National Trends in the United States Eye Care Workforce from 1995 to 2017

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• PURPOSE: To describe temporal and geographic trends in the US eye care workforce.
• DESIGN: Cross-sectional study.
• METHODS: We obtained data from the 2017 Area Health Resources File. The main outcomes were ophthalmologist and optometrist density, as defined as the number of providers per 100,000 individuals, the ratio of ophthalmologists ≥55 years of age to those <55 years of age, and county characteristics associated with the availability of an ophthalmologist.
• RESULTS: From 1995 to 2017, the national ophthalmologist density decreased from 6.30 to 5.68 ophthalmologists per 100,000 individuals. Although rural counties experienced a mean annual increase in ophthalmologist density by 2.26%, they still had a lower mean ophthalmologist density (0.58/100,000 individuals) compared with nonmetropolitan (2.19/100,000 individuals) and metropolitan counties (6.29/100,000 individuals) in 2017. The ratio of older to younger ophthalmologists increased from 0.37 in 1995 to 0.82 in 2017, with the greatest ratio increase occurring in rural counties (0.29 to 1.90). The presence of an ophthalmologist was significantly associated with a greater proportion of individuals with a college degree and health insurance, and more developed health care infrastructure. From 1990 to 2017, the density of optometrists increased from 11.06 to 16.16 optometrists per 100,000 individuals.
• CONCLUSIONS: Over the last 2 decades, the national density of ophthalmologists has decreased and the workforce has aged. In contrast, the density of optometrists has increased. Rural counties continue to have a disproportionately lower supply of eye care providers, although some growth has occurred. Given the rising ratio of optometrists to ophthalmologists, it is of interest for future work to determine how the optometrist workforce can best complement potential shortages of ophthalmologists. (Am J Ophthalmol 2020;218: 128–135. © 2020 Published by Elsevier Inc.)

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PROJECTIONS OF PHYSICIAN SUPPLY AND DEMAND BY the United States (US) Department of Health and Human Services report ophthalmology as the surgical specialty with the greatest predicted workforce shortage by 2025.[1] An aging US population and increasing prevalence of systemic diseases with associated ophthalmic sequalae, such as diabetes and hypertension, have contributed to a rapidly growing patient population that is expected to outpace the supply of ophthalmologists.[1,2] In contrast, workforce projections of optometrists indicate that the projected supply of optometrists is expected to exceed projected demand.[3] Given that previous work has demonstrated that the local availability of eye care providers is associated with improved patient awareness of disease, screening frequency, and even visual health outcomes, it is of interest to characterize and understand the distribution of ophthalmologists and optometrists in the United States.[4–10]

Previous research examining the geographic distribution of eye care providers has reported disparities in ophthalmologist and optometrist availability among different counties in the United States.[11–13] A study using data from 2011 found that areas with greater rural populations had a lower density of both types of eye care providers.[13] However, we are unaware of any updated reports of the national distribution of the eye care workforce in our literature review. Furthermore, temporal trends in the workforce have not been described since 1970.[11] Lastly, as the number of initiatives to increase rural health care providers has grown over the past decade, more recent workforce data is required to assess how these programs have impacted the distribution of ophthalmologists and optometrists.[14–16]

Therefore, the purpose of this study was to describe changes in the US ophthalmologist and optometrist workforces over the last 2 decades. Specifically, we 1) examined the density of ophthalmologists and optometrists at a county level over time; 2) compared rural vs urban differences; 3) assessed changes over time in the age of the ophthalmologist workforce; and 4) determined county characteristics associated with the presence of an ophthalmologist.

METHODS

THIS IS A CROSS-SECTIONAL STUDY USING DATA FROM THE 2017 Area Health Resources File (AHRF), a product of the US Department of Health and Human Services that

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combines data from >50 sources.[17] The AHRF reports the number of ophthalmologists per county using data from the American Medical Association Physician Masterfile, as well as various county characteristics. Data on the number of ophthalmologists participating in patient care were available for the years 1995, 1997-2008, and 2010-2017. Optometrist data were available for the years 1990, 2000, and 2009-2017. We collected county-level population data from the 2017 Census Population Estimates. This study was prospectively exempted by the Yale University Institutional Review Board, as the data are publicly available, and adhered to the tenets of the Declaration of Helsinki.

