart, Larson, & Lishner, 2005). As such, by not controlling for geo-spatial factors, an analysis will fail in truly identifying a defined population's distinct health care needs (e.g., the need for medical specialists or surgical services). Therefore, controlling for population density measures such as county and population size, in addition to RUCC, aids in distinguishing anesthesia providers by not mixing providers in high population density areas with those in low population density areas. Statistical significance was determined at p<0.05. Analyses were conducted using SAS statistical software version 9.2.

Limitations. This study explores population access to CRNAs and anesthesiologists. The studied population is not patient specific but extends to all populations that may encounter an anesthesia provider. Hence, correlation analyses was used to capture multi-collinear factors based on a variety of county population characteristics related to health care access, socioeconomic status, and geography. One limitation of these correlation analyses is that it cannot capture or determine those populations or providers that may cross county borders for care or work respectively. The other limitation is the correlation between anesthesia provider and population was limited to counties with a radius under approximately 26 miles (90th percentile).

Results

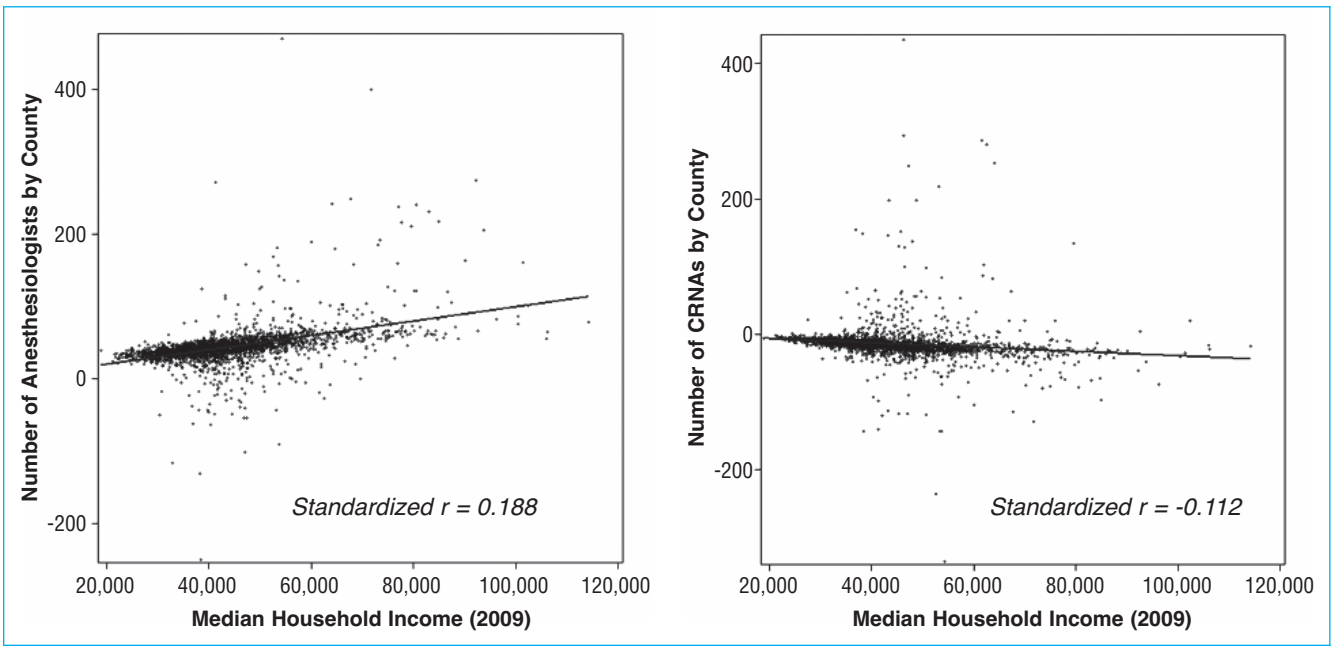
According to the 2010 U.S. Census, there are 3,143 counties with a total population of 308,745,538 (Mackun, Wilson, Fischetti, & Goworowska, 2011). Based on the descriptive analysis in Table 1, there were 41,236 anesthesiologists and 35,570 CRNAS, with slightly more anesthesiologists (1.16 times) than CRNAs. Of the 3,143 counties, anesthesia providers (anesthesiologists and CRNAs) occupied 2,098 (67%) counties of which 296, 305,069 (96%) of the population resided. Anesthesiologists were located in 1,433 (45%) counties that consist of 90.7% of the U.S. population, and CRNAs were located in 1,854 (59%) counties that consist of 91.9% of the U.S. population. When reviewing the presence of an anesthesia provider type by median household income and county, 26,348 (64%) of anesthesiologists occupied those counties where the median household income was in the top 75th percentile; whereby only 15,103 (42%) of CRNAs were present in the same income percentile (see Table 1). In addition, CRNAs are consistently found in counties where median income is less than the 25th percentile regardless of RUCC grouping (metropolitan and nonmetropolitan areas).

