Educational Program Rankings Are Independently Associated With Residents' Academic Career Trajectory in Neurological Surgery

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OBJECTIVE: Many studies have sought to determine predictors of academic career placement in surgical subspecialities. However, previous research has yet to establish whether the ranking of a surgeon's undergraduate institution or medical school is significantly associated with pursuit of an academic career. The purpose of this study was to investigate these novel factors' predictive impact on an academic career in the surgical subspeciality of neurosurgery. Factors investigated included undergraduate university rankings, medical school rankings, and residency program rankings.

DESIGN: Data were retrospectively collected for 884 alumni of Accreditation Council for Graduate Medical Education neurological surgery residency programs. Bivariate analyses were conducted to determine covariates for a logistic regression model, and multivariate analysis was performed with 13 covariates to determine which factors were independently associated with academic career trajectory.

RESULTS: In multivariate analysis, factors that were independently associated with an academic career in neurological surgery included having 1 year or more of protected research time during residency (odds ratio [OR] =1.96, p = 0.020), attending a "top" undergraduate university (OR =1.88, p = 0.00033), attending a "top" research medical school (OR = 1.53, p = 0.031) attending a residency program affiliated with a "top" research medical school (OR = 1.78, p = 0.012), possessing a Master of Science (OR = 3.46, p = 0.00097), or Doctor of Philosophy (OR = 2.05, p = 0.0019) degree, and completing a clinical fellowship (OR = 2.56, $p = 1.90 \times 10^{-8}$).

CONCLUSIONS: Our study establishes 3 novel factors for predicting residents' choice of pursuing an academic career in neurological surgery, namely undergraduate university rank, medical school rank, and completing residency at a program affiliated with a "top" research medical school. Such findings reinforce the notion that educational and training environments are key in shaping the career trajectory of future academic surgical subspecialists. (J Surg Ed 77:1312–1320. © 2020 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: academic career, graduate medical education, neurosurgery, residency

COMPETENCIES: Medical Knowledge, Professionalism, Interpersonal and Communication Skills, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Research investigating factors that predict academic career trajectory among surgical trainees has been conducted in many different surgical subspecialties, ranging from urology to otolaryngology.[1-16] Given that surgical residency programs have a significant incentive to produce not only clinically excellent surgeons but also prolific researchers whose scholarly output will advance their respective fields, determining factors that influence career trajectory will likely remain a priority in graduate education research.[1,17] Prior studies on this topic have examined factors such as number of publications prior

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to and during residency, length of dedicated research time during residency, sex, ethnicity, and medical school as well as residency training environments.[10-16]

Over the past several years, there has been considerable work undertaken to investigate factors that predict a career in the surgical subspeciality of academic neurological surgery specifically.[1,2,9-14] Within this surgical subspeciality, research has yet to directly examine whether attendance at a top undergraduate university, top medical school, or top residency program is associated with pursuit of an academic career path. Quantifying this association was the primary goal of this study. Establishing additional variables that are predictive of an academic career could be helpful in identifying and cultivating the best and brightest young minds who have an interest in entering this surgical subspeciality. The present investigation can also serve to spur further research into predictors of career trajectory relating to educational environment within other surgical subspecialties.

MATERIALS AND METHODS

Dataset Creation

Using publicly available online data, we created a database of all neurosurgeons that graduated from 78 Accreditation Council for Graduate Medical Education (ACGME) residency programs for neurological surgery between the years 1982 and 2018. Alumni information was obtained primarily from residency websites. This information was verified and supplemented with additional information obtained from an individual Internet search for each alumna or alumnus; this individual search was conducted through online search engines (i.e., Google) and professional websites (i.e., Doximity and LinkedIn). As of June 2019, there were 1387 neurological surgeons listed in our database of ACGME-accredited residency alumni. For this study, we excluded current fellows (n = 27) and those for whom we were missing data for any of the variables we sought to analyze (n = 476).

