Relationship Between State Policy and Anesthesia Provider Supply in Rural Communities

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Background: There is a significant geographic variation in anesthesia provider supply. Lower supply in rural communities raises concerns about access to procedures that require anesthesia in rural areas. State policies related to certified registered nurse anesthetist (CRNA) practice may help to alleviate rural supply concerns.

Objectives: To estimate the association between state CRNA policy and anesthesia provider supply especially in rural communities.

Research Design: Repeated cross-sectional design using ordinary least squares and 2-stage least squares regressions.

Subjects: All counties in the United States from 2010 to 2015.

Measures: Dependent variables include anesthesia provider counts per 100,000 people, calculated separately for anesthesiologists, CRNAs, and their sum. Key variables of interest include state-level CRNA policy based on scope of practice (SOP) regulations and Medicare opt-out status.

Results: Opt-out status and less restrictive SOP regulations were consistently correlated with a greater supply of CRNAs, especially in rural counties. Furthermore, we found that anesthesiologists and CRNAs tend to be complements to each other, but less restrictive SOP and opt-out status tend to weaken the importance of this relationship.

Conclusions: State regulations may lead to increased supply of CRNAs in rural communities. However, the design of our study makes causality difficult to assert. So, it is also possible that states set CRNA policy as a response to counts of anesthesia providers in rural areas. Furthermore, given supply of anesthesiologists and CRNAs are complementary to one another, improving access to anesthesia services may require addressing issues pertaining to the supply of all anesthesia provider types.

Key Words: state policy, anesthesia, certified registered nurse anesthetists

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The American health care system is changing rapidly. There has been a significant reduction in the rate of uninsured people across the United States between 2010 and 2016 after insurance coverage was expanded through the Affordable Care Act.[1,2] Policy initiatives are also restructuring payments toward value-based models and care delivery towards population health management approaches.[3] At the same time, the population has been and will continue to age, increasing health service needs.[4] The health care workforce must have the adequate size and skills to meet the future demand for services. The adequacy of the anesthesia workforce is especially important, impacting patient access to surgical, obstetrical, diagnostic, and pain management services.

The anesthesia workforce includes anesthesiologists, physicians with residency and fellowship training in anesthesiology, and certified registered nurse anesthetists (CRNAs), who are advanced practice registered nurses that have earned either a masters or doctorate degree from an accredited nurse anesthesia program. The composition of anesthesia teams in health care facilities depends in part on state CRNA policies. Specifically, state scope of practice (SOP), which regulates the extent to which CRNAs can deliver services with or without physician supervision, may determine how CRNAs are utilized. In addition, Medicare conditions of participation for health care facilities require that CRNAs be supervised by either an operating physician or have an immediately available anesthesiologist on premise. However, state governors have been allowed to "opt-out" of this federal requirement since 2001; 17 states have done so as of 2018.[5]

Although limited, there is some evidence about the geographic distribution and capacity of anesthesia providers.[6–8] These studies have found significant geographic and regional variation in anesthesia provider supply.[7,8] In particular, the supply of anesthesia providers per capita is significantly lower in rural areas.[8] CRNAs, however, were more likely than anesthesiologists to work in rural communities and communities with higher concentrations of vulnerable populations including Medicaid eligible, uninsured population, and the unemployed. However, no studies to date have directly examined the relationship between state CRNA policy and the supply of anesthesia providers. Previous studies have found a limited relationship between state CRNA policy and access to surgical or anesthesia services or anesthesia complications.[5,9–11] These studies, however, focused on either SOP and opt-out status separately and did not focus specifically on anesthesia provider supply.

In this study, we used national data and multivariate regression models to estimate the association between state CRNA policies and the supply of anesthesia providers, focusing particularly on rural communities. This study may have important implications for state policy decisions with regard to providing access to anesthesia services in rural communities.

METHODS

We used regression analyses to estimate the association between CRNA policy and supply of anesthesia providers across the United States. We also used 2-stage least squares regressions to examine the extent to which anesthesiologist and CRNAs are complements or substitutes to each other and if this relationship changes based on the state policies. The unit of analysis of this study was the county-year and we used data from every county in the United States (excluding territories) for the years 2010–2015.

