

# Geographic Distribution of US Ophthalmic Surgical Subspecialists

Aishah Ahmed, BA; Muhammad Ali, MBBS; Chen Dun, MHS; Cindy X. Cai, MD, MS; Martin A. Makary, MD, MPH; Fasika A. Woreta, MD, MPH

**IMPORTANCE** While urban counties maintain higher densities of ophthalmologists than rural counties, the geographic distribution of ophthalmic surgical subspecialists has not yet been elucidated. A potential workforce discrepancy may impact the burden of care faced by rural surgeons.

**OBJECTIVE** To assess the geographic distribution of the ophthalmic subspecialist surgeon workforce and evaluate factors associated with practicing in rural areas.

**DESIGN, SETTING, AND PARTICIPANTS** This cross-sectional population-based study of Medicare patients and surgeons performing subspecialized procedures took place from 2012 through 2022. Medicare Fee-for-Service claims were analyzed in 2023 for patients 65 years or older who underwent subspecialized ophthalmic procedures between 2012 and 2022 using *Current Procedural Terminology* codes (n = 1619 043). Surgeons were defined as a subspecialist based on *Current Procedural Terminology* codes, indicating performance of at least 1 subspecialty procedure from the following subspecialties: cornea, glaucoma, oculoplastic, retina, or strabismus (n = 13 526).

**MAIN OUTCOMES AND MEASURES** The primary outcome was the population density of practice for subspecialist surgeons and residence for patients (rural or urban). The secondary outcomes were the characteristics associated with rural practice.

**RESULTS** Among 13 526 ophthalmic surgical subspecialists, 9823 were male (72.6%), 3235 were female (26.8%), and 4484 (33.2%) practiced in the South. There were 2540 cornea subspecialists (18.5%), 3676 glaucoma subspecialists (26.8%), 1951 oculoplastic subspecialists (14.2%), 4123 retina subspecialists (30.0%), and 1236 strabismus subspecialists (9.0%). Across subspecialties, a higher proportion of patients (17.4%; 95% CI, 16.9%-17.9%) resided in rural areas relative to surgeons (5.6%; 95% CI, 5.3%-5.9%) with differences ranging from 6.2% to 14.8% across subspecialties. Female surgeons (adjusted odds ratio [aOR], 0.63; 95% CI, 0.51-0.79;  $P < .001$ ), surgeons in the Northeast (aOR, 0.62; 95% CI, 0.48-0.78;  $P < .001$ ), surgeons in the West (aOR, 0.63; 95% CI, 0.50-0.79;  $P < .001$ ), and recent graduates relative to those who graduated 11 to 20 years ago (aOR, 1.66; 95% CI, 1.25-2.21;  $P < .001$ ), 21 to 30 years ago (aOR, 1.83; 95% CI, 1.38-2.42;  $P < .001$ ), or 31 years ago or longer (aOR, 1.43; 95% CI, 1.08-1.90;  $P = .013$ ), were less likely to practice rurally.

**CONCLUSIONS AND RELEVANCE** This cross-sectional study between 2012 and 2022 identified higher proportions of rural patients compared with rural surgeons. Percentages of rural surgeons declined over time, with female surgeons and recent medical school graduates less likely to practice rurally. This suggests a disparity in the number of rural subspecialist surgeons available to serve rural patients.

 **Invited Commentary**

 **Supplemental content**

Over 90 million Americans older than 40 years have vision problems.<sup>1</sup> As the US population continues to expand and age, the demand for ophthalmic care is expected to rise.<sup>2,3</sup> The most commonly performed ophthalmic surgery in the US is cataract removal, typically considered a general ophthalmology procedure.<sup>4</sup> However, a growing aging population demands an increase in the number of subspecialty-specific ophthalmic surgeries performed as well.<sup>5</sup> Yet, access to these interventions hinges on the accessibility of subspecialist ophthalmic surgeons, which may vary with location.

Physician density is higher in metropolitan counties than in rural counties,<sup>6</sup> with a growing urban-rural gap among primary care physicians.<sup>7</sup> Additionally, general surgeons in rural communities have been shown to perform specialized procedures more frequently than their urban counterparts due to shortages of rural surgical specialists.<sup>8</sup> Among ophthalmologists, there is a larger workforce density in metropolitan and nonmetropolitan counties compared with rural counties.<sup>9</sup> Previous research shows that as the proportion of a county's urban residents increases, the density of ophthalmologists increases,<sup>10</sup> highlighting the scarcity of rural ophthalmologists. It has been established that limited access to ophthalmic care generates negative outcomes among rural or patients in underserved communities, including increased prevalence of visual impairment, diabetic retinopathy, and macular degeneration.<sup>11-14</sup> As such, it is crucial that there is a rural ophthalmic subspecialist workforce available to meet rural patients' ophthalmic needs.

