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Geospatial Distribution of Neurosurgeons Age 60 and Older Relative to the Spread of COVID-19

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■ **OBJECTIVE:** To perform an ecological study to analyze the geospatial distribution of neurosurgeons ≥ 60 years old and compare these data with the spread of 2019 novel coronavirus disease (COVID-19) across the United States.

■ **METHODS:** Data regarding distribution of COVID-19 cases were collected from the Environmental Systems Research Institute, and demographic statistics were collected from the American Association of Medical Colleges 2019 State Workforce Reports. These figures were analyzed using geospatial mapping software.

■ **RESULTS:** As of July 5, 2020, the 10 states with the highest number of COVID-19 cases showed older neurosurgical workforce proportions (the proportion of active surgeons ≥ 60 years old) of 20.6%–38.9%. Among states with the highest number of COVID-19 deaths, the older workforce proportions were 25.0%–43.4%. Connecticut demonstrated the highest with 43.4% of neurosurgeons ≥ 60 years old.

■ **CONCLUSIONS:** Regional COVID-19 hotspots may coincide with areas where a substantial proportion of the neurosurgical workforce is ≥ 60 years old. Continuous evaluation and adjustment of local and national clinical

practice guidelines are warranted throughout the pandemic era.

INTRODUCTION

Despite local and national attempts to contain 2019 novel coronavirus disease (COVID-19), it has continued to spread, with 32 states reporting surges related to reopening throughout the United States as of July 1, 2020.¹ The continued prevalence of the disease and wide fluctuations in hospital resources have forced many health care institutions, including neurosurgical departments, to repeatedly amend departmental practices.^{2,3} The pandemic has disrupted and reconfigured supply chains on local and international levels. Most notable and most publicized was the unreliability in available personal protective equipment (PPE) for the health care workforce. The fluctuations in both COVID-19 case numbers and PPE availability could prove dangerous, especially as states enter into various phases of reopening. It is important to conscientiously assess the risks faced by the neurosurgical workforce and identify the most vulnerable populations within the specialty.

Numerous risk factors have been found to contribute to COVID-19 severity and mortality. However, age independently has been reported as one of the most significant risk factors for death

Key words

- Age distribution
- At-risk
- Coronavirus
- COVID-19
- Neurosurgeons
- Pandemic

Abbreviations and Acronyms

ACS: American College of Surgeons

COVID-19: 2019 novel coronavirus disease

PPE: Personal protective equipment

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resulting from COVID-19.⁴⁻⁸ Characterization of the geospatial patterns between COVID-19 and the most at-risk neurosurgeons will help to determine regions that must optimize resources and commit to safety precautions to safeguard the neurosurgical workforce. Thus, this study was performed first to establish the geographical distribution of neurosurgeons ≥ 60 years old and second to compare these data to the distribution of COVID-19 cases across the United States. Recent publications have analyzed similar distributions with respect to orthopedic surgeons and otolaryngologists, but a specific focus on the neurosurgical workforce is vital because it would allow for protective precautions to be taken more strategically.^{9,10}

MATERIALS AND METHODS

This is an ecological cross-sectional study extracting data on the age and number of practicing neurosurgeons and the number of active COVID-19 cases in the United States. The demographic distribution of active neurosurgeons in the United States was extracted from the 2018 Physician State Workforce Reports created by the American Association of Medical Colleges.¹¹ Data collected included the total number of neurosurgeons in each state, the number and proportion of neurosurgeons ≥ 60 years old per state, and the total state population. Next, geospatial data describing the spread and severity of COVID-19 were gathered from the Environmental Systems Research Institute.¹² To compile and display all of these data, QGIS geospatial analysis software version 3.12.1 (<https://qgis.org/en/site/>) was used, creating a map of all 50 states that displayed the coordinates of active COVID-19 cases and deaths as of July 5, 2020. Based on the distribution of the neurosurgeon ages, states were grouped into quintiles, and a graduated color scheme was established to visualize and compare with regional COVID-19 statistics. Finally, temporal data regarding

the daily and cumulative incidence of confirmed COVID-19 cases were extracted from the *New York Times* online data repository and graphed to visualize the national trajectory of the pandemic over the past 6 months.¹³