Variables

Dependent Variables of Interest

The dependent variables of interest for this study were counts of anesthesia providers per 100,000 people. The counts were calculated for anesthesiologists alone, CRNAs alone, and the sum of anesthesiologists and CRNAs. We collected these data from the Area Health Resource File (AHRF). In order to minimize the impact of outliers that result from some very small population counties with providers having very large provider per capita rates, we winsorized the per capita rates by setting any value above the 99th percentile equal to the 99th percentile.

Independent Variables of Interest

The independent variables of interest were indicators of state-level CRNA policy. These variables were constructed using states' SOP regulations and Medicare opt-out status. State SOP was designated as either (1) high restrictive or (2) medium or low restrictive. In states where SOP was different across inpatient and ambulatory settings, we used the more restrictive regulations of the 2. These categorizations were obtained from the American Association of Nurse Anesthetists (AANA). AANA uses information from nurse practice acts, board of nursing rules, medical practice acts, board of medicine rules, and hospital licensing statutes and rules to determine the extent to which the states require CRNA supervision, collaboration, or direction with physicians. States that are designated as high restrictive require CRNA to have physician supervision; states designated as medium restrictive require collaboration or direction from a physician; states designated as low restriction do not require any physician, collaboration, direction, or supervision.

In addition to state SOP regulations, we designated states as either opt-out or non–opt-out from the Centers for Medicare and Medicaid Services' (CMS) physician supervision requirements.[12,13] We combined SOP and opt-out into a single variable to categorize the policies of each state. Of note, there were no states that had high restrictive SOP but had opted out, so this category was not included. The states were designated as (1) high restrictive non–opt-out, (2) medium to low restrictive non–opt-out, and (3) medium to low restrictive opt-out. We combined medium and low restrictive due to the small number of states in some categories. In the regression equations, high restrictive SOP, non–opt-out was used as the referent category.

We used rurality to contrast the regression coefficients for the overall sample as well as limited to rural counties. Rurality for a county is defined using the Rural-Urban Continuum (RUCC) codes, for values 7 (Nonmetro—Urban population of 2500–19,999, not adjacent to a metro area), 8 (Nonmetro—Completely rural or <2500 urban population, adjacent to a metro area), and 9 (Nonmetro—Completely rural or <2500 urban population, not adjacent to a metro area). These variables are available in AHRF.

Covariates

We included a number of key covariates in the models. First, we had variables measuring local availability of anesthesia provider training. We calculated (1) the count of anesthesiology residency matches, (2) medical school enrollees, and (3) new CRNA graduates within various radii of the centroid of each county (20 miles, 50 miles, 100 miles, and 200 miles). The variables were measured as per 100,000 population. We geocoded the addresses of the training programs using the Google Maps Application Programming Interface (API) and then used the "geopy" package in Python to calculate driving distance between county centroids and each program. These data were collected from the National Residency Matching Program, Association of American Medical Colleges, American Association of Colleges of Osteopathic Medicine, and National Board of Certification and Recertification for Nurse Anesthetists.

We also included variables describing health care–related characteristics in each county (percent of population on Medicare, hospital beds per capita, percent of population on Medicaid, Medicare advantage penetration rate, and the percent of the population under age 65 with no health insurance). We also included variables that controlled for local demographics (the population density, that is, persons per square mile, and the proportions of county populations that were over age 65, college graduates, Black, and Hispanic). These data were retrieved from AHRF.

We also included variables to control for local economic conditions, including the percent of the population under the federal poverty line, the unemployment rate in the county, average earnings of hospital workers in the county, and whether the local economy is dominated by one of the following industries: farming, mining, manufacturing, federal/state government, or recreation. These data were retrieved from AHRF and from the Bureau of Labor Statistics.

Finally, we included variables that controlled for community characteristics that may attract health providers to a county, including housing costs, local school quality, local property and violent crime rates, and the extent of local amenities, such as museums. These variables were retrieved from the American Community Survey, Inter-University Consortium for Political and Social Research, and ZIP Code Business Patterns data.