Variables Analyzed

For each neurological surgeon in our database, we collected the following information: sex, medical school name and graduation year, residency program name and graduation year, length of residency training, and months of protected research time during training. The number of clinical fellowships completed by a surgeon, as well as fellowship locations, was also noted. Furthermore, we catalogued advanced degrees that have been associated with increased odds of attaining an academic position, namely a Master's of Science (MS) and Doctor of Philosophy (PhD).[2,10,12] Current employment location was categorized, and positions were considered "academic" if they were affiliated with a neurological surgery residency program; other positions were considered "non-academic." Retired neurosurgeons were excluded from our cohort since they were not employed in a clinical setting at the time of the study.

We further attempted to catalogue the education and training environments for each neurological surgeon. For this study, a "top" undergraduate university, medical school, or residency program was defined as an educational institution listed at least once within the top 10 rankings of *US News' National Universities* list (1993-2019), *US News' Top Medical Schools for Research* list (1993-2019), or *US News' Best Hospitals for Neurology & Neurosurgery* list (2007-2019), respectively. Additionally, we tracked whether residents completed their training at a program listed within the top 20 rankings of *Doximity's Neurological Surgery Residency Programs* (sorted by reputation) 2019-2020 list. Finally, we noted whether surgeons completed their residency at a program affiliated with a medical school that appeared at least once within the top 10 rankings of *US News' Top Medical Schools for Research (*1993-2019). This methodology has been previously used in studies by Grimm et al and Dorsey et al.[17,18] The full list of schools and programs within the "top" rankings utilized in this study are listed in Table 1.

Statistical Analysis

Data were collected using Microsoft Excel (version 2016, Microsoft Corp.). Statistical analyses were conducted using R Statistical Software (Version 3.3.2, Vienna, Austria). Fisher's exact test was used for bivariate analyses of categorical variables, and a logistic regression model was used for a multivariate analysis.

Data were analyzed in 2 phases. First, bivariate analyses were performed to determine the association between independent and dependent variables. Odds ratios (ORs) and 95% confidence intervals were also calculated. Next, a multivariate analysis was performed for the dependent variable of a current academic position. Covariates for this analysis included all variables that were statistically significant in bivariate analyses ($p < 0.05$). Values of $p < 0.05$ were considered significant and p values were reported as 2-sided.

RESULTS

Neurological Surgeon Demographics

The present study utilized data from 884 neurosurgical residency alumni, whose demographics are displayed in

TABLE 1. List of Top Undergraduate Universities, Medical Schools, and Neurosurgery Residency Programs (in Alphabetical Order)

Top 10 US News Undergraduate Schools (1993-2019)	Top 10 US News Research Medical Schools (1993-2019)	Top 10 US News Residency Programs (2007-2019)	Top 20 Doximity Residency Programs (2019)	Residency Programs Affiliated With a Top 10 US News Research Medical School (1993-2019)
Brown University	Columbia University	Barnes-Jewish Hospital	Cleveland Clinic	Brigham and Women's Hospital
California Institute of Technology	Cornell University	Cleveland Clinic	Duke University Hospital	Columbia University
Columbia University	Duke University	Hospitals of the University of Pennsylvania—Penn Presbyterian	Emory University	Cornell University
Cornell University	Harvard University	Johns Hopkins Hospital	Johns Hopkins University	Duke University
Dartmouth University	Johns Hopkins University	Massachusetts General Hospital	Massachusetts General Hospital	Johns Hopkins University
Duke University	Mayo Clinic School of Medicine	Mayo Clinic (Rochester, Minnesota)	Mayo Clinic College of Medicine	Massachusetts General Hospital
Emory University	New York University	Methodist Hospital (Houston, Texas)	New York Presbyterian Hospital (Columbia Campus)	Methodist Hospital (Houston, Texas)
Harvard University	Stanford University	New York Presbyterian Hospital-Columbia and Cornell	New York University School of Medicine	New York University
Johns Hopkins University	University of California, Los Angeles	Northwestern Memorial Hospital	Stanford Health Care	Stanford University
Massachusetts Institute of Technology	University of California, San Francisco	New York University Langone Hospitals	St. Joseph's Hospital-Barrow	University of California, Los Angeles
Stanford University	University of Chicago	Rush University Medical Center	University of California, San Francisco	University of California, San Francisco
Northwestern University	University of Michigan	St. Joseph's Hospital-Barrow (Phoenix, Arizona)	University of California, Los Angeles	University of Michigan
Princeton University	University of Pennsylvania	Stanford Healthcare-Stanford Hospital	University of Michigan Health System	University of Pennsylvania
University of Chicago	University of Washington	University of California, Los Angeles Medical Center	University of Pennsylvania Health System	University of Washington
University of Pennsylvania	Washington University in St. Louis	University of California, San Francisco Medical Center	University of Pittsburgh	Washington University in St. Louis
Washington University in St. Louis	Yale University	University of Michigan Hospitals-Michigan Medicine	University of Southern California	Yale University
Yale University	—	University of Pittsburgh Medical Center	University of Texas Southwestern Medical Center	—
—	—	—	University of Virginia	—
—	—	—	University of Washington	—
—	—	—	Washington University in St. Louis	—