• **MEASURES:** The primary outcome measures of this study were the densities of practicing ophthalmologists and optometrists, defined as the number of providers per 100,000 individuals. Additional outcomes were the ratio of ophthalmologists ≥55 years of age to those <55 years of age and county characteristics associated with the availability of an ophthalmologist. We classified counties as metropolitan, nonmetropolitan, or rural using the 2013 US Department of Agriculture Urban/Rural Continuum Code (RUCC). The RUCC is a 9-point system that categorizes counties by degree of urbanization, population, and proximity to metropolitan areas; RUCC scores of 1-3 designate a metropolitan county, 4-7 a nonmetropolitan county, and 8 to 9 a rural county.[18] We also collected county-level characteristics including the proportion of females, white non-Hispanic individuals, persons ≥65 years of age, persons >25 years of age who completed 4 years of college, persons in poverty, and persons 18-64 years of age without health insurance, as well as per capita income and total number of hospitals, rural referral centers, primary care physicians, and advanced practice registered nurses (APRNs). Supplement 1 describes the sources of these county-level data (supplemental material available at AJO.com).

• **STATISTICAL ANALYSIS:** We used simple linear regressions to determine the association between provider density and year for ophthalmologists (1995-2017) and optometrists (1990-2017). Simple linear regression was also used to identify if the ratio of older to younger ophthalmologists was significantly associated with time. χ^2 tests were used to compare the proportions of counties that lacked an ophthalmologist or optometrist and the proportion of the ophthalmologist workforce that was <55 years of age between the different county types. We conducted univariate and multivariable logistic regressions to identify county characteristics associated with the presence of ≥1 ophthalmologist in the county in 2017. A 2-sided P value $< .05$ was considered statistically significant. Data analysis, statistical analysis, and figures were generated with Microsoft Excel for Mac 2011 (v 14.4.7; Microsoft, Redmond, Washington, USA), R software (v 13.1.0; R Foundation for Statistical Computing, Vienna, Austria), and GraphPad Prism software (v 8; GraphPad Software, San Diego, California, USA).

RESULTS

• **OPHTHALMOLOGIST DENSITY OVER TIME:** In 2017, there were 18,512 ophthalmologists in the United States, corresponding to a mean national density of 5.68 ophthalmologists per 100,000 individuals. Rural counties had a mean density of 0.58 ophthalmologists per 100,000 individuals, which was lower than the 2.19 and 6.29 ophthalmologists per 100,000 individuals found in nonmetropolitan and metropolitan counties, respectively. Ophthalmologist densities by individual county are shown in Figure 1, A. The majority of counties lacked an ophthalmologist (60.5%). The proportion of rural counties that lacked an ophthalmologist (97.4%) was significantly greater than the proportions of nonmetropolitan (67.0%; $P < .001$) and metropolitan counties (35.3%; $P < .001$) with 0 ophthalmologists.

From 1995 to 2017, the national ophthalmologist density significantly decreased from 6.30 to 5.68 ophthalmologists per 100,000 individuals, corresponding to a loss of 0.033 ophthalmologists per 100,000 individuals each year ($P < .001$; Figure 2, A). There was a mean decrease in the total ophthalmologist density by 0.44% per year, and a mean annual decline in density of 0.47% and 1.12% in metropolitan and nonmetropolitan counties, respectively. However, rural counties experienced a mean annual increase in ophthalmologist density by 2.26%, with an upward trend beginning in 2014.

• **AGE OF OPHTHALMOLOGY WORKFORCE OVER TIME:** In 2017, the total number of ophthalmologists <55 years of age was 10,353 (54.8%). Metropolitan counties had a significantly younger workforce, as 55.5% of ophthalmologists in metropolitan areas were younger compared with 43.0% in nonmetropolitan areas ($P < .001$) and 34.5% in rural areas ($P = .04$). From 1995 to 2017, the overall ratio of older to younger ophthalmologists significantly increased from 0.37 to 0.82 ($P < .001$; Figure 3). The greatest increase in the age ratio occurred in rural counties (from 0.29 to 1.90), followed by nonmetropolitan (0.37 to 1.32) and metropolitan counties (0.37 to 0.80). Rural counties had the greatest percent increase in older practitioners, with a 375.00% increase from 1995 to 2017, followed by metropolitan and nonmetropolitan counties, which increased by 86.09% and 70.72%, respectively. Concurrently, the number of younger ophthalmologists decreased by 28.57%, 52.49%, and 13.68% in rural, nonmetropolitan, and metropolitan counties, respectively.