Analysis

In order to estimate the relationship between the state CRNA policy and the anesthesia provider supply, we fit a series of

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ordinary least squares regression equations. We fit separate regression equations for total providers per 100,000 population as the dependent variables for the following 3 groups of providers: CRNAs, anesthesiologists, and total anesthesia providers (CRNAs and anesthesiologists). We ran separate models using data from all counties in the United States as well as rural counties only. Given the cross-sectional approach, the models are implicitly constructed as a series of repeated cross-sections. Other studies estimating the effect of state CRNA policy used a difference-in-differences approach to compare outcomes in states before and after a policy change to states that did not change their policies.[5,10,11] However, during the years of anesthesia provider data that we have available, there were no changes in SOP regulations and only a single state (Kentucky in 2012) changed their opt-out designation. Therefore, the causal interpretation of effect estimates of the key state policies relies on our models including all variables that are correlated both with state regulations and anesthesia provider supply. It was thus important that we had strong control variables such that we were contrasting like counties and parsing out the differences due to systematic differences in observables that affect both provider counts and CRNA policy. However, as a sensitivity check, we did perform difference-in-difference regression based on Kentucky opting out in 2012.

Finally, we also examined the extent to which anesthesiologist and CRNAs are complements or substitutes to each other and if this relationship changes based on the state policies. To do this, we included anesthesiologists as covariates in the CRNA models and vice versa, which we refer to in the text and tables as the "other provider" counts. However, these "other provider" variables are endogenous, suffering from simultaneity bias. This is because the local counts of CRNAs likely affect the presence of anesthesiologists, and vice versa. This would bias the estimated coefficients. Given these provider counts are also likely correlated with the anesthesia policy, the simultaneity bias would seep into the estimates on the policy.

In order to allow for us to include the "other provider" counts into our estimates (and allow it to differ by anesthesia policy), we estimated a series of 2-stage least squares or instrumental variables regressions. The equation of interest is the same as the primary model described above, except that we also include the counts of "other providers" per capita interacted with each type of state anesthesia policy (allowing the effect of the other providers to vary depending on the regulatory environment). These interactions are the endogenous variables which we must instrument. In the first-stage equations, we use, as instrumental variables, the per capita counts of anesthesiology residency matches and medical school enrollees per 100,000 people within 20, 50, 100, and 200 miles of the centroid of each county for anesthesiologist counts, and the same interacted with indicators for the anesthesia policy. These instruments likely affect the number of anesthesiologists that end up working in that county (because, for example, they would have established roots in the area), but not the number of CRNAs per capita except through the anesthesiologists per capita in the county. For the model with anesthesiologists per capita as outcome, we instrument the CRNAs per capita interacted with the policy using new CRNA graduates per capita within 20, 50, 100, and 200 miles of the centroid each county instruments for CRNA counts, also interacted with the anesthesia policy.

The inclusion of the interaction between the other providers with the policy yields an estimate of how, within each type of policy, an increase of an additional anesthesiologist affects the counts of CRNAs and vice versa. A positive coefficient on the interaction suggests that in a state with a given CRNA policy, anesthesiologists and CRNAs are complements, whereas a negative coefficient suggests they are substitutes for each other. This approach also changes the interpretation of the coefficients on the anesthesia policy indicators (not interacted with other providers). Now, the interpretation is the effect of the state policies compared with the reference category (high restrictive) within a county with zero other providers. This in and of itself is an interesting shift in the interpretation and parameters of interest, given that rural communities have relatively few anesthesiologists with many counties having zero.

In all of the analyses, we clustered the SEs by state and year to account for intraclass correlation within the state in a year; other state-level policies and economic trends may shift county counts of anesthesia providers together.

RESULTS

On average, there are 13.44 total anesthesia providers per 100,000 people (Table 1) in the United States. Of those, 4.72 per 100,000 were anesthesiologists and 8.73 per 100,000 were CRNAs. Thirty-seven percent of all counties in the United States were rural. We also found that compared with nonrural counties, rural counties had significantly fewer anesthesia providers, 7.72 versus 16.42 per 100,000 people. We found that 32% of the counties were medium or low restrictive SOP, opt-out, 28% were low or medium restrictive SOP, non–opt-out, and 41% high restrictive, non–opt-out. In Figure 1, we show the distribution of those state CRNA policies. In general, states in the mid-Atlantic and southeast have the most restrictive regulations, while states in the pacific west, the least restrictive.

In Figure 2, we show the descriptive statistics for the unadjusted differences in anesthesia provider counts by state CRNA policies and by all counties and rural counties alone. We find that counties in states that have low or medium SOP but have opted out have higher counts of CRNAs per capita than counties in non–opt-out states, especially for rural areas. In contrast, the most restrictive states have higher counts of CRNAs per capita overall, although fewer than the medium to low restrictive opt-out states for rural counties. We find the same trends for overall anesthesia providers. Further, while less restrictive SOP is also associated with fewer anesthesiologists per capita, opt-out status is related to fewer anesthesiologists per capita, unlike CRNAs.