Though there is an admixture of both providers throughout the country, CRNAs tend to aggregate in the west north central region of the Midwest and the South, whereas anesthesiologists appear to aggregate around coastal regions on both the Western and Eastern seaboards. CRNAs and anesthesiologists are not evenly distributed throughout the country, and Table 1 indicates median income appears to be a factor regardless of RUCC grouping.

To address whether median income truly played a role in anesthesia provider distribution, PLS correlation was used to identify the top three most influential variables that could be attributed to anesthesia provider distribution. Based on PLS correlation, the variables attributed to provider distribution were number of operating rooms, county median income, and population density, of which the standardized PLS coefficients were r = 0.871, r = 0.188, r = 0.090 respectively for anesthesiologists and r = 0.791, r = -0.112, r = -0.066 for CRNAs (see Figure 1). These three variables were statistically considered the most influential factors for provider variation by county. The PLS results indicate both anesthesia providers strongly correlated with the number of operating rooms based on location. On the other hand, the two providers were distributed very differently when population median incomes varied.

To study the population in relation to the ACA requires studying multi-collinear variables. To better address what access and economic factors are associated with anesthesia providers, the Pearson partial correlation was used to analyze median income, number of operating rooms, insurance type, poverty, and unemployment after removing the effects of geographic factors such as RUCC and county and population size. CRNAs correlated with lower-income populations (r = -0.0839, p=0.0001) where anesthesiologists correlated with higher income populations (r=0.1831,

Figure 1.
Partial Residual of PLS Results Demonstrating Anesthesia Provider Correlations by County Median Income



NOTE: The dependent set of variables used in the PLS correlation are number of anesthesiologists and number of CRNAs. The control set of variables used are 2013 RUCC categories (based on 2010 Census), median household income (2009), total area in square miles (2010), population density per square mile (2010), short-term general operating rooms (2008), percent of county population without insurance (2009), percent of county population in Medicare (2009), and percent of county population in Medicaid (2007). Operating rooms, county median income, and population density, whose standardized PLS coefficients were 0.871, 0.188, 0.09 respectively for anesthesiologists and 0.791, -0.112, -0.066 for CRNAs. The rest of the variables in the PLS have the standardized coefficients less than 0.09 for anesthesiologists and 0.07 for CRNAs. The control set of variables of the PLS explained 74.1% of the variation of the dependent set of variables.

$p<0.0001$) (see Table 2). When further analyzing population in terms of Medicaid or Medicare, CRNAs and anesthesiologists were both negatively correlated with the Medicaid-eligible population and positively correlated with Medicare-eligible population. In this case, the magnitude of correlation does matter when comparing the two providers. The presence of CRNAs correlated *more* with the eligible Medicaid population ($r = -0.0424$, $p=0.0529$) compared to anesthesiologists ($r = -0.1366$, $p<0.0001$). Among the Medicaid population, anesthesiologists are four times more negatively correlated with Medicaid eligibles than CRNAs. Similar results show CRNAs also correlate more with both the Medicare disabled and Medicaid blind/disabled population (see Table 2).