While there are known distribution discrepancies in the physician and general ophthalmologist workforce,<sup>15</sup> the geographic distribution of ophthalmic surgical subspecialists has not been elucidated. Furthermore, rurality practice patterns of ophthalmic surgical subspecialists have not been analyzed over time, limiting insight on trends in the rural ophthalmic subspecialist-surgeon workforce.<sup>16</sup> In this study, we aimed to determine the geographic and urban-rural distribution of ophthalmic surgical subspecialists, including cornea, glaucoma, oculoplastic, retina, and strabismus specialists, across the US and assess surgeon characteristics associated with rural practice from 2012 to 2022.

## Methods

### Study Population

We conducted a retrospective, cross-sectional analysis using 100% Medicare Fee-For-Service claims data for traditional Medicare obtained from the US Centers for Medicare and Medicaid Services virtual research data center. For this reason, informed consent was not needed. This study received approval from the institutional review board of the Johns Hopkins University School of Medicine and adhered to the principles of the Declaration of Helsinki. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

We identified patients 65 years or older who underwent a subspecialized ophthalmic surgery between January 1, 2012,

## Key Points

**Question** What is the geographic distribution of ophthalmic surgical subspecialist surgeons in the US and what surgeon demographics are associated with rural practice?

**Findings** This cross-sectional study between 2012 and 2022 identified higher proportions of rural patients compared with rural surgeons. The percentage of rural surgeons declined over time; furthermore, female surgeons and more recent medical school graduates were less likely to practice rurally.

**Meaning** These results suggest that the rural US faces increasing ophthalmic subspecialty surgeon shortages.

and December 31, 2022, using *Current Procedural Terminology* codes (eTable 1 in the *Supplement*). Our criteria to define ophthalmic subspecialists, based on Cai et al,<sup>17</sup> incorporated procedural minimums from the Accreditation Council for Graduate Medical Education, fellowship training requirements, credentialing guidelines, and expert consensus to construct a list of subspecialty-specific operations. A surgeon's subspecialty was defined via *Current Procedural Terminology* code if they performed at least 1 of the following subspecialty operations: cornea (corneal transplant), glaucoma (trabeculectomy, aqueous shunt implant), oculoplastic (lacrimal gland procedure, enucleation, exenteration, orbitotomy, ocular implant procedure), retina (repair of retinal detachment, pars plana vitrectomy), or strabismus (strabismus surgery). Surgeons who performed procedures across multiple subspecialties were defined based on the plurality of procedures performed.

For surgeons performing equal numbers of operations across more than 1 subspecialty domain ( $n = 233$ ), we reviewed practice website information and virtual physician profiles to determine if they held a fellowship<sup>17</sup>; based on this method, 30 surgeons were sorted into cornea (12.9%), 9 into glaucoma (3.9%), 1 into oculoplastic (0.4%), 8 into retina (3.4%), and 7 into strabismus (3.0%). The remaining surgeons were determined to be general ophthalmologists, and thus were excluded from the data. Patients were excluded from the study population if they were younger than 65 years and/or did not have demographic information (eFigure 1 in *Supplement 1*).

### Outcomes: Surgeon and Patient Characteristics

Each procedural claim was linked to a National Provider Identifier to extract surgeon characteristics from the Medicare Data on Provider Practice and Specialty and Physician Compare National Downloadable file. Characteristics collected were sex (male, female, unknown), census region (Midwest, Northeast, South, West, other, or unknown), rurality (urban, rural, not available), and years since medical school graduation (0 to 10, 11 to 20, 21 to 30, 31 or more, or unknown). We defined an urban area of practice as a metropolitan or micropolitan core-based statistical area (CBSA) and a rural area of practice as a non-CBSA. The CBSA or non-CBSA that contained the most line items for that surgeon was used to identify the census region and rurality of practice for that surgeon. Years since graduation were calculated from graduation until the last operation in the study period.