In Table 2, we present the results from the ordinary least squares regressions, which provide the main associations with CRNA policies. Each column represents a separate regression. For each case, counties in states with the most restrictive SOP regulations (that are all non–opt-out states) serve as a baseline reference group. We find that across all counties (rural and nonrural), counties in opt-out states with medium or low restrictive SOP regulations have significantly fewer anesthesiologists and total anesthesia providers (−1.689 and −1.419 fewer per 100,000

TABLE 1. Summary Statistics

	Overall	Nonrural	Rural
No. Observations			
No. counties in sample	3143	2006	1007
No. county/year observations in sample	18,857	12,395	6462
Dependent variables			
CRNAs per 100,000 people	8.73 (12.06)	10.00 (12.48)	6.27 (10.80)
Anesthesiologists per 100,000 people	4.72 (7.65)	6.42 (8.33)	1.45 (4.64)
Anesthesia providers per 100,000 people	13.44 (16.58)	16.42 (17.59)	7.72 (12.58)
Key variables of interest (%)			
Rural/urban continuum scores 1–3	37.13	56.48	0.00
Rural/urban continuum scores 4–6	28.60	43.52	0.00
Rural/urban continuum scores 7–9	34.27	0.00	100.00
High restrictive; non–opt-out	40.53	45.98	30.08
Medium and low restrictive; non–opt-out	27.52	30.01	22.75
Medium and low restrictive; opt-out	31.95	24.01	47.17
Covariates			
Percent of population on Medicare	0.16 (0.05)	0.15 (0.04)	0.18 (0.05)
Hospital beds per 100,000 people	314.95 (448.19)	273.18 (319.13)	395.06 (617.34)
Population per square mile	264.70 (1767.73)	391.37 (2169.65)	21.85 (37.62)
Proportion of population over age 64	16.9% (4.4%)	15.8% (3.8%)	19.1% (4.6%)
Percent Medicaid eligible	0.17 (0.06)	0.17 (0.06)	0.18 (0.07)
Percent of population below poverty line	0.17 (0.06)	0.17 (0.06)	0.18 (0.07)
Percent with no health insurance (for below age 65)	0.16 (0.06)	0.16 (0.06)	0.18 (0.06)
Percent college graduates	0.20 (0.09)	0.22 (0.10)	0.18 (0.07)
Unemployment rate	0.07 (0.03)	0.08 (0.03)	0.07 (0.03)
Percent Hispanic	0.08 (0.13)	0.09 (0.13)	0.07 (0.13)
Percent Black	0.09 (0.14)	0.10 (0.14)	0.06 (0.14)
Weighted amenity score (range: −0.168 to 0.159)	−0.05 (0.05)	−0.04 (0.05)	−0.06 (0.04)
Average local earnings for hospital workers	$56,301 (7163)	$56,724 (7809)	$55,488 (5638)
Medicare advantage penetration rate	0.19 (0.13)	0.22 (0.13)	0.13 (0.10)
Property crime rate per 100,000 people	388.14 (286.66)	446.40 (285.99)	276.39 (252.81)
Violent crime rate per 100,000 people	119.36 (102.89)	130.58 (103.65)	97.84 (97.91)
School quality score (range: 1–519)	8.03 (16.61)	10.50 (19.94)	3.30 (2.85)
Nonspecialized industry county (%)	39	48	23
Farming-dependent county (%)	14	5	31
Mining-dependent county (%)	7	5	11
Manufacturing-dependent county (%)	16	19	11
Federal/state government-dependent county (%)	13	15	10
Recreation-dependent county (%)	11	9	13
Anesthesiology residency matches within 20 miles per 100,000 people	0.52 (4.32)	0.79 (5.30)	0.01 (0.31)
Anesthesiology residency matches within 50 miles per 100,000 people	9.91 (33.31)	12.15 (30.49)	5.61 (37.78)
Anesthesiology residency matches within 100 miles per 100,000 people	60.84 (123.56)	54.84 (94.52)	72.36 (164.98)
Anesthesiology residency matches within 200 miles per 100,000 people	286.15 (454.98)	216.65 (297.02)	419.45 (638.64)
Medical school enrollees within 20 miles per 100,000 people	80.70 (671.11)	98.30 (680.91)	46.94 (650.64)
Medical school enrollees within 50 miles per 100,000 people	986 (2675)	1099 (2455)	770 (3040)
Medical school enrollees within 100 miles per 100,000 people	5521 (12,127)	4601 (9383)	7287 (15,988)
Medical school enrollees within 200 miles per 100,000 people	23,956 (39,995)	17,028 (23,421)	37,246 (57,856)
New CRNA graduates within 20 miles per 100,000 people	1.03 (11.57)	1.44 (13.73)	0.26 (5.33)
New CRNA graduates within 50 miles per 100,000 people	17.25 (67.03)	18.95 (63.96)	13.98 (72.46)
New CRNA graduates within 100 miles per 100,000 people	94.26 (211.34)	77.82 (151.70)	125.78 (291.03)
New CRNA graduates within 200 miles per 100,000 people	449.01 (1075.04)	300.89 (447.37)	733.11 (1692.96)