RESULTS

In the 5 states with the highest number of active COVID-19 cases as of July 5, 2020, the percentage of neurosurgeons ≥ 60 years old was 28.7%–38.9% (Figure 1 and Table 1). Similarly, in the 5 states with the largest number of COVID-19–related deaths as of July 5, 2020, the percentage of neurosurgeons ≥ 60 years old was as high as 35% (Figure 2 and Table 2). The states in the highest quintile of neurosurgical workforce age were Connecticut, Florida, Montana, Idaho, North Carolina, Alabama, Georgia, Oklahoma, and Massachusetts. Of this quintile, 3 states, Florida, Massachusetts, and Georgia, were in the top 10 for number of active COVID-19 cases, and 3 states, Massachusetts, Connecticut, and Florida, were in the top 10 for COVID-19–related deaths (Tables 1 and 2). Overall, the states in the highest quintile of neurosurgical workforce age showed 35%–43.4% of actively practicing neurosurgeons to be ≥ 60 years old (Table 3). Additionally, of this quintile, Florida, Alabama, and Montana were in the top 5 for the oldest average physician workforce (Figure 3). It is also important to note that when comparing state workforce age proportions across specialties, neurosurgery has a higher proportion of the workforce ≥ 60 years old than only vascular surgery, obstetrics and gynecology, and emergency medicine (Figure 4).

Across the United States, the number of daily COVID-19 cases continues to fluctuate, with early reports from July indicating a daily increase of 50,000 cases per day.¹³ The first spike and subsequent downtrend in COVID-19–related deaths occurred in mid-April, which simultaneously marked the return to elective

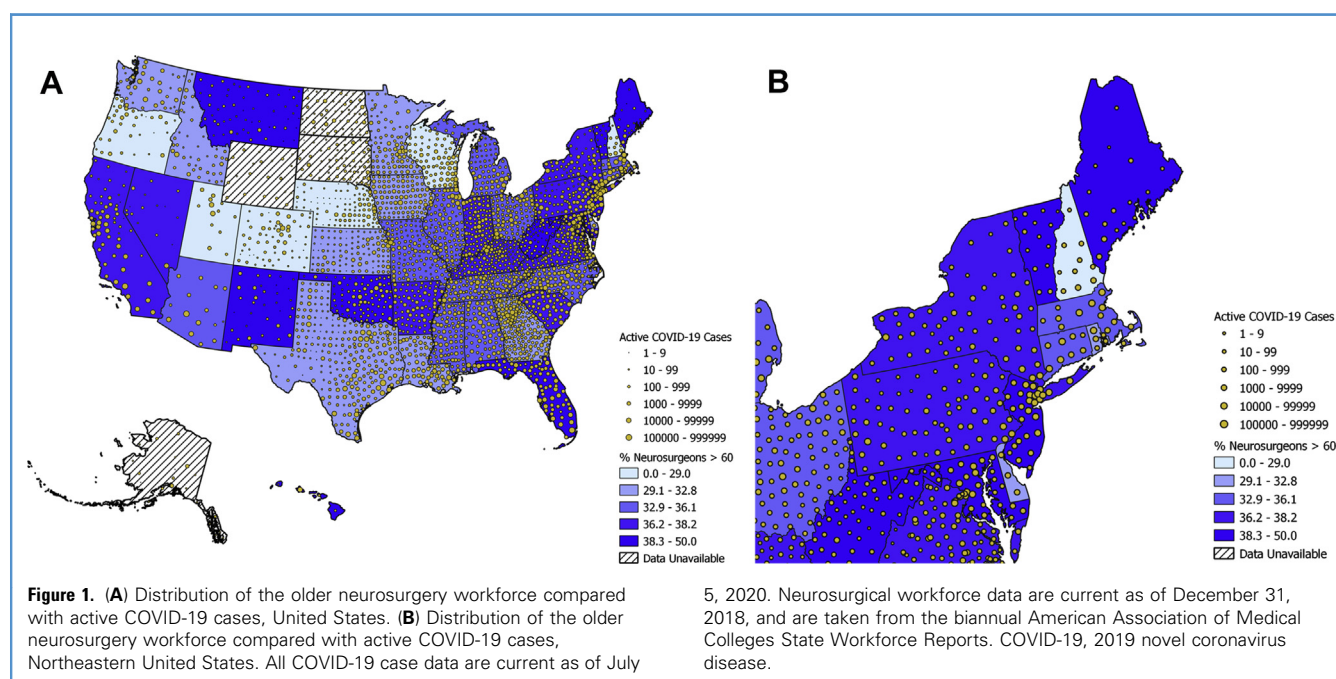


Table 1. State Neurosurgeon Workforce and COVID-19 Statistics Ranked by Current Number of Active COVID-19 Cases