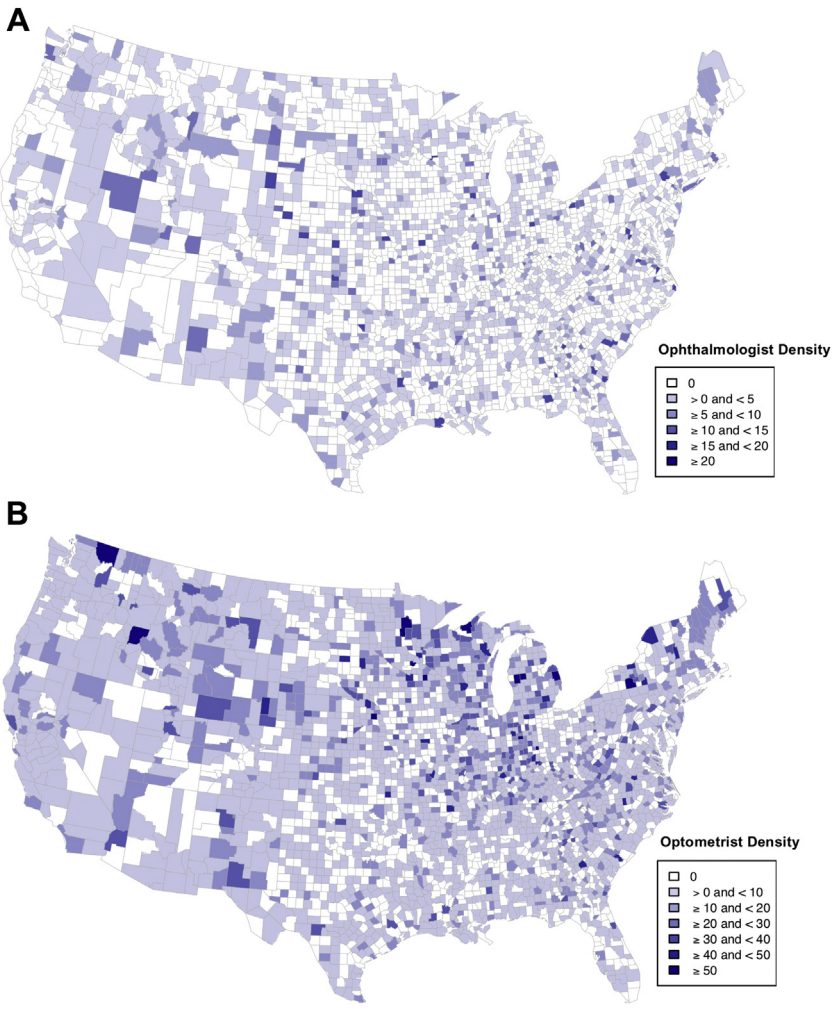

FIGURE 1. A. The density of ophthalmologists by individual county in 2017. B. The density of optometrists by individual county in 2017. Density was defined as the number of providers per 100,000 individuals.

• **OPTOMETRIST DENSITY OVER TIME:** In 2017, there were 52,625 optometrists nationwide, corresponding to a density of 16.16 providers per 100,000 individuals. Optometrist densities by county are shown in Figure 1, B. Approximately a quarter of counties (23.3%) had 0 optometrists. Similar to the geographic distribution of ophthalmologists, optometrist density was lower in rural areas (6.77) compared with nonmetropolitan (15.84) and metropolitan areas (16.36 per 100,000 individuals). There was an overall significant increase in optometrist density between 1990 and 2017, from 11.06 to 16.16 providers per 100,000 individuals, with an estimated annual increase of 0.21 optometrists per 100,000 individuals per year ($P = .002$; Figure 2, B). The mean annual optometrist growth rate was lower in rural areas (1.04%) compared with nonmetropolitan (1.64%) and metropolitan areas (1.71%). When comparing the optometrist and ophthalmologist workforces over years for which data were available for both specialties, the ratio of optometrists to ophthalmologists increased from 2.46 to 2.84 between 2010 and 2017, representing a 15.6% increase.