Table 2. Our cohort was majority (88.2%) male, with 410 (46.4%) surgeons currently employed in an academic position and 474 (53.6%) employed in a nonacademic position. Fifty-one (5.8%) of the surgeons in our cohort graduated from residency before 2004, 309 (35.0%) graduated between 2005 and 2009, 368 (41.6%) graduated between 2010 and 2014, and 156 (17.6%) graduated during and after 2015. One hundred ninety-eight (22.4%) surgeons in our study completed 6-year residency programs, and 686 (77.6%) completed 7-year programs. Two hundred ninety-eight (33.7%) alumni attended a "top" undergraduate university, while 253 (28.6%) attended a "top" medical school. Regarding residency programs, 316 (35.7%) surgeons attended a "top"

TABLE 2. Neurosurgeon Demographics (n = 884)

Characteristic	Number (%)
Sex	
Male	780 (88.2)
Female	104 (11.8)
Academic position	
Yes	410 (46.4)
No	474 (53.6)
Residency graduation year	
≤ 2004	51 (5.8)
2005-2009	309 (35.0)
2010-2014	368 (41.6)
≥ 2015	156 (17.6)
Residency program length	
6	198 (22.4)
7	686 (77.6)
Top 10 undergraduate university (1993-2019)	
Yes	298 (33.7)
No	586 (66.3)
Top 10 research medical school (1993-2019)	
Yes	253 (28.6)
No	631 (71.4)
Top 10 US News residency program (2007-2019)	
Yes	316 (35.7)
No	568 (64.3)
Top 20 Doximity residency program (2019)	
Yes	338 (38.2)
No	546 (61.8)
Residency program affiliated with a top 10 research medical school (1993-2019)	
Yes	316 (35.7)
No	568 (64.3)
Top rankings in all 5 categories	
Yes	85 (9.6)
No	799 (90.4)
Protected research time (months)	
≥ 1 year	762 (86.2)
< 1 year	122 (13.8)
Medical degree	
MD	846 (95.7)
DO	38 (4.3)
Other higher degrees	
MS	42 (4.8)
PhD	114 (12.9)
Completion of a clinical fellowship	
Yes	607 (68.7)
No	277 (31.3)

DO, Doctor of Osteopathic Medicine; MD, Doctor of Medicine; MS, Masters of Science; PhD, Doctor of Philosophy.

program by *US News* criteria, 338 (38.2%) attended a "top" program by *Doximity* criteria, and 316 (35.7%) attended a residency program affiliated with a "top" research medical school. There were 85 (9.6%) surgeons who attended "top" programs for all of the 5 "top" categories. A total of 762 (86.2%) neurological surgeons had ≥1 year of protected research time during residency. Additionally, our cohort was composed of 846 (95.7%) surgeons holding an MD degree and 38 (4.3%) holding a DO degree. Finally, 42 (4.8%) surgeons held a MS degree, and 114 (12.9%) held a PhD.