When looking at unemployment status, the uninsured population, and persons in poverty in Table 2, CRNAs correlated more with the unemployed population ($r = -0.0434$, $p=0.0474$) compared to anesthesiologists ($r = -0.1425$, $p<0.0001$), and also the uninsured population ($r = -0.0467$, $p=0.0328$) compared to anesthesiologists ($r = -0.1647$, $p<0.0001$). Anesthesiologists were positively correlated with people's employment ($r = 0.1696$, $p<0.0001$) and negatively correlated with persons in poverty ($r = -0.0802$, $p=0.0002$) where CRNAs were statistically insignificant in both cases (see Table 2). When statistical insignificance is found, the CRNA-to-population ratio remains proportional to county population and size.

Discussion

These results demonstrate CRNAs and anesthesiologists tend to distribute themselves in the United States differently among populations, especially when income and factors related to health insurance are assessed. Previous research confirmed populations in metropolitan areas have greater geographic access to physicians and specialists after accounting for multiple geographic measures (Rosenthal et al., 2005). In this case, Table 1 reaffirms this trend demonstrating anesthesiologists tended to be more densely situated in urban counties.

An estimated 22.3 million un-

Table 2.
Pearson Partial Correlation Coefficients for Anesthesia Provider per 10,000 population (*n*=2,098)

Health Care Access and Economic Factors Related to Anesthesia Services	Pearson Partial *r* – Anesthesiologists	*p*	Pearson Partial *r* – CRNAs	*p*
Median Household Income (2009)	0.1831	<0.0001	-0.0839	0.0001
Operating Rooms (2008)	0.3116	<0.0001	0.2616	<.0001
Eligible for Medicare (2009)	0.0924	<0.0001	0.0702	0.0013
Medicare Enrollment, Disabled Tot (2007)	0.0729	0.0009	0.121	<.0001
Medicaid Eligibles, Total (2007)	-0.1453	<0.0001	-0.0433	0.0483
Medicaid Eligibles, Children (2007)	-0.1638	<0.0001	-0.0236	0.2814
Medicaid Eligibles, Blind/Disabled (2007)	0.0137	0.533	0.0827	0.0002
Persons < 65 with Health Insurance (2009)	0.13	<0.0001	0.0185	0.3973
Persons < 65 without Health Insurance (2009)	-0.1647	<0.0001	-0.0467	0.0328
Persons < 19 without Health Insurance (2009)	-0.1164	<0.0001	-0.0403	0.0659
% Persons in Poverty (2009)	-0.0802	0.0002	0.0312	0.1538
Number Employed, 16+ (2009)	0.1696	<0.0001	0.0263	0.2293
Number Unemployed, 16+ (2009)	-0.1425	<0.0001	-0.0434	0.0474

NOTE: Unlike semi-partial correlation that only partials out the predictor (Stevens, 2003) and were mostly used in a regression, Pearson partial correlation is known for its capability in controlling experimental factors by parsing out all the effects influenced by the control variables. With the exception of median income, a positive correlation should be viewed as demonstrating that as the concentration of population type increases (e.g., Medicare, Medicaid, Insured, Uninsured, Employed, Persons in Poverty), the concentration of anesthesia provider type also increases. A negative correlation indicates an opposing direction of population type and provider type. In cases where both providers are both either positively or negatively correlated, distinction around the degree to which they vary should be noted. Because county median income can be high or low among all population types, a negative correlation is associated with more low-income populations around a provider type (CRNA), and a positive correlation is associated with more high-income populations around a provider type (anesthesiologist).

insured individuals were expected to quality for Medicaid by 2014 (Kenney et al., 2012). Expanded insurance coverage is expected to increase the number of primary care visits from 15.07 million to 24.26 million in 2019 (Hofer, Abraham, & Moscovice, 2011). Though the increase to anesthesia services is currently unknown, demand for anesthesia and pain management services will likely increase as well. This analysis indicates population income appears to be a driving force. Medicaid eligibility is sensitive to income. An estimated 35% of adults with a family income below the 200% federal poverty level may shift from being insured in the marketplace to becoming eligible for Medicaid due to household income fluctuations (Sommers & Rosenbaum, 2011). Developing policy to address this gap will be necessary to assure vulnerable populations have continuing access to anesthesia services provided by CRNAs.