Rank	State	Active COVID-19 Cases	Number of Neurosurgeons ≥60 Years Old (% of Total Neurosurgeons in State)	Total Number of Neurosurgeons in State	Population Per Neurosurgeon	Total Number of People ≥60 Years Old (% of Total State Population)	Confirmed Cases per 1 Million Population
1	New York	366,678	125 (34.2)	366	53,394	4,480,458 (22.9)	22,491
2	California	286,049	214 (32.9)	653	60,577	7,963,713 (20.20)	10,942
3	Texas	222,054	122 (28.7)	426	67,375	5,139,025 (18.0)	13,016
4	Florida	219,894	162 (38.9)	416	51,200	5,765,648 (27.2)	18,152
5	New Jersey	158,707	31 (25)	124	71,843	2,022,272 (22.7)	20,719
6	Illinois	143,245	71 (34.6)	206	61,850	2,804,799 (22.0)	13,266
7	Arizona	106,652	22 (20.6)	107	67,025	1,695,429 (23.60)	21,012
8	Massachusetts	102,359	50 (35)	143	48,267	1,588,116 (23.0)	16,586
9	Georgia	100,968	55 (36.7)	150	70,130	2,070,692 (19.80)	14,748
10	Pennsylvania	89,913	82 (30.5)	269	47,610	3,227,151 (25.2)	8526

All COVID-19 case data are current as of July 5, 2020. Neurosurgical workforce data are current as of December 31, 2018, and are taken from the biannual American Association of Medical Colleges State Workforce Reports. State-level population data are from U.S. Census Bureau 2018 National and State Population Estimates (<https://www.census.gov/newsroom/press-kits/2018/pop-estimates-national-state.html>). COVID-19, 2019 novel coronavirus disease.

surgeries authorized by the American College of Surgeons (ACS) on April 17, 2020. The number of daily COVID-19 deaths has continued to decrease from this original peak of >2000 deaths per day.¹³ A second peak occurred in mid-July at 66,000 daily confirmed cases followed by a valley that leveled off at 43,000 cases daily as of September 29, 2020,; however, this number now again appears to be increasing.¹⁴

DISCUSSION

This study performed an overlay of cross-sectional data to understand more intimately the risks to the neurosurgical workforce by geographical region and age. This study found that, as of July 5, 2020, certain states, specifically Florida, Massachusetts, Georgia, Alabama, and Connecticut, have been significantly affected by COVID-19, have some of the highest average physician workforce