• **COUNTY FACTORS ASSOCIATED WITH THE PRESENCE OF AN OPHTHALMOLOGIST:** Univariate analysis revealed that counties with a greater percentage of females and individuals who had completed 4 years of college, or a lower percentage of white individuals and individuals ≥65 years of age were more likely to have ≥1 ophthalmologist (Table). In addition, counties with a higher per capita income and a lower proportion of individuals in poverty or without health insurance were more likely to have an ophthalmologist. Counties that had a greater number of hospitals, rural referral centers, primary care physicians, APRNs, and optometrists were also more likely to have ≥1 ophthalmologist. Lastly, the degree of urbanization of a county, as measured by the RUCC, was significantly associated with the presence of an ophthalmologist.

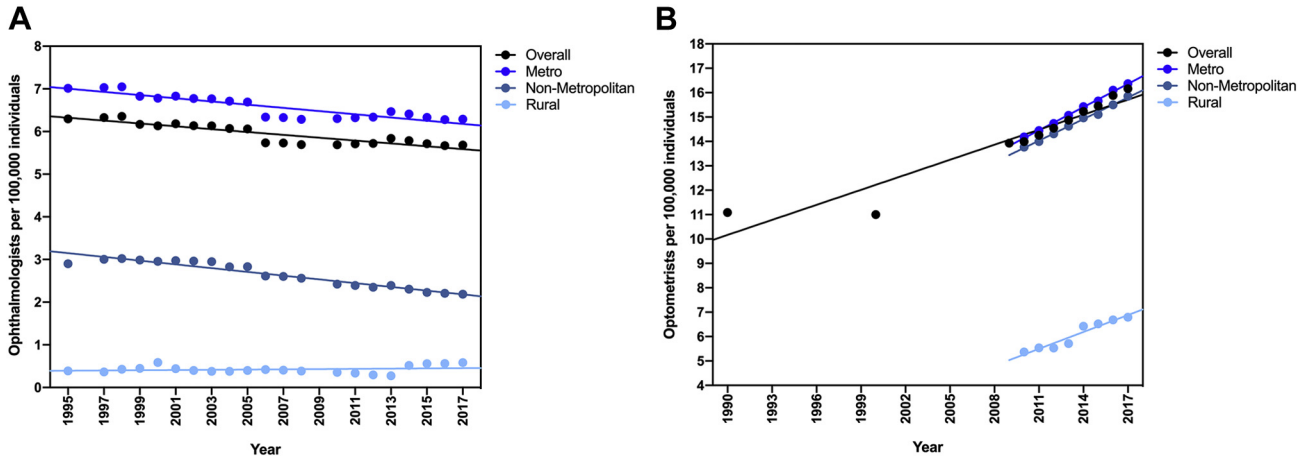

FIGURE 2. A. The density of ophthalmologists from 1995 to 2017. B. The density of optometrists from 1990 to 2017. Density was defined as the number of providers per 100,000 individuals. Mean annual densities are shown by county type and fit to simple linear regressions. Note the overall decline in the density of ophthalmologists at the national level as well as in metropolitan and nonmetropolitan areas, but the rising trend in rural areas beginning around 2014. Data for optometrist density by county type were only available for 2010 to 2017, and showed that there was an increase in optometrist density over time in all county types.