We found that there was no significant difference in the proportion of surgeons who attended a "top" undergraduate university remaining as faculty at that university compared to surgeons who did not attend a "top" undergraduate university ($p = 0.65$). Additionally, there was no significant difference in the proportion of surgeons who completed a residency program affiliated with a "top" medical school ($p = 0.56$) remaining as faculty at the hospital affiliated with their residency program compared to surgeons who did not complete such a residency. However, a significant proportion of surgeons who attended a "top" research medical school are currently employed as faculty at hospitals affiliated with their alma mater ($OR = 1.92$, $p = 0.018$).

Bivariate Analyses

Next, we investigated characteristics associated with choosing an academic career in neurological surgery via bivariate analyses. As shown in Table 3, significant predictors of academic career included holding an MD versus a DO degree ($OR = 2.90$, $p = 0.004$), having ≥1 year of protected research time ($OR = 4.57$, $p < 0.001$) during residency, holding an MS degree ($OR = 3.08$, $p < 0.001$); holding a PhD degree ($OR = 3.36$, $p < 0.001$); and completing at least 1 clinical fellowship ($OR = 2.60$, $p < 0.001$). Additional statistically significant factors included attending a "top" undergraduate university ($OR = 2.41$, $p < 0.001$), attending a "top" medical school ($OR = 2.75$, $p < 0.001$), attending a "top" *US News* residency program ($OR = 2.64$, $p < 0.001$), attending a "top" *Doximity* residency program ($OR = 2.61$, $p < 0.001$), attending a residency program affiliated with a "top" research medical school ($OR = 3.27$, $p < 0.001$), and attending "top" programs for all 5 aforementioned categories ($OR = 3.27$, $p < 0.001$).

Multivariate Analysis

To further define the association between characteristics within our cohort and an academic career, we conducted a multivariate analysis using a logistic regression model. Our covariates for this model were the characteristics found to be significant in bivariate analyses, as noted above. To test for collinearity among the variables in our model, we calculated variance inflation factors (VIF) for each variable; a VIF greater than 5 is generally considered to indicate collineary.[19] The VIFs for medical degree type (1.42), protected research time (1.49), undergraduate school ranking (1.27), medical school ranking (1.44), *US News* residency program ranking

TABLE 3. Bivariate Analysis of Academic Career Choice (n = 884)

Characteristic	Academic Position, Number (%)	Nonacademic Position, Number (%)	p Value	OR	95% CI
Sex					
Male	356 (45.6)	424 (54.4)	0.25	0.78	0.50-1.20
Female	54 (51.9)	50 (48.1)			
Medical degree					
MD	401 (47.4)	445 (52.6)	0.0043*	2.90	1.32-7.05
DO	9 (23.7)	29 (76.3)			
Protected research time (months)					
≥ 1 year	382 (93.2)	28 (6.8)	8.14×10^{-13}	4.57	2.88-7.45
< 1 year	380 (80.2)	94 (19.8)			
Top 10 undergraduate university (1993-2019)					
Yes	181 (60.7)	117 (39.3)	1.15×10^{-9}*	2.41	1.79-3.24
No	229 (39.1)	357 (60.9)			
Top 10 research medical school (1993-2019)					
Yes	162 (64.0)	91 (36.0)	3.65×10^{-11}*	2.75	2.01-3.77
No	248 (39.3)	383 (60.7)			
Top 10 US news residency program (2007-2019)					
Yes	195 (61.7)	121 (38.3)	1.11×10^{-11}*	2.64	1.97-3.55
No	215 (37.9)	353 (62.1)			
Top 20 residency program (Doximity)					
Yes	206 (60.9)	132 (39.1)	8.63×10^{-12}*	2.61	1.96-3.49
No	204 (37.4)	342 (62.6)			
Residency program affiliated with a top 10 research medical school (1993-2019)					
Yes	205 (64.9)	111 (35.1)	$<2.20 \times 10^{-16}$*	3.27	2.43-4.41
No	205 (36.1)	363 (63.9)			
Top rankings in all 5 categories					
Yes	61 (71.8)	24 (28.2)	9.77×10^{-7}*	3.27	1.96-5.61
No	349 (43.7)	450 (56.3)			
MS degree					
Yes	30 (71.4)	12 (28.6)	0.0013*	3.04	1.49-6.60
No	380 (45.1)	462 (54.9)			
PhD degree					
Yes	76 (66.7)	38 (33.3)	4.65×10^{-6}*	2.61	1.70-4.06
No	334 (43.4)	436 (56.6)			
Completion of a clinical fellowship					
Yes	325 (53.5)	282 (46.5)	2.06×10^{-10}*	2.60	1.91-3.56
No	85 (30.7)	192 (69.3)			