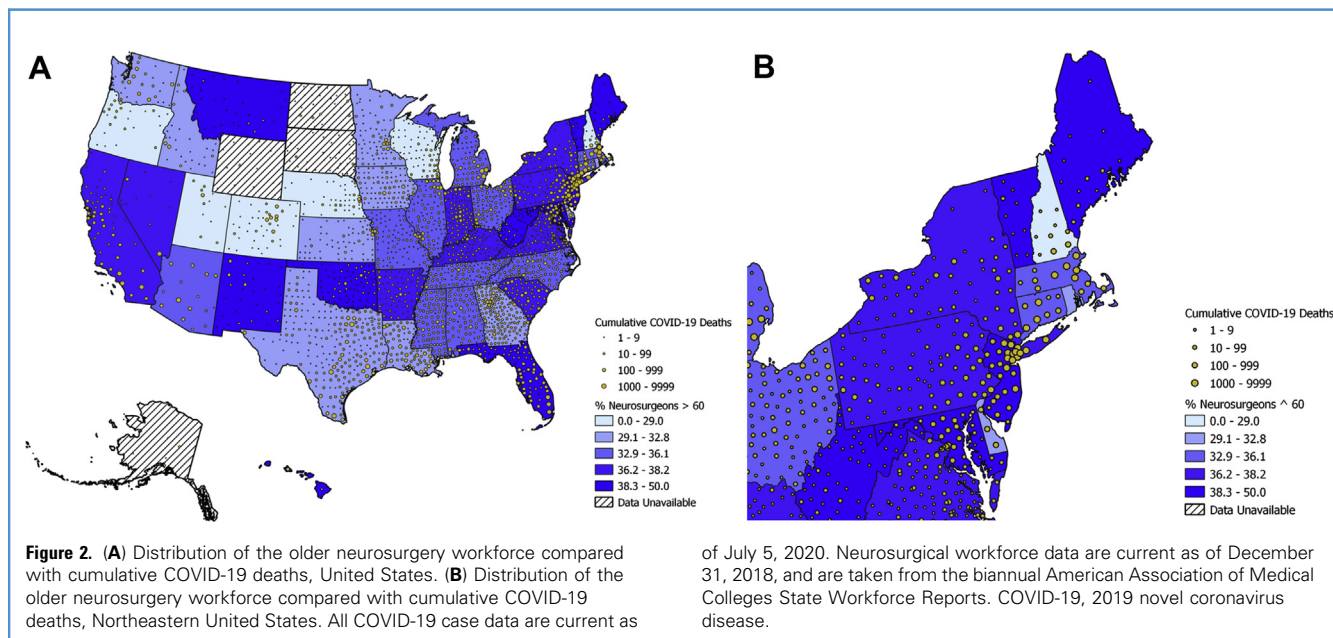


Table 2. State Neurosurgeon Workforce and COVID-19 Statistics Ranked by Cumulative Deaths Due to COVID-19

Rank	State	Cumulative COVID-19 Deaths	Number of Neurosurgeons ≥ 60 Years Old (% of Total Neurosurgeons in State)	Total Number of Neurosurgeons in State	Population Per Neurosurgeon	Total Number of People ≥ 60 Years Old (% of Total State Population)	Deaths per 1 Million Population
1	New York	32,251	125 (34.2)	366	53,394	4,480,458 (22.9)	1679
2	New Jersey	15,332	31 (25)	124	71,843	2,022,272 (22.7)	1780
3	Massachusetts	8243	50 (35)	143	48,267	1,588,116 (23.0)	1229
4	Illinois	7309	71 (34.6)	206	61,850	2,804,799 (22.0)	597
5	Pennsylvania	6812	82 (30.5)	269	47,610	3,227,151 (25.2)	560
6	California	6724	214 (32.9)	653	60,577	7,963,713 (20.20)	208
7	Michigan	6262	55 (32)	172	58,116	2,421,416 (24.2)	640
8	Connecticut	4343	33 (43.4)	76	47,009	865,770 (24.2)	1237
9	Florida	3889	162 (38.9)	416	51,200	5,765,648 (27.2)	257
10	Louisiana	3339	35 (34.7)	101	46,138	1,019,862 (21.9)	794

All COVID-19 case data are current as of July 5, 2020. Neurosurgical workforce data are current as of December 31, 2018, and are taken from the biannual American Association of Medical Colleges State Workforce Reports. State-level population data are from U.S. Census Bureau 2018 National and State Population Estimates (<https://www.census.gov/newsroom/press-kits/2018/pop-estimates-national-state.html>). COVID-19, 2019 novel coronavirus disease.

ages, and report the largest proportion of neurosurgeons ≥ 60 years old. As suggested in this article and by most news sources across the country, the number of COVID-19 cases in the United States continues to increase, but, as emergent, urgent, and even elective neurosurgical procedures are cleared to proceed, it is important that local entities, such as state neurosurgical societies, encourage hospitals, particularly those in states with the highest