Table 1. Ophthalmic Surgeon Characteristics By Subspecialty Type Between 2012 and 2022

Characteristic	No. (%)					P value
	Cornea (n = 2540)	Glaucoma (n = 3676)	Oculoplastic (n = 1951)	Retina (n = 4123)	Strabismus (n = 1236)	
Surgeon sex						
Male	1791 (70.51)	2659 (72.33)	1384 (70.94)	3276 (79.46)	713 (57.69)	
Female	639 (25.16)	888 (24.16)	531 (27.22)	669 (16.23)	508 (41.10)	
Unknown	110 (4.33)	129 (3.51)	36 (1.85)	178 (4.32)	5 (1.21)	<.001
Difference between male-female, % (95% CI)	45.35 (41.39-49.31)	48.17 (44.88-51.46)	43.72 (39.25-48.19)	63.23 (60.11-66.35)	16.59 (10.90-22.19)	
Census region of practice location						
Midwest	477 (18.78)	691 (18.80)	355 (18.20)	753 (18.26)	282 (22.82)	
Northeast	518 (20.39)	806 (21.93)	368 (18.86)	889 (21.56)	250 (20.23)	
South	857 (33.74)	1171 (31.86)	690 (35.37)	1349 (32.72)	417 (33.74)	
West	567 (22.32)	846 (23.01)	490 (25.12)	915 (22.19)	265 (21.44)	<.001
Other or unknown	121 (4.76)	162 (4.41)	48 (2.46)	217 (5.26)	22 (1.78)	
Difference across regions, % (95% CI)	28.89 (25.50-32.46)	27.45 (24.16-30.74)	32.91 (28.95-36.87)	27.46 (24.17-30.75)	21.04 (17.63-24.45)	
Rurality of practice location						
Urban	2319 (91.30)	3270 (88.96)	1780 (91.24)	3745 (90.83)	1169 (94.58)	
Rural	110 (4.33)	277 (7.54)	135 (6.92)	200 (4.85)	52 (4.21)	
NA	111 (4.37)	129 (3.51)	36 (1.85)	178 (4.32)	15 (1.21)	<.001
Difference between urban-rural, % (95% CI)	86.97 (82.9-90.95)	81.42 (78.13-84.71)	84.32 (79.85-88.79)	85.98 (82.86-89.10)	90.37 (84.77-95.97)	
Years since medical school graduation						
0-10	545 (21.46)	588 (16.00)	278 (14.25)	679 (16.47)	132 (10.68)	
11-20	678 (26.69)	712 (19.37)	468 (23.99)	1038 (25.18)	253 (20.47)	
21-30	488 (19.21)	740 (20.13)	392 (20.09)	868 (21.05)	251 (20.31)	
≥31	551 (21.69)	1037 (28.21)	476 (24.40)	1004 (24.35)	328 (26.54)	<.001
Unknown	278 (10.94)	599 (16.29)	337 (17.27)	534 (12.95)	272 (22.01)	
Difference among years, % (95% CI)	7.48 (5.62-9.34)	12.21 (9.43-15.00)	10.15 (7.93-12.37)	8.88 (7.01-10.7%)	15.86 (12.77-18.95)	

Abbreviation: NA, not available.

The Medicare Master Beneficiary Summary File was used to extract patient characteristics per claim, including age (65 to 74 years, 75 to 84 years, 85 years or older), sex (male, female), race and ethnicity (White, Black, Hispanic, Asian, other or unknown, North American native), census region of zip code (Midwest, Northeast, South, West, other, or unknown), Charlson Comorbidity Index (0, 1 to 6, or 7 or more), zip code rurality (urban, rural), and zip code median income (\$0 to 45 999, \$46 000 to 60 999, \$61 000 to 81 999, \$82 000 or more, or unknown). To determine Charlson Comorbidity Index, we reviewed patients' inpatient, outpatient, and carrier claims up to 1 year before their procedure. At least 1 diagnosis from inpatient claims or at least 2 diagnoses recorded more than 30 days apart from outpatient and carrier claims was required for comorbidity.<sup>18</sup>