Values in each row are either means and SDs (in parentheses) across all counties or proportions of all counties, except for the *P*-value column, which reports the *P*-value of a *t* test of the difference in means or proportions between rural and nonrural counties. All differences are significant at the $P<0.001$ except for percent Medicaid eligible which was significant at the $P<0.05$ level.

CRNA indicates certified registered nurse anesthetist.

people) compared with the most restrictive states. In contrast, in rural areas, counties in states with medium to low restrictive SOP, non–opt-out have more anesthesiologists and total anesthesia providers (0.392 and 1.234 more per 100,000 people) compared with the most restrictive states. For rural counties with medium and low restrictive SOP, opt-out, we find more CRNAs (1.325 more per 100,000 population) and fewer anesthesiologists (−1.095 fewer per 100,000 people) with no significant change in overall anesthesia provider counts.

In our difference-in-differences sensitivity analysis to examine Kentucky's policy to opt-out, we found no significant effects of CRNA policies.

In Table 3, we provide the results from the instrumental variable models. We first examine the coefficients on the noninteracted anesthesia delivery model, which shows the effects given the county having zero of the other providers. We find for CRNAs in these zero anesthesiologists counties that the effect of being in a state with lower restrictions versus high restrictions is

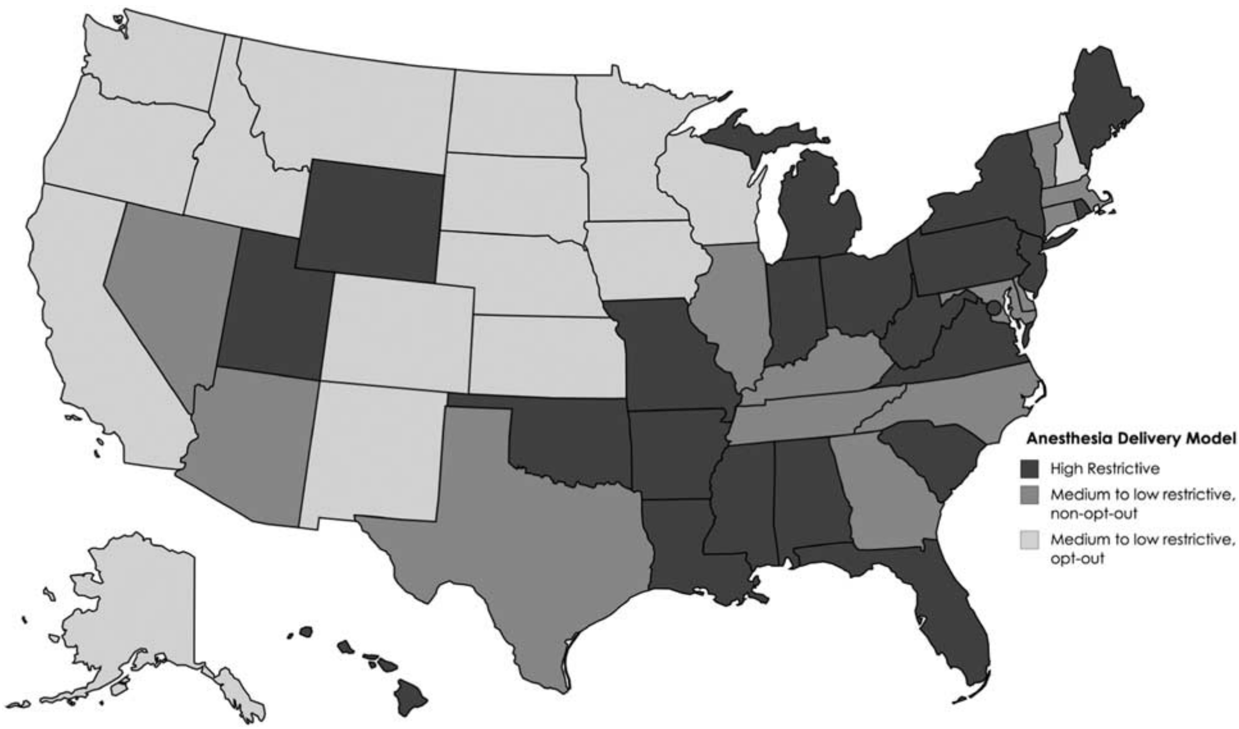

FIGURE 1. State CRNA Policies. CRNA indicates certified registered nurse anesthetist.

positive (ranging from 1.2 to 3.2 more CRNAs per 100,000 people), both overall and for rural counties. The difference is relatively comparable for rural and all counties. We consistently find positive interactions of the "other providers" variable and the anesthesia delivery model, with the positive effects generally being largest for high restrictive states. For example, in high restrictive states, an increase of one anesthesiologist per 100,000 people is associated with an increase of 0.95 CRNAs per 100,000 people, all else equal. The effect of each additional anesthesiologist on the predicted number of CRNAs is much larger than the effect of each

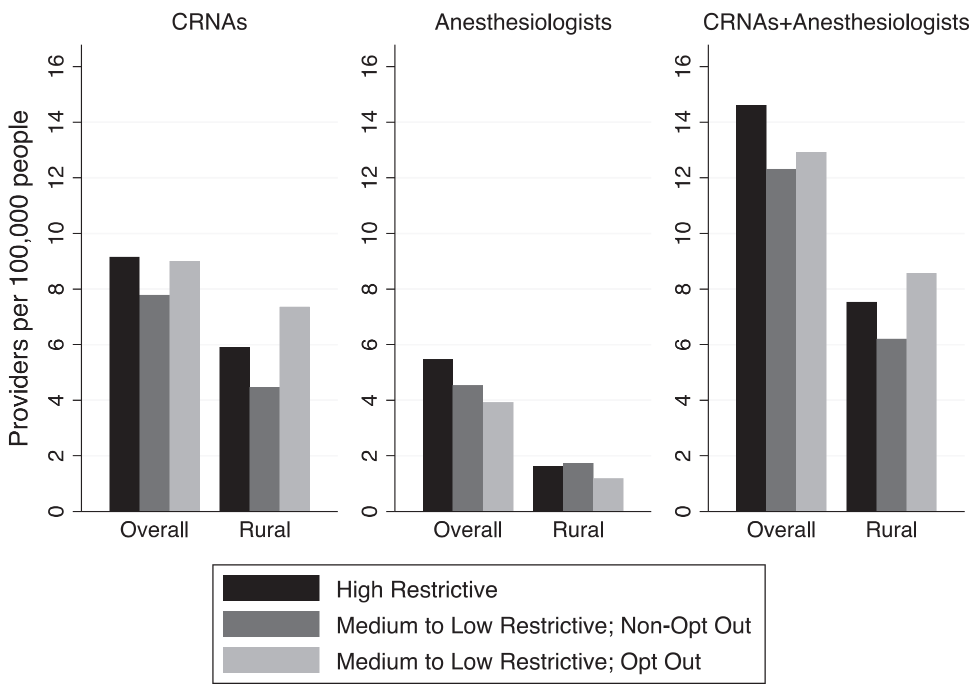

FIGURE 2. Unadjusted anesthesia provider counts. CRNA indicates certified registered nurse anesthetist.