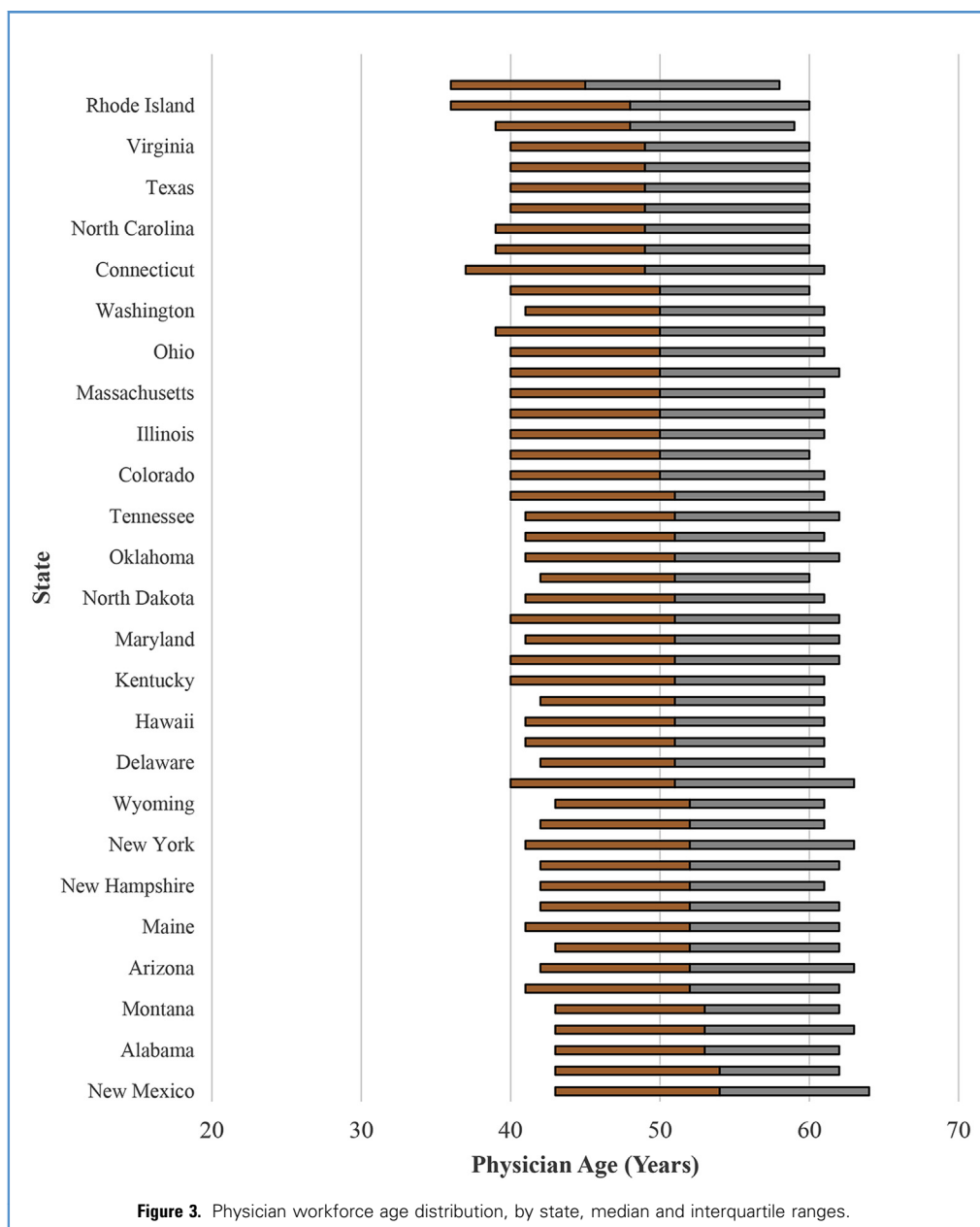
proportion of practicing neurosurgeons ≥ 60 years old, to take proper steps to guarantee the safety and security of the neurosurgical workforce.

Age is a known independent risk factor for poor outcomes and higher rates of mortality in both the general and the physician populations infected with COVID-19. One study reported a Google search of physician deaths as of April 15, 2020, and found 278

Table 3. State Neurosurgeon Workforce and COVID-19 Statistics Ranked by Workforce Proportion Age ≥ 60 Years

Rank	State	Number of Neurosurgeons ≥ 60 Years Old (%)	Total Number of Neurosurgeons	Population Per Neurosurgeon	Active COVID-19 Cases	Cumulative COVID-19 Deaths
1	Connecticut	33 (43.4)	76	47,009	42,765	4343
2	Florida	162 (38.9)	416	51,200	219,894	3889
3	Montana	26 (38.5)	26	40,858	1348	23
4	Idaho	29 (37.9)	29	60,490	8871	98
5	North Carolina	165 (37.6)	165	62,931	76,225	1462
6	Alabama	70 (37.1)	70	69,827	45,904	1058
7	Georgia	150 (36.7)	150	70,130	100,968	2922
8	Oklahoma	69 (36.2)	69	57,146	17,487	407
9	Massachusetts	143 (35)	143	48,267	102,359	8243
10	Louisiana	101 (34.7)	101	46,138	66,812	3339