### Statistical Analysis

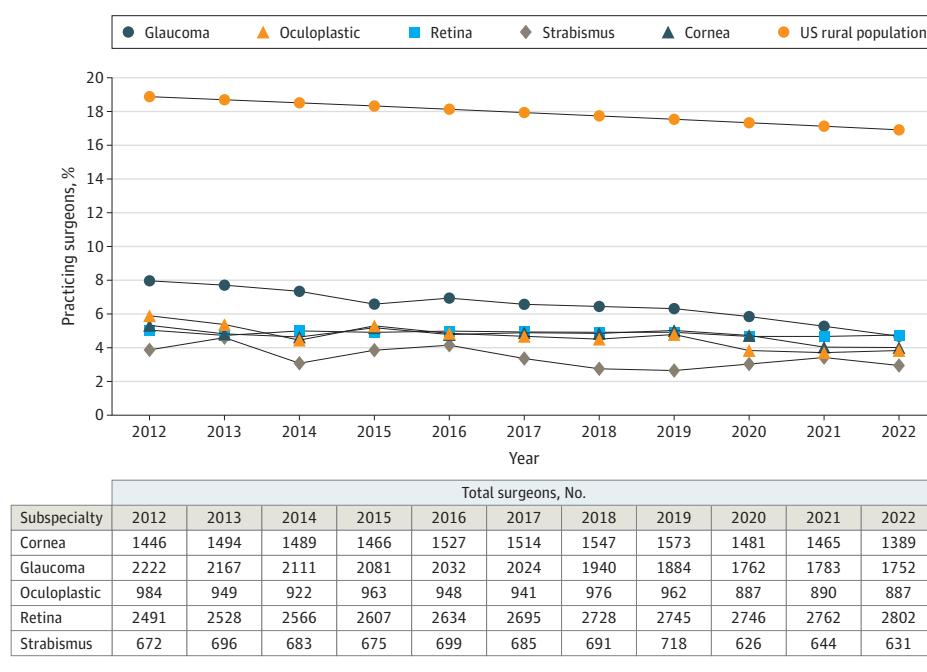
Continuous variables were presented as mean with SD or median with IQR. Categorical data were expressed as numbers and percentages. Two-sample *t* tests were used to compare continuous variables, while Pearson  $\chi^2$  tests were used for com-

paring categorical variables. Cochran-Mantel-Haenszel test was used to evaluate trends in surgeon data over time. Multivariable logistic regression model, adjusted for surgeon sex, census region of practice, years since medical school graduation, and surgical volume by quartile, was used to evaluate surgeon characteristics associated with rural practice. The statistical analyses were executed using SAS Enterprise version 7.1 (SAS Institute). All *P* values were 2-sided but not adjusted for multiple analyses.

### Results

**Surgeon and Patient Demographics With Trends Over Time**  
**Table 1** summarizes surgeon demographics by subspecialty type. There was a total of 2540 cornea, 3676 glaucoma, 1951 oculoplastic, 4123 retina, and 1236 strabismus surgical subspecialists in the US who performed subspecialty operations between 2012 and 2022 in the Medicare database. There was a difference in the number of operations performed between male and female surgeons, with male surgeons completing

Figure 1. Percentage of Subspecialist Surgeons Who Practice in Rural Areas by Year, 2012 to 2022



Between 2012 and 2022, the percentage of surgeons practicing in rural settings declined, with cornea surgeons declining by 1.3% (95% CI, 0.9%-1.7%), glaucoma declining by 3.3% (95% CI, 2.6%-4.0%), oculoplastic declining by 2.1% (95% CI, 1.3%-2.9%), retina declining by 0.4% (95% CI, -0.2% to 1%), and strabismus declining by 1.0% (95% CI, 0.4%-1.6%) (Cochran-Mantel-Haenszel test;  $P < .001$ ). This is occurring alongside a 2.0% decline in the US rural population (95% CI, 1.5%-2.4%), values for which were obtained from the World Bank Open DataBank.

more procedures than female surgeons across all subspecialties (cornea difference, 45.4%; 95% CI, 41.4%-49.3%; glaucoma difference, 48.2%; 95% CI, 44.9%-51.5%; oculoplastic difference, 43.7%; 95% CI, 39.3%-48.2%; retina difference, 63.2%; 95% CI, 60.1%-66.4%; and strabismus difference, 16.6%; 95% CI, 11.0%-22.2%) ( $P < .001$ ). A higher proportion of ophthalmic subspecialist surgeons practiced in the South (857 cornea [33.7%], 1171 glaucoma [31.9%], 690 oculoplastic [35.4%], 1349 retina [32.7%], and 417 strabismus [33.7%]) relative to other census regions ( $P < .001$ ). The Midwest had the lowest proportion of cornea (477 [18.8%]), glaucoma (691 [18.8%]), oculoplastic (355 [18.2%]), and retina (753 [18.3%]) surgeons and the Northeast had the lowest proportion of strabismus surgeons (250 [20.2%]) ( $P < .001$ ).