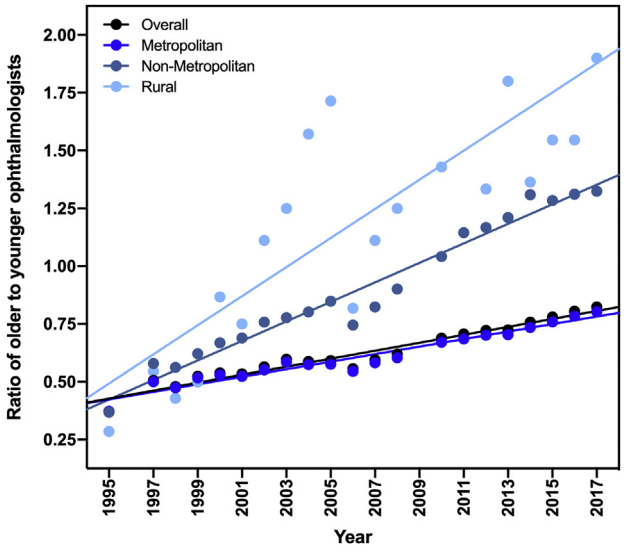

FIGURE 3. Changes in the ratio of older to younger ophthalmologists from 1995 to 2017. Mean annual ratios are shown by county type and fit to simple linear regressions. In all county types, there is a rising trend in the ratio of older to younger ophthalmologists over time, suggestive of an aging ophthalmology workforce. The steepest increase is seen in rural counties.

In multivariable analysis, the county factors that remained significantly associated with the presence of ≥1 ophthalmologist included a greater proportion of individuals with 4 years of college (odds ratio [OR] 1.08 [95% confidence interval {CI} 1.04-1.13]; $P < .001$) and a lower proportion of individuals without health insurance (OR 0.97 [95% CI 0.94-0.99]; $P = .019$; Table). Indicators of greater health care infrastructure, such as a greater number of hospitals (OR 1.23 [95% CI 1.00-1.50]; $P = .045$), rural referral centers (OR 3.18 [95% CI 1.57-6.95]; $P = .002$), primary care physicians (OR 1.09 [95% CI 1.07-1.11]; $P < .001$), and APRNs (OR 1.04 [95% CI 1.02-1.05]; $P < .001$) were also associated with having an ophthalmologist.

DISCUSSION

OUR STUDY FOUND THAT OVER THE PAST 2 DECADES, THERE was a decline in the national density of ophthalmologists and an increase in the age of the ophthalmologist workforce. When analyzing geographic and temporal trends on a county level, ophthalmologist density increased in rural counties, but remained significantly lower relative to metropolitan and nonmetropolitan counties in 2017. Conversely, all county types, rural and otherwise, experienced an increase in the density of optometrists over the study period.

The decline in ophthalmologist density contrasts with a rising density of total US physicians.[19] While the total number of medical school graduates and residency positions have continued to increase on the whole, ophthalmology has maintained a relatively fixed number of residency positions, contributing to a declining provider density in the context of a growing population.[20–23] This lack of growth, combined with the trend of practicing ophthalmologists retiring later, likely explains the increase in the ratio of older to younger ophthalmologists found in this study.[24]

Examination of the ophthalmologist workforce by rural/urban classification revealed that, in contrast to national trends among all physicians, there was an increase in the

TABLE. Univariate and Multivariable Regressions of County Level Factors Associated with the Presence of ≥1 Ophthalmologist in the County

County Variable	Univariate Model OR (95% CI)	*P* Value	Multivariable Model OR (95% CI)	*P* Value
Demographics				
Percent female	1.45 (1.38-1.53)	<.001	1.08 (1.00-1.16)	.051
Percent white, non-Hispanic	0.99 (0.98-0.99)	<.001	0.99 (0.98-1.00)	.055
Percent ≥65 years of age	0.85 (0.84-0.87)	<.001	0.98 (0.94-1.02)	.25
Percent persons >25 years of age with 4 years of college	1.23 (1.21-1.25)	<.001	1.08 (1.04-1.13)	<.001[a]
Economic				
Per capita income (dollars)	1.00 (1.00-1.00)	<.001	1.00 (1.00-1.00)	.84
Percent persons in poverty	0.94 (0.93-0.95)	<.001	1.02 (0.99-1.05)	.30
Percent persons 18-64 years of age without health insurance	0.93 (0.92-0.94)	<.001	0.97 (0.94-0.99)	.019[a]
Health care infrastructure				
No. of hospitals	4.25 (3.76-4.83)	<.001	1.23 (1.00-1.50)	.045[a]
No. of rural referral centers	20.59 (11.96-39.17)	<.001	3.18 (1.57-6.95)	.002[a]
No. of primary care physicians	1.16 (1.14-1.17)	<.001	1.09 (1.07-1.11)	<.001[a]
No. of APRNs	1.10 (1.09-1.11)	<.001	1.04 (1.02-1.05)	<.001[a]
No. of optometrists	1.42 (1.38-1.47)	<.001	0.99 (0.96-1.03)	.67
Degree of urbanization				
Rural/urban continuum code (1 = urban, 9 = rural)	0.62 (0.60-0.64)	<.001	0.99 (0.93-1.06)	.84