CI, confidence interval; DO, Doctor of Osteopathic Medicine; MD, Doctor of Medicine; MS, Master of Science; OR, odds ratio; PhD, Doctor of Philosophy. p values were obtained using Fisher's exact test.

*Statistical significance ($p < 0.05$).

(2.37), *Doximity* residency program ranking, affiliation of residency program with a "top" research medical school (2.24), attendance of "top" programs for all of the 5 "top" categories (1.71), MS degree attainment (1.02), PhD degree attainment (1.03), and completion of a clinical fellowship (1.02) all indicated noncollinearity. The results of the multivariate analysis are summarized in Table 4. We found that the factors independently associated with an academic career were having 1 year or more of protected research time during residency (OR = 1.96, p = 0.020), attending a "top" undergraduate university (OR = 1.88, $p < 0.001$), attending a "top" medical school (OR = 1.53, p = 0.031), attending a residency program affiliated with a "top" medical school (OR = 1.78, p = 0.012), possessing an MS degree (OR = 3.46, $p < 0.001$), possessing a PhD degree (OR = 2.51, p = 0.002), and completing at least 1 clinical fellowship (OR = 2.56, $p < 0.001$). None of the other factors that were significant in bivariate analyses were significant in multivariate analysis.

DISCUSSION

Prior Research

An important study that motivated our present investigation was conducted by Dorsey et al who found that, among a cohort of 68 neurology residents who graduated from the University of Pennsylvania between 1986

TABLE 4. Multivariate Analysis of Academic Career Choice (n = 884)

Characteristics	p Value	OR	95% CI
Medical degree			
MD	0.98	0.12	0.40-2.62
DO			
Protected research time (months)			
≥ 1 year	0.020*	1.96	1.13-3.52
< 1 year			
Top 10 undergraduate university (1993-2019)			
Yes	0.00033*	1.88	1.33-2.66
No			
Top 10 research medical school (1993-2019)			
Yes	0.031*	1.53	1.04-2.26
No			
Top 10 US News residency program (2007-2019)			
Yes	0.63	1.12	0.70-1.78
No			
Top 20 Doximity residency program (2019)			
Yes	0.74	1.08	0.68-1.72
No			
Residency program affiliated with top 10 research medical school (1993-2019)			
Yes	0.012*	1.78	1.13-2.81
No			
Top rankings in all 5 categories			
Yes	0.73	0.89	0.46-1.75
No			
MS degree			
Yes	0.00097*	3.46	1.70-7.51
No			
PhD degree			
Yes	0.0019*	2.05	1.31-3.24
No			
Completion of a clinical fellowship			
Yes	1.90×10^{-8}*	2.56	1.85-3.56
No			

CI, confidence interval; DO, Doctor of Osteopathic Medicine; MD, Doctor of Medicine; MS, Master of Science; OR, odds ratio; PhD, Doctor of Philosophy.