Across all surgical subspecialties, there was a difference in the number of surgeons practicing in urban settings compared with rural settings, with most surgeons practicing in urban settings compared with rural settings (cornea difference, 87.0%; 95% CI, 83.0%-91.0%; glaucoma difference, 81.4%; 95% CI, 78.1%-84.7%; oculoplastic difference, 84.3%; 95% CI, 79.9%-88.8%; retina difference, 86.0%; 95% CI, 82.9%-89.1%; and strabismus difference, 90.4%; 95% CI, 84.8%-96.0%) ( $P < .001$ ). Between 2012 and 2022, the percentage of surgeons practicing in rural settings declined with cornea surgeons declining by 1.3% (95% CI, 0.9%-1.7%), glaucoma declining by 3.3% (95% CI, 2.6%-4.0%), oculoplastic declining by 2.1% (95% CI, 1.3%-2.9%), retina declining by 0.4% (95% CI, -0.2% to 1%), and strabismus declining by 1.0% (95% CI, 0.4%-1.6%). This is occurring alongside a 2.0% decline in the US rural population (95% CI, 1.5%-2.4%) (Figure 1) (eTable 2 in Supplement 1).

eTable 3 in Supplement 1 summarizes patient demographics by subspecialty surgery received. There was a difference

between the number of patients residing in urban areas compared with rural areas across all subspecialties, with most patients who underwent subspecialty surgery residing in urban areas (cornea difference, 63.7%; 95% CI, 63.2%-64.1%; glaucoma difference, 69.2%; 95% CI, 68.8%-69.6%; oculoplastic difference, 73.8%; 95% CI, 73.1%-74.5%; retina difference, 60.6%; 95% CI, 60.5%-60.8%; strabismus difference, 65.1%; 95% CI, 64.3%-66.0%; combined 2 or more subspecialty surgeries difference, 68.0%; 95% CI, 65.2%-70.8%) ( $P < .001$ ). eTable 4 in Supplement 1 shows the number of each subspecialty's rurally residing patients by year from 2012 to 2022.

## Geographic and Rural Distribution of Ophthalmic Subspecialty Surgeons vs Patients

Figure 2 shows the geographic distribution of subspecialty surgeons per 10 000 patients by census region. The West had the highest number of surgeons per 10 000 patients for cornea (158) and glaucoma (156), while the Midwest and South had the lowest for cornea (102) and glaucoma (110), respectively. The West also led in oculoplastic surgeons per 10 000 patients (300) with the fewest in the South (196). The Northeast had the highest number of retina surgeons per 10 000 patients (54) and the South had the lowest (33). The Northeast also had the most strabismus surgeons per 10 000 patients (332), with the South having the least (208).

Across all subspecialties, a greater proportion of patients resided rurally (cornea, 18.2%; glaucoma, 15.4%; oculoplastic, 13.1%; retina, 19.7%; strabismus, 16.0%) compared with the proportion of rurally practicing surgeons (cornea, 4.3%; glaucoma, 7.5%; oculoplastic, 6.9%; retina, 4.9%; strabismus, 4.2%) ( $P < .001$ ). The cornea patient-surgeon difference was 13.8% (95% CI, 13.2%-14.5%). The glaucoma patient-surgeon difference was 7.9% (95% CI, 7.3%-8.4%). The oculoplastic patient-

Figure 2. Number of Surgeons Per 10 000 Patients Per Subspecialty by US Census Region (Northeast, South, Midwest, West) Between 2012 and 2022

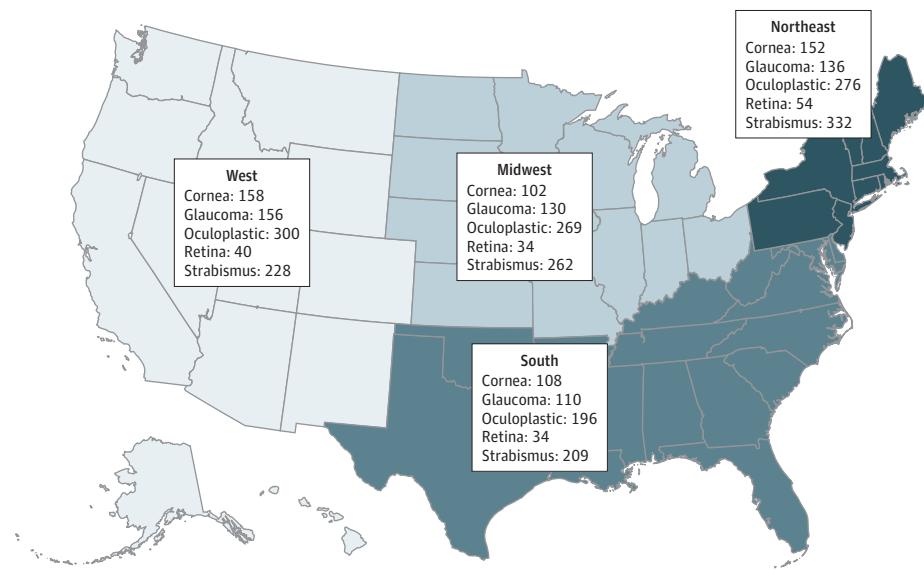
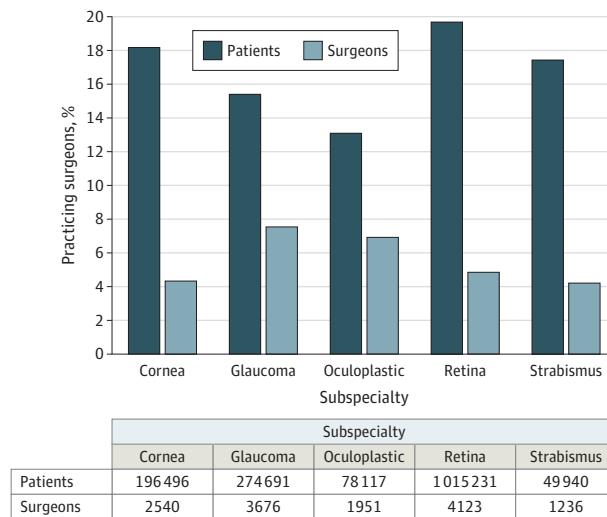