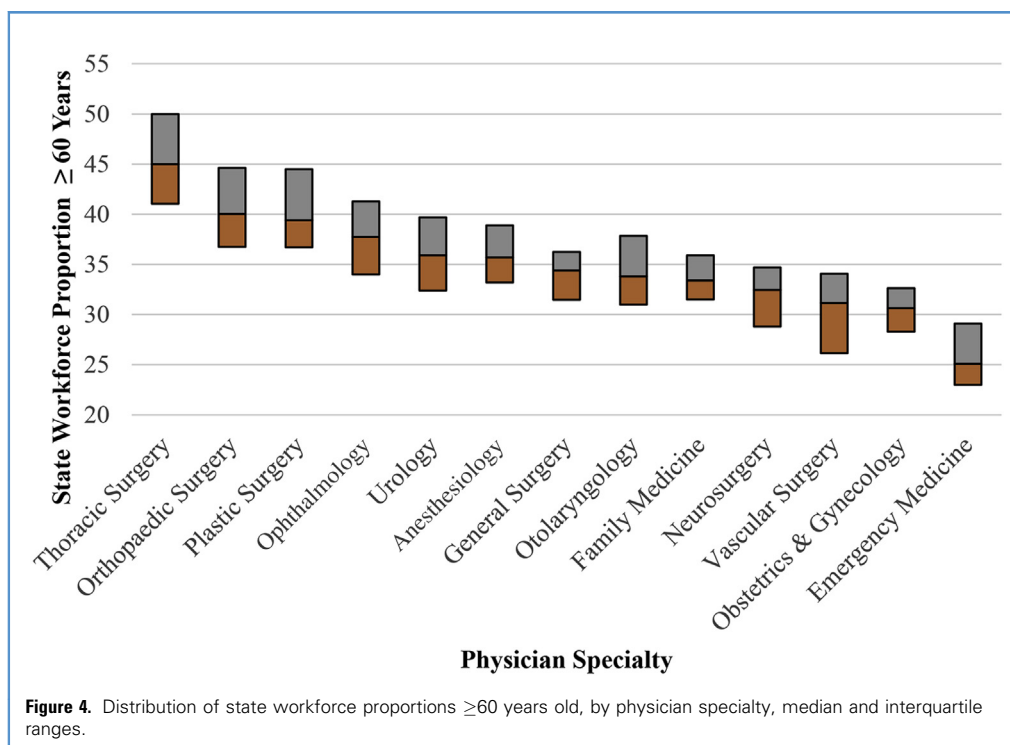
All COVID-19 case data are current as of July 5, 2020. Neurosurgical workforce data are current as of December 31, 2018, and are taken from the biannual American Association of Medical Colleges State Workforce Reports. COVID-19, 2019 novel coronavirus disease.



physicians worldwide had died as a result of COVID-19, and their average and median ages were 63.7 and 66 years, respectively.¹⁵ Additionally, as of June 2, 2020, 19 neurosurgeons across the world have died as a result of COVID-19, with the average and median ages at death being 61 and 62 years, respectively.¹⁶ The case-fatality rate in Italy as of March 17, 2020, for individuals ≥ 60 years old was nearly 3 times higher than that of individuals < 60 years old.¹⁷ Such correlations are alarming, considering the large proportion of neurosurgeons > 60 years old across the United States. A recent analysis of the vulnerable physician workforce during the COVID-19 pandemic found that of the 985,026 licensed physicians in the United States, 19.5% were

60–70 years old and 10.8% were ≥ 70 years old. Across states, the median proportion of physicians ≥ 60 years old was 28.9% (interquartile range: 27.2%–31.4%).^{18,19} General data suggest that contact between COVID-19–positive patients and older physicians should be limited if possible, and if contact is necessary, maximum precautions should be taken.