*Statistical significance ($p < 0.05$).

and 2001, neither attendance at a top 20 *US News* college/university (p = 0.67) nor attendance at a top 20 *US News* medical school (p = 0.91) was associated with ever holding an academic position.[18] Another study that examined undergraduate universities and medical schools among possible career predictors was conducted by Grimm et al using radiology residency applications.[17] Among many other variables, the authors found that attending an elite undergraduate school (p = 0.003) and attending an elite medical school (p = 0.006) were associated with an academic career.[17]

Within neurological surgery, Campbell et al have already conducted research investigating the influence of medical schools and residency programs on the choice of an academic career.[14] Their research established which medical schools and residency programs had the greatest number of graduates remaining in academic neurological surgery. Their study of 986 academic faculty members within 97 neurological surgery training programs demonstrated that medical school graduates of Columbia University College of Physicians and Surgeons chose to enter academics most frequently, while the residency program at the University of Pittsburgh produced the highest number of academic neurological surgeons.[14] Our study sought to supplement their conclusions through a quantitative evaluation of the association between medical school and residency rankings upon an academic career.

Additionally, Jean and Felbaum have found that early career academic neurological surgeons with the highest h-indices were more likely to have attended an elite medical school or a high-ranking residency program. They also noted a positive correlation between 616 subjects' academic productivity and the ranking of their current institution.[9] In contrast to our findings, this study focused on investigating predictors of early career research productivity (as defined by the h-index), rather than focusing on trainees' proclivity to pursue an academic or nonacademic career.[15] Nevertheless, both this study and our findings point toward the importance of programmatic and environmental factors in encouraging an academic career trajectory in surgical subspecialists.

Results of Our Study

The results of our study introduce 3 novel predictors of academic career trajectory among residents within neurological surgery, namely undergraduate university rank, medical school rank, and completing residency at a program affiliated with a "top" research medical school. While previously uninvestigated within the subspeciality of neurological surgery, Grimm et al established that attendance at an elite undergraduate school (as defined by *US News* rankings) was predictive of choosing an academic career among radiology residency graduates.[17] Grimm et al note that attendance at higher ranked educational institutions (including undergraduate universities, medical schools, and residency programs) likely exposes students and trainees to more research-intensive environments, facilitating involvement in research activities and also providing an extensive support system to obtain mentorship and guidance.[17] Such exposure may lead to students and residents gaining the necessary skills to succeed in research endeavors early in their career. Jean and Felbaum's study further demonstrated a positive correlation between academic neurological surgeons' research productivity and the ranking of their educational institutions.[15] However, these findings may also represent a self-selective effect, where research-focused students

and trainees may be more drawn to research-intensive, elite institutions. Thus, it is difficult to definitively establish whether research experience and proclivity are crucial in the development of academic neurosurgeons or are simply shared features among academic neurosurgeons. While further research is required to fully explore the associations between educational environments and career trajectory, our results seem to support the findings of prior studies demonstrating a positive association between educational program rank and an academic career in neurological surgery. Additionally, investigating whether the specific associations observed in our study of neurological surgeons holds for other surgical specialties could be informative for determining if the relative influence of educational environment on academic career trajectory differs by surgical subspecialty.

Another possible reason for the observed associations between educational environment and academic career trajectory may be that the professional networks obtained by students and trainees at such institutions are more likely to encourage the pursuit of an academic career. To further investigate, we tracked the proportion of neurosurgeons currently employed in academic positions against their undergraduate and medical school alma maters as well as against their former residency program-affiliated hospital. Our results showed that a significant proportion of graduates who attended a "top" research medical school are currently employed as faculty at hospitals affiliated with their medical school alma mater (OR = 1.92, p = 0.02). However, this finding did not hold for graduates from "top" undergraduate institutions or residency programs affiliated with "top" medical schools. This finding suggests that professional networks established during medical school may play a significant role in helping trainees to obtain academic positions.