TABLE 2. Key Coefficients of Interest From Ordinary Least Squares Regression of Providers Per Capita on Anesthesia Policy

	All Counties			Rural Counties		
	CRNA Counts Per 100,000 People	Anes. Counts Per 100,000 People	Total Anesthesia Provider Counts Per 100,000 People	CRNA Counts Per 100,000 People	Anes. Counts Per 100,000 People	Total Anesthesia Provider Counts Per 100,000 People
Medium to low restrictive; non–opt-out	0.553 (0.446)	−0.372 (0.196)	0.181 (0.525)	0.843 (0.450)	0.392 (0.183)*	1.234 (0.554)*
Medium to low restrictive; opt-out	0.271 (0.459)	−1.689 (0.233)**	−1.419 (0.549)*	1.325 (0.362)**	−1.095 (0.244)**	0.230 (0.517)

Reference category: high restrictive, non–opt-out.

Control variables: CRNA new graduates per 100,000 people within 20, 50, 100, and 200 miles; anesthesiology residency matches per 100,000 people within 20, 50, 100, and 200 miles; medical school enrollees per 100,000 people within 20, 50, 100, and 200 miles; percent of population on Medicare; hospital beds per capita; population per square mile; fraction of population over age 65; percent of population Medicaid eligible; percent of population below the poverty line; percent of population with no health insurance (below age 65); percent of population college graduates; unemployment rate; percent of population Hispanic; percent of population Black; weighted local amenity score; average earnings in hospital industry in the county; Medicare advantage penetration rate; property crime rate; violent crime rate; school quality score; economy-dependent industry specialization indicators (farming, mining, manufacturing, federal/state government, recreation, or nonspecialized); year indicators; rural-urban continuum grouping score; missing observation indicators.

SEs in parentheses.

Anes. indicates anesthesiologists; CRNA, certified registered nurse anesthetist.

*$P<0.05$.

**$P<0.01$.

additional CRNA on the predicted number of anesthesiologists, especially in rural counties. As noted in the table footnote, the anesthesiologists per capita regression for rural counties (last column in Table 3) relies upon weak instruments.

DISCUSSION

In this study, we estimated the relationship between state anesthesia policies and supply of anesthesia providers, especially within rural communities. Although the nature of the data and our analysis design prevent us from drawing strong causal conclusions, we have identified a number of important relationships that could have implications for state workforce policy and rural health.

First, we find that rural communities have significantly fewer anesthesia providers than nonrural communities, 8.7 fewer per 100,000 people. This difference represents both fewer CRNAs and anesthesiologists. However, the difference was especially acute for anesthesiologists. We also found that CRNAs comprised over 80% of all anesthesia providers in rural communities. These findings are consistent with previous studies.[8] No studies to date, however, have explicitly examined the extent to which a lower

TABLE 3. Key Coefficients of 2-stage Least Squares (2SLS) Regression of Providers Per Capita on Anesthesia Policy and Anesthesia Policy Interacted With Number of Other Kind of Provider

	All Counties		Rural Counties	
	CRNAs Per 100,000 People	Anes. Per 100,000 People	CRNAs Per 100,000 People	Anes. Per 100,000 People
Medium or low restrictive; non–opt-out	2.517 (1.104)*	1.703 (1.195)	1.269 (0.538)*	3.147 (2.017)
Medium or low restrictive; opt-out	3.366 (1.066)**	0.546 (0.815)	1.401 (1.061)	0.196 (0.834)
Other type workers per capita×high restrictive	0.811 (0.306)**	0.606 (0.138)**	0.580 (0.352)	0.564 (0.180)**
Other type workers per capita×medium or low restrictive, non–opt-out	0.424 (0.135)**	0.371 (0.169)*	0.0103 (0.0410)	0.0869 (0.360)
Other type workers per capita×medium or low restrictive, opt-out	0.427 (0.215)*	0.373 (0.124)**	1.431 (0.534)**	0.283 (0.0998)**

Instruments in CRNA model: anesthesiology residency matches per 100,000 people within 20, 50, 100, and 200 miles; medical school enrollees per 100,000 people within 20, 50, 100, and 200 miles.

Instruments in anesthesiologist model: CRNA new graduates per 100,000 people within 20, 50, 100, and 200 miles.

Control variables: percent of population on Medicare; hospital beds per capita; population per square mile; fraction of population over age 65; percent of population Medicaid eligible; percent of population below the poverty line; percent of population with no health insurance (below age 65); percent of population college graduates; unemployment rate; percent of population Hispanic; percent of population Black; weighted local amenity score; average earnings in hospital industry in the county; Medicare advantage penetration rate; property crime rate; violent crime rate; school quality score; economy-dependent industry specialization indicators (farming, mining, manufacturing, federal/state government, recreation, or nonspecialized); year indicators; rural-urban continuum grouping score; missing observation indicators.