APRN = advanced practice registered nurse; CI = confidence interval; OR = odds ratio.
[a]Statistically significant values ($P < .05$).

density of ophthalmologists in rural counties from 2014 onward.[25] However, in 2017, 97% of rural counties still did not have a single ophthalmologist. Furthermore, rural counties had the highest proportion of older ophthalmologists and experienced the greatest increase in the ratio of older to younger ophthalmologists, which is consistent with previous reports of an aging rural physician workforce.[26] These results suggest that the recent increase in ophthalmologists in rural areas may be related to the retention of older ophthalmologists rather than the recruitment of new ophthalmologists, and that the retirement of currently practicing ophthalmologists may disproportionally impact rural residents' access to ophthalmic care.

There may be several explanations for the persistent rural/urban disparity in ophthalmologist availability. First, rural areas have a lower population density and may lack sufficient health care infrastructure and referral networks to sustain practices. Indeed, in our multivariable analysis, the number of hospitals, rural referral centers, primary care physicians, and APRNs were all independently associated with the presence of an ophthalmologist. Second, patients in rural counties are more likely to be uninsured, which may dissuade ophthalmologists from practicing in these areas due to uncertain and limited reimbursements.[27] We found that counties with a greater proportion of insured individuals were more likely to have ≥1 ophthalmologist. Lastly, most residencies are located in urbanized areas, and physicians who train in academic institutions may be more likely to settle in familiar practice settings or prefer an urban location for lifestyle reasons.[28,29] The relatively higher rates of career dissatisfaction and attrition reported among rural physicians may be partially explained by these factors.[30]

Addressing geographic disparities in ophthalmologist availability is of particular importance as previous literature suggests that the local availability of eye care providers is associated with clinical outcomes, including earlier disease detection and better visual health outcomes.[4–10,31] Several interventions have been proposed to address the shortage of ophthalmologists nationally, and in rural areas specifically.[32] Although an increase in the number of training positions appears to be an obvious solution, it would be resource intensive and may only have a nominal effect on the provider shortage, and that too with a delayed effect. Indeed, Lee and associates[32] proposed that increasing the number of residency training positions by 20% would result in only a 10% change in the number of practicing ophthalmologists over a span of ≥20 years. In addition, because the location of residency training is often associated with where physicians choose to practice, and most residencies are located in urbanized areas, an increase in the number of training positions may disproportionately impact the supply of ophthalmologists in urban areas.[29]

Instead, it may be more efficient to focus on policies to recruit younger ophthalmologists to rural areas. Proposed initiatives include financial incentives in the form of loan repayment programs or the development of ophthalmology-specific scholarships for medical students or residents interested in practicing in rural locations, such as the National Health Services Corps Program.[33] Federal funding for the development of rural-specific training programs with partnerships between medical schools and rural medical centers may attract medical students with rural backgrounds, who are more likely to end up practicing in a rural area but are currently underrepresented in graduate medical education.[34,35] These programs have already demonstrated success in increasing the number of rural medical applicants and graduating physicians who choose to practice in rural communities.[36] The incorporation of rural rotations into medical training could also increase the number of physicians who choose to practice in a rural area, as participation in a rural clinical location has been found to be the strongest predictor of a later decision to practice in a rural area.[37]