Dill, Pankow, Erikson, and Shipman (2013) demonstrated practitioners such as advance practice registered nurses (APRNs) and physician assistants (PAs) are more accessible to low-income or Medicaid patients seeking primary care. The major factors for respondents preferring APRNs or PAs were access to care and cost compared to their physician counterparts (Dill et al., 2013). Given anesthesia providers are located in high-density areas (e.g., RUCC 1, Detroit), based on our PLS analysis, CRNAs still correlate more among the low-income population compared to anesthesiologists who correlate more with high-income populations within the same area. In addition, the Pearson partial correlation demonstrated there is a greater relationship between populations with higher unemployment, Medicaid, and being uninsured among CRNAs than anesthesiologists, even after controlling for geographic factors such as RUCC, county size, and population density.

Policy implications. The Institute of Medicine (2011) report titled *The Future of Nursing: Leading Change, Advancing Health* succinctly outlined the key policy issues needed to assure all APRNs rightfully assert their role in health care delivery. The IOM indicated APRNs should be able to practice based on their education and competency to "help bridge the gap between insurance coverage and access to care" (p.

23). The findings in this study indicate CRNAs are more likely found in locations where low-income, Medicaid, and uninsured patients reside. As such, if these vulnerable populations were in need of anesthesia care, CRNAs are more readily available to provide the required care. Researchers have suggested issues around access to care are more apparent at the local level such as in rural and inner-city areas (Ku, Jones, Shin, Bruen, & Hayes, 2011).

All APRNs (CRNAs, certified nurse midwives, nurse practitioners, clinical nurse specialists) face a myriad of barriers reducing access to their services ranging from restricting scope of practice to reimbursement and hospital privileging (Fairman, Rowe, Hassmiller, & Shalala, 2011; Naylor & Kurtzman, 2010). State scope of practice as defined by a state's nurse practice act and/or state board of nursing regulates the requirement for physician involvement regarding supervising, authorizing, delegating, and/or directing care. As APRNs, CRNAs also encounter significant variation in barriers to practice at both the state and institutional levels.

An analysis of Medicare data demonstrated a 2.5-fold greater likelihood of patients receiving primary care from APRNs in states with the least-restrictive APRN scope of practice (Kuo, Loresto, Rounds, & Goodwin, 2013). Regarding CRNAs specifically, other researchers reported CRNAs were more likely found in states with less-restrictive practice regulations where more rural counties were present (Skillman, Kaplan, Fordyce, McMenamin, & Doescher, 2012). To maximize the utilization of CRNAs, removing barriers to scope of practice would aid in preparing for the influx of newly insured and Medicaid participants, while assuring these vulnerable populations have access to anesthesia services.

Conclusion

Analyses such as PLS and Pearson partial correlation are particularly useful when attempting to distinguish similar providers (e.g., CRNAs and anesthesiologists) amid a variety of variables. This study may also provide a template for future APRN and PA studies for similar populations.

The correlation analyses demonstrate the importance of population income in association with anesthesia provider distribution. Anesthesia providers are not evenly distributed throughout the country, lending to the probability different populations have disproportionate access to these providers. Compared to anesthesiologists, CRNAs are more likely to be found in counties where populations have lower median incomes but also where unemployment, the uninsured, and Medicaid are more densely populated. Certified registered nurse anesthetists provide anesthesia services to these vulnerable populations. Anesthesia access issues will become more apparent after full implementation of the ACA, especially if uninsured low-income Americans participate in Medicaid and the health insurance marketplace.

Previous research has established the quality of anesthesia care by CRNAs is both safe (Dulisse & Cromwell, 2010; Needleman & Minnick, 2009) and cost effective (Hogan, Seifert, Moore, & Simonson, 2010). Placing unnecessary restrictions via limiting scope of practice for CRNAs may hinder patient access to a readily available workforce where patients may incur a higher indirect cost (e.g., travel expense, time off work) for an anesthesiologist's care when a CRNA is nearby. This analysis demonstrates although where one lives matters, socioeconomic factors are just as important when it comes to anesthesia access. Lessening restrictions on CRNA practice would improve the opportunity for CRNAs to better serve the 47 million uninsured and vulnerable populations. **$**

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