Figure 3. Percentage of Patients Undergoing Cornea, Glaucoma, Oculoplastic, Retina, and Strabismus Procedures and Surgeons Residing in Rural Areas



The cornea patient-surgeon difference was 13.8% (95% CI, 13.2%-14.5%). The glaucoma patient-surgeon difference was 7.9% (95% CI, 7.3%-8.4%). The oculoplastic patient-surgeon difference was 6.2% (95% CI, 5.6%-6.8%). The retina patient-surgeon difference was 14.8% (95% CI, 14.2%-15.5%). The strabismus patient-surgeon difference was 13.2% (95% CI, 12.6%-13.9%).

surgeon difference was 6.2% (95% CI, 5.6%-6.8%). The retina patient-surgeon difference was 14.8% (95% CI, 14.2%-15.5%). The strabismus patient-surgeon difference was 13.2% (95% CI, 12.6%-13.9%) (Figure 3).

#### Characteristics of Surgeons Associated With Rural Practice

On multivariable analysis (Table 2), female surgeons were less likely to practice rurally (adjusted odds ratio [aOR],

0.634; 95% CI, 0.511-0.787;  $P < .001$ ) than male surgeons. Surgeons practicing in the Midwest were more likely to practice rurally (aOR, 1.459; 95% CI, 1.195-1.780;  $P < .001$ ) compared with the South, while surgeons practicing in the Northeast (aOR, 0.615; 95% CI, 0.482-0.783;  $P < .001$ ) and the West (aOR, 0.627; 95% CI, 0.497-0.792;  $P < .001$ ) were less likely to practice rurally relative to the South. Cornea surgeons (aOR, 0.737; 95% CI, 0.545-0.988;  $P < .05$ ), retina surgeons (aOR, 0.911; 95% CI, 0.692-1.200;  $P = .51$ ), and strabismus surgeons (aOR, 0.665; 95% CI, 0.456-0.970;  $P = .03$ ) were less likely to practice rurally, while glaucoma surgeons (aOR, 1.182; 95% CI, 0.923-1.513;  $P = .18$ ) were more likely to practice rurally relative to oculoplastic surgeons. Compared with surgeons who recently graduated medical school (0 to 10 years ago), more experienced surgeons who graduated 11 to 20 years ago (aOR, 1.662; 95% CI, 1.253-2.205;  $P < .001$ ), 21 to 30 years ago (aOR, 1.828; 95% CI, 1.380-2.421;  $P < .001$ ), and 31 years ago or longer (aOR, 1.432; 95% CI, 1.079-1.902;  $P < .05$ ) were more likely to practice rurally. Surgeons with higher surgical volume (2nd quartile: aOR, 0.633; 95% CI, 0.504-0.794;  $P < .001$ ; 3rd quartile: aOR, 0.534; 95% CI, 0.425-0.671;  $P < .001$ ; 4th quartile: aOR, 0.465; 95% CI, 0.364-0.593;  $P < .001$ ) were less likely to practice rurally than surgeons with the lowest quartile surgical volume.