First-stage regressions for each endogenous variables have F-statistics >10 for all models and all variables except for the anesthesiologists per capita for rural counties regression, where instrumenting CRNAs per capita for high restrictive states and for medium or low restrictive, opt-out states have F-statistics of 7 and 4.2, respectively.

SEs in parentheses.

Anes. indicates anesthesiologists; CRNA, certified registered nurse anesthetist.

*$P<0.05$.

**$P<0.01$.

supply of anesthesia providers in rural communities may affect access to surgeries or other procedures requiring anesthesia.

Second, we also found that opt-out status was correlated with a greater supply of CRNAs in rural communities. We also found that opt-out status was associated with a significantly greater number of CRNAs in rural counties with no anesthesiologists compared with the most restrictive states. This is especially important as >80% of rural countries have zero anesthesiologists. Again, given the design of our study, we cannot infer causality, and the mechanism and direction of the relationship is unclear. One plausible explanation for the results that we observe is that CRNAs are more likely to enter rural counties in response to states' decisions to opt-out of the CMS conditions of participation regulations. Conversely, states that rely heavily on CRNAs to deliver anesthesia may decide to opt-out to better take advantage of extant CRNA supply. The fact that we found more anesthesiologists in rural counties in states with low SOP restrictions but which did not opt-out supports the idea that states opt-out as a result of greater reliance on CRNAs. In other words, states that had ample supply of anesthesiologists in rural communities had less need to opt-out and therefore did not opt-out. Our analysis of Kentucky suggests as much; we did not find an increase in CRNAs after Kentucky opted out. So, although opt-out may make it easier for CRNA's to work efficiently, it is unclear if it draws in more CRNAs. This may explain why previous studies did not find an effect of opt-out on access to surgical services.[5,10,11] That said, if state regulations do draw in more CRNAs, our results suggest that the effect is likely to be strongest in rural counties.

Finally, anesthesiologists and CRNAs tend to be complements to each other, meaning an increase in one type of provider, all else equal, is associated with an increase in the other type of provider. This suggests that factors such as facility policies or relative attractiveness of rural and nonrural communities other than state policies are likely influencing supply. The complementary relationship is particularly strong for the effect of each additional anesthesiologist on the predicted number of CRNAs. This may be because anesthesiologists are more likely to practice without CRNAs than CRNAs without anesthesiologists. Overall, we also find less restrictive SOP and opt-out status tends to (but not always) weaken the importance of this relationship, suggesting that anesthesia employers may be more willing to substitute CRNAs for anesthesiologists when states lower restrictions to CRNA SOP and billing requirements.

Limitations

Our study is limited by being a repeated cross-section analysis. Only Kentucky changes opt-out status in our data frame, while no state changes scope of practice restrictiveness. As a result, we are not able to control for state characteristics that may be associated with the decision to opt-out or reduce the SOP restrictions. Although we can assess that there is a relationship between the CRNA regulations and anesthesia provider supply, we cannot directly test which direction this relationship flows. That said, based on patterns between the relationships of the anesthesia delivery model and anesthesiologist versus CRNA supply patterns as well as a difference-in-differences model in Kentucky, we suspect that the policy changes are largely responsive to CRNA workforce. Moreover, the AHRF workforce data only includes a single practice location for each provider. This approach would not allow for anesthesia providers to practice at separate locations, which we know anecdotally is the case for many rural CRNAs. This may underestimate the actual provider supply in some rural communities. However, AHRF remains the best source of workforce data in the United States.

CONCLUSIONS

Rural US counties had significantly fewer anesthesia providers compared with nonrural counties and this relationship is especially significant for anesthesiologists, who are 4 times more likely to work in nonrural communities. State regulations may be an important mechanism, either for allowing existing anesthesia providers to work more effectively with lower restrictions or for increasing anesthesia supply in rural communities. We found opt-out status was correlated with greater CRNA supply per capita in rural counties although our findings seem to suggest that opt-out may not lead to more CRNAs; rather, states may respond to the current supply of CRNAs in the state by opting out. However, as the supply of anesthesiologists and CRNAs appears to be complementary to one another, improving access to anesthesia services in rural communities may require addressing not only state and federal policy, but also other issues influencing the supply of all anesthesia provider types.

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