The use of PPE has been consistently linked to a reduction in COVID-19 transmission, and the supply chain for PPE in the United States appears to have stabilized.²⁰ As of September 29, 2020, data suggest that COVID-19 cases are again uptrending across the country, meaning that tactical prioritization of older practitioners should be considered. Even though neurosurgery is



not a specialty with a particularly high proportion of the workforce ≥ 60 years old, health care institutions across the world have implemented a variety of ways through which older members of the neurosurgical workforce can be protected during this pandemic. For instance, Jackson Memorial Hospital in Miami, Florida, and University Hospitals Cleveland Medical Center in Cleveland, Ohio, both Level 1 trauma centers, removed attending physicians >60 years old from the call pool and worked to consolidate subspecialty call schedules.³ Similarly, of 201 neurosurgeons surveyed in India, 106 of whom were ≥ 40 years old, 19.4% reported that they had switched over to telemedicine.²¹ The distribution of PPE has become much more streamlined in the past few months, but adopting methods to ensure continued equitable distribution among the local workforce should remain a focus for institutions.

As has been suggested for orthopedic surgeons ≥ 60 years old, neurosurgeons >60 years old could transition more significantly to telemedicine services during this time.⁹ However, if the presence of older neurosurgeons is necessary in the operating room, the spread of COVID-19 could be limited through implantation of the 5-zone operative complex proposed by Rodrigues-Pinto et al.,²² which suggests the use of separate rooms for the donning and doffing of PPE. Neurosurgical departments across the United States, and particularly those in hotspot regions, should consider logistical modifications, especially at the points where neurosurgeons most frequently interface with high risk for COVID-19 transmission. This includes endonasal or skull base procedures that involve significant mucosal disruption, use of powered drills and high-speed aspirators, and exposure during intubation/extubation

phases of surgery as well as in the management of patients with COVID-19-related cerebrovascular accidents.²³⁻²⁶

Study Limitations

This study analyzed the age distribution of the neurosurgical workforce but could not control for other known COVID-19 risk factors, such as tobacco use, pulmonary and cardiac disease, and immunocompromised states. Furthermore, this study did not directly establish a relationship between risk for COVID-19 and neurosurgeon age, and it did not provide concrete data regarding the spread of COVID-19 among the neurosurgical workforce.

Given that this analysis is performed with state-level data, we cannot distinguish age distributions or COVID-19 cases by urban or rural regions, academic or private hospitals, or hospital networks. Furthermore, states where <10 neurosurgeons are >60 years old did not report data for this metric owing to privacy reasons and were thus excluded from our study. Nine states (Alaska, Arizona, Maine, Nebraska, North Dakota, New Hampshire, South Dakota, Vermont, Wyoming) did not provide data on age of neurosurgeons. Our data also could not distinguish whether providers were practicing full-time or part-time and/or the age distribution of neurosurgeons by subspecialty. Also, the data provided regarding the neurosurgeon workforce are from December 2018, and more recent data are not available, so recent changes in the workforce demographics are not reflected.

This was a cross-sectional evaluation that was unable to accurately capture the rapid undulation in COVID-19 rates, and it furthermore did not report these data as true rates. In other words, the data presented provide a relatively broad overview that will continue to change

as time passes. The data that are provided with regard to the number of COVID-19 cases or deaths by state represent relatively general information that is likely not novel for many readers. Since the data for this study were acquired on July 5, 2020, the daily surge in cases has peaked at 75,600, rather than 50,000, as reported above. Further, determining an accurate point estimate of COVID-19 incidence has proven to be an national epidemiologic challenge. It is undermined by the significant variance in proportion of state populations that actually receive testing, the range of sensitivity of tests offered, and a high rate of resistance to contact tracing. Additionally, as the virus continues to spread, hospitals have strengthened their policies with regard to PPE usage and testing, which has both mitigated the risk that providers faced early on during the pandemic and minimized the spread of COVID-19 in hospitals.

CONCLUSIONS

In addition to the importance of PPE availability, numerous COVID-19-related guidelines and consensus recommendations

already have been published for a host of neurosurgical subspecialties.^{25,27-30} Armed with this increased awareness of regional hotspots in the United States, it is our hope that state associations, hospitals, neurosurgery departments, and neurosurgeons will apply and improve these guidelines to ensure that the most at-risk populations among the U.S. neurosurgical workforce are properly protected during this pandemic.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Tarun K. Jella: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing - review & editing. **Ansh Desai:** Formal analysis, Writing - original draft, Writing - review & editing. **Taral Jella:** Data curation, Resources, Software. **Michael Steinmetz:** Supervision, Validation. **Kristopher Kimmell:** Supervision, Validation. **James Wright:** Supervision, Validation, Writing - review & editing. **Christina Huang Wright:** Supervision, Validation, Writing - review & editing.

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