#### Discussion

While the broad geographic practice patterns of ophthalmologists are well researched, the rural distribution of subspecialists, like cornea, glaucoma, oculoplastic, retina, and strabismus surgeons, to our knowledge, has not been studied previously. Existing literature focuses on individual practices<sup>19</sup> or compares general ophthalmologists to subspecialists.<sup>17,20</sup>

**Table 2. Multivariable Analysis Assessing Ophthalmologist Characteristics Associated With Practicing in a Rural Area From 2012 to 2022 in the US Centers for Medicare and Medicaid Database**

Characteristic	Unadjusted odds		Adjusted odds	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Surgeon sex				
Male	Reference	NA	Reference	NA
Female	0.616 (0.501-0.758)	<.001	0.634 (0.511-0.787)	<.001
Census region of practice location				
Midwest	1.435 (1.178-1.748)	<.001	1.459 (1.195-1.780)	<.001
Northeast	0.623 (0.490-0.792)	<.001	0.615 (0.482-0.783)	<.001
South	Reference	NA	Reference	NA
West	0.644 (0.511-0.812)	<.001	0.627 (0.497-0.792)	<.001
Subspecialty				
Cornea	0.622 (0.467-0.828)	.001	0.737 (0.549-0.988)	.04
Glaucoma	1.063 (0.834-1.354)	.62	1.182 (0.923-1.513)	.18
Oculoplastic	Reference	NA	Reference	NA
Retina	0.744 (0.580-0.955)	.02	0.911 (0.692-1.200)	.51
Strabismus	0.610 (0.420-0.886)	.01	0.665 (0.456-0.970)	.03
Other/none	1.900 (1.118-3.230)	.02	1.397 (0.812-2.402)	.23
Years since medical school graduation				
0-10	Reference	NA	Reference	NA
11-20	1.478 (1.120-1.950)	.01	1.662 (1.253-2.205)	<.001
21-30	1.827 (1.388-2.405)	<.001	1.828 (1.380-2.421)	<.001
≥31	1.474 (1.121-1.938)	.01	1.432 (1.079-1.902)	.01
Surgeon's volume (surgeries), quartile				
1st	Reference	NA	Reference	NA
2nd	0.594 (0.476-0.740)	<.001	0.633 (0.504-0.794)	<.001
3rd	0.515 (0.413-0.643)	<.001	0.534 (0.425-0.671)	<.001
4th	0.515 (0.415-0.640)	<.001	0.465 (0.364-0.593)	<.001

Abbreviation: NA, not applicable.

Given that fewer eye care professionals have been linked to an increase in visual impairment prevalence,<sup>12,13</sup> our study provides evidence to suggest that there are fewer rural ophthalmic surgical subspecialists available. Furthermore, these data suggest that there has been a decline in the percentage of rural subspecialists over time. Our study reveals regional variations in subspecialty distribution, with characteristics like being female, practicing in the Northeast or West, being a recent graduate, and having a higher patient volume being less associated with practicing in rural settings. Notably, these findings do not determine if clinically relevant outcomes of care within these subspecialties have declined.

Data on the number of ophthalmic surgical subspecialists within the US per year vary: between 338 and 840 cornea surgeons,<sup>17,20</sup> 378 and 457 glaucoma surgeons,<sup>17,20</sup> 329 and 1238 oculoplastic surgeons,<sup>17,20-22</sup> 1084 and 2591 retina surgeons,<sup>17,20,23</sup> and 382 and 1056 strabismus surgeons.<sup>20,24,25</sup> More ophthalmology residents are matching into a subspecialty fellowship program, with 73.7% of applicants accepted into fellowship programs between 2010 and 2017.<sup>26</sup> Moreover, general ophthalmologists may gain experience in various subspecialist-specific procedures, via Accreditation Council for Graduate Medical Education residency graduation requirements. This enables general ophthalmologists to perform subspecialized operations, potentially increasing rural

care availability. Our methodology for defining subspecialists based on procedures performed accounts for potentially broader availability of care than indicated by solely examining fellowship.

Patients were more likely than surgeons to be located rural. Furthermore, we observed that between 2012 and 2022, there was a decline in the percentage of ophthalmic subspecialist surgeons practicing in rural areas. Previous work showed that between 1995 and 2017, the density of ophthalmologists decreased from 6.3 to 5.68 ophthalmologists per 100 000 individuals, with rural counties exhibited the lower mean density (0.58 ophthalmologists per 100 000 individuals).<sup>9</sup> These findings collectively underscore a potential concern regarding an increasing burden for rural subspecialists.

Our results suggest that 18.2% of patients undergoing cornea transplants are rural located. Previous research indicated that only 3.5% of transplants occur in a rural area,<sup>27</sup> suggesting that many rural patients do not receive care locally. As of 2016, 90% of contiguous US Medicare beneficiaries resided within a 30-minute drive of an ophthalmologist.<sup>28</sup> However, this includes both general and subspecialized ophthalmologists. Our findings suggest that there is a disparity in ophthalmic subspecialist surgeon availability between rural and urban areas; this may be concerning for older rural patients, who may face impairments hindering their ability to drive to a subspecialist surgeon. Alternative transportation

modes, such as buses or shuttles, also may not be readily available in rural settings.