However, until these changes are implemented and the supply of ophthalmologists grows, interventions are needed to optimize the accessibility of the current workforce. One option is for ophthalmologists to increase their patient volume; it has been proposed that if half of ophthalmologists increased their patient volume by 33%, there would be a 17% increase in overall work availability.[32] Many ophthalmologists appear to support this proposal, as 45% of American Academy of Ophthalmology members indicated that they wished to increase their patient volume in a 2016 poll.[38] However, an expansion of patient load may have a limited impact on rural areas where there are fewer providers to begin with. Telemedicine has been proposed as a potential method to connect ophthalmologists with patients in areas without access to eye care providers, and has increasingly been used for screening for common diseases, such as age-related macular degeneration and diabetic retinopathy.[39] Although cost and equipment are major barriers for implementation and widespread adoption, ophthalmic telemedicine programs have shown promise in improving access to care.[39–41] Additional solutions include the incorporation of primary care physicians or mid-level providers, both of whose populations are increasing in rural areas, into eye screening programs.[25] Indeed, a study reported that the majority of diabetics who missed their annual dilated eye examination had visited a primary care physician in that year and therefore could have received appropriate screening if it were provided by their primary care provider.[42]

Finally, we found that the national optometrist density and the ratio of optometrists to ophthalmologists has increased. This is likely caused by an increase in the capacity of optometry training programs over the last decade, while the number of ophthalmology residency positions has not significantly increased.[22,43] We also note that while the mean optometrist density increased in rural counties, there remained a significant rural/urban disparity similar to that seen in the distribution of ophthalmologists. It is possible that optometrists may be dissuaded from practicing in rural areas for similar reasons as ophthalmologists. Furthermore, rural counties not only had a lower density of practicing optometrists but also experienced the smallest growth in the supply of optometrists over the study period. These results suggest that the geographic disparities in optometrist density may also be best addressed by providing incentives to practice in rural areas rather than increasing the number of training positions.

The rise in optometrist availability has led for calls to expand optometrists' scope of practice, particularly in areas with fewer ophthalmologists. However, there is little evidence to support the necessity and effectiveness of this proposal.[44] A recent study examining states with an expanded scope of practice for optometrists found that most patients who underwent surgeries by an optometrist did not live in rural communities and already had access to an ophthalmologist within an hour driving distance.[44] Similarly, studies show that there is no difference in the geographic access to procedures such as laser capsulotomy whether they are performed by ophthalmologists or optometrists.[45] An alternative proposal that uses the current optometrist availability without requiring significant legislative action is an increased emphasis on "shared care" models, in which optometrists monitor patients with chronic eye diseases and refer patients to partner ophthalmologists when treatment is required.[46,47] However, additional work is needed to determine how the growing supply of optometrists can best complement the ophthalmology workforce to optimize patient care and outcomes.

There are several limitations that should be considered when interpreting this study's findings. First, all ophthalmologists and optometrists were considered equally productive; differences in the number of patients seen, services performed, or hours worked were not identifiable and thus were not accounted for. Second, AHRF data use a single preferred mailing address for each provider, and we were unable to account for providers who may practice in multiple locations or travel across county lines to work in satellite clinics. In addition, the distance between neighboring counties with and without ophthalmologists and optometrists was not calculated. It is possible that patients in counties without an ophthalmologist or optometrist could have had access to an eye care provider in a nearby county. Third, all density calculations used data from the 2017 Census Population Estimates, and thus we may have underestimated the density of providers in earlier years given the increase in population size over time. Finally, ophthalmologist/optometrist density does not necessarily equate to the needed supply of ophthalmologists or optometrists, and we did not assess county-

level demand for eye care services. Future work should consider examining how the density of eye care providers impacts accessibility to ophthalmic services and effectiveness of care.

In this study, we found that the national density of ophthalmologists in the United States has decreased over the past 2 decades, while the density of optometrists has increased. In addition, we found that the ophthalmologist workforce has aged. Rural/urban disparities in ophthalmologist and optometrist availability have persisted, and the rural ophthalmologist workforce is aging more than its urban counterparts. Ophthalmologists were more likely to be found in counties with greater health care infrastructure and a higher proportion of insured patients. Future work should examine how the increasing demands on the shrinking and aging ophthalmologist workforce are impacting the quality of patient care as well as physician well-being. Further efforts should also determine how to leverage the expanding optometrist workforce to best complement the predicted ophthalmologist shortage, particularly in areas with lower ophthalmologist availability.

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