Our results also suggested that the census region—Northeast, South, Midwest, or West—exhibiting the most surgeons per 10 000 patients was subspecialty dependent. Retina specialists preferentially practice in the Mid-Atlantic and Pacific subregions<sup>23</sup>; our analysis corroborated this, revealing the most retina surgeons per 10 000 patients in the Northeast and the West. Regarding oculoplastic surgeons, we observed more surgeons per 10 000 patients in the West and Northeast. This aligns with findings showing Los Angeles county and New York county having the most oculoplastic surgeons.<sup>22</sup> Trabeculectomies, performed by glaucoma specialists, are preferentially performed in the Northeast<sup>29</sup>; our results indicated that the West and the Northeast possess the most surgeons per 10 000 patients. In 2021, 89% of US counties lacked an oculoplastic surgeon<sup>22</sup>; in 2023, 90% of counties did not have a pediatric/strabismus ophthalmologist.<sup>25</sup> This underscores geographic disparities in the distribution of subspecialist surgeons, even within census regions.

We found that female ophthalmic surgeons were less likely to practice in rural areas, a trend also noted by Webb et al<sup>27</sup> for female cornea surgeons. The preference for urban settings may stem from lifestyle factors or a lack of female mentors in rural areas, discouraging recent female graduates from practicing there.<sup>30</sup> Additionally, we discovered that rural subspecialist surgeons were less likely to practice in the West and Northeast, indicating that rural residents within these regions may face less access. Our findings also revealed that newer medical school graduates (0 to 10 years out) were less likely to practice rurally than more experienced surgeons. This aligns with the decreasing percentage of medical students who are interested in rural practice<sup>31</sup> but may be troubling for the ophthalmic subspecialist workforce considering the projected increase in demand for rural physicians.<sup>15</sup> Understanding the demographics of subspecialist surgeons who choose to practice in rural areas may help develop incentives for rural practice. This could include financial compensation, debt forgiveness, research stipends, predefined service obligations, and enhanced work-life balance.<sup>32</sup>

### Strengths and Limitations

A strength of our study is that it is large and nationally representative, due to Medicare data. In 2023, approximately 65 million Americans were enrolled in Medicare,<sup>33</sup> with 94% of Americans aged 65 years or older enrolled in Medicare.<sup>34</sup> An-

other strength is that we included multiple ophthalmic surgeries as subspecialized practice markers.

Limitations include that the Medicare Fee-For-Service dataset used in our analysis does not encompass data from Medicare Advantage insurance plans, which accounted for 51% of patients in 2023.<sup>33</sup> We did not include these plans due to lack of associated surgeon data. Therefore, the surgeons analyzed in this study were only those participating in traditional Medicare, and thus, may not be representative of the total subspecialty surgeon workforce. Our findings are also in Medicare patients 65 years or older, and thus, may not be generalizable to younger patients possessing commercial insurance plans; this may be particularly relevant to pediatric strabismus patients. Additionally, our study defined a subspecialist as a surgeon who has performed a subspecialist-specific procedure; this means that a subspecialist may not be fellowship-trained, and therefore, may perform more general ophthalmology procedures than subspecialty-specific procedures. Furthermore, while this work characterized the urban-rural subspecialist workforce discrepancy, we did not directly quantify rural patient access to subspecialist care through specific measurements, such as driving distance. Lastly, these findings do not necessarily determine if clinically relevant outcomes of care within these subspecialties have declined in rural settings, with evidence being mixed as to whether increased medical specialist presence leads to improved care.<sup>12,13,35,36</sup>

### Conclusions

In summary, our work suggests a concerning geographic disparity in rural ophthalmic surgeons available to serve the needs of rural patients across cornea, glaucoma, oculoplastic, retina, and strabismus subspecialties. Despite a decrease in both the rural US population and the proportion of rural subspecialty surgeons over time, we discovered that rural patients still disproportionately outnumber rural surgeons. We also identified factors associated with a lower likelihood of practicing in rural areas, including being female, practicing in the Northeast and the West, being recently graduated, and having a high patient volume. While our findings underscore the potentially pressing issue of a dwindling rural ophthalmic subspecialist workforce, this study may also inform policy interventions aimed at increasing access to ophthalmic subspecialist surgeons and incentivizing rural practice among ophthalmic subspecialist surgeons.

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**Drafting of the manuscript:** Ahmed, Makary.

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