Our finding that attainment of an MS (OR = 3.46, p < 0.001) or PhD (OR = 2.05, p = 0.002) degree are both independently associated with an academic career choice are consistent with previous research.[2,10,12] A possible reason for such an association is that those with MS or PhD degrees are likely research-inclined trainees with experience conducting scientific investigations. Such experiences would naturally draw more research-oriented physicians toward a research-focused career. Daniels et al showed that neurological surgeons who attained a PhD or completed a research fellowship during medical school had significantly more publications before (p < 0.001), during (p < 0.001), and after (p < 0.001) residency compared to those who did not.[10] Additionally, Choi et al demonstrated that MD-PhD neurological surgeons were significantly more likely to have received NIH funding compared to their MD-only peers (p < 0.05).[2] Collectively, these findings point toward an association between those with advanced research degrees possibly being more competitive for academic faculty positions due, in part, to their more extensive research backgrounds.[2,10,12]

Our finding that completion of a clinical fellowship is independently associated with academic career trajectory (OR = 2.56, p < 0.001) reinforces Lawton et al's result that pursuit of a subspecialty fellowship is predictive of a career in academic neurological surgery (p = 0.006).[1] Given that fellowships expose trainees to very specific clinical issues and highly specialized techniques within the field, it is feasible that trainees pursuing fellowship likely have an interest in finding a specific niche career within the field. Such an interest would be compatible with an academic career, where a surgical subspecialist would spend much of their career addressing clinical and research problems within a focused, narrow domain. Therefore, noting which trainees are interested in completing subspeciality fellowships could be a reasonable proxy for gauging interest in an academic career.

Overall, our results highlight a common theme of research experience and exposure. We hope our study can serve to emphasize to faculty members and to other mentors the importance of encouraging aspiring academic neurosurgeons to explore available research opportunities and to develop their scholarly interests while preparing for their future careers.

Limitations

There are several limitations to our study. First, although we took steps to ensure the validity of our data, information gathered from online sources may not necessarily be fully accurate or comprehensive, preventing us from further analyzing additional factors such as undergraduate major for which data were largely unavailable. Second, our definition of an "academic" career is specific and may differ from studies that define an "academic" career by other criteria.[17] The fact that we only considered neurosurgeons who held academic positions at the time of data collection to be "academic neurosurgeons" means that our study failed to capture any neurosurgeons who were previously employed in academia but had transitioned out by the time we were creating our database. Third, this was a retrospective study conducted using information from specific online sources, which may introduce a degree of selection bias. The retrospective nature of our study also limits our ability to establish definitive causal relationships between the variables we investigated. Fourth, it is clear that *US News and World Report* and *Doximity* rankings are imperfect proxies for determining a program's academic strength or prestige. Additionally, given it has limited publication record, we were only able to obtain *US News* rankings

back to 1993 (for undergraduate universities and medical schools) and back to 2007 (for residency programs). We identified these rankings via Internet searches and lists created by previous investigators using the same methodology.[17] We believe the methodology used, which has previously been used in studying radiology and neurology residents, is valid for our purposes because it takes into account variance in program rankings over time. Additionally, given the strong statistical associations we have described, we believe that such rankings may have utility in predicting academic career outcomes. Last, it is important to note that our sample cohort of 884 neurological surgeons from 78 ACGME residency programs comprises a small fraction of programs and surgeons trained between the years 1982 and 2018. The ACGME website currently lists 115 neurological surgery programs and a 2012 statement endorsed by the American Association of Neurological Surgeons estimated there were 3689 board-certified neurosurgeons practicing in the United States.[20,21] Thus, our study comprises only 67.8% of catalogued residency programs, and our sample size comprises only 24.0% of the total number of US neurological surgeons. Despite these limitations, our study identifies novel predictors of career trajectory which may help further elucidate the effects of educational and training environments on the development of future academic surgical subspecialists.

CONCLUSIONS

Our study found that attending a "top" undergraduate university, attending a "top" medical school, attending a residency program affiliated with a "top" research medical school, holding an MS degree, holding a PhD degree, and completing at least 1 clinical fellowship were all independently associated with an academic career. Our findings may be useful for predicting trainees' future potential in an academic surgical subspeciality and they may also be useful for advising aspiring academic neurosurgeons on how best to prepare for their future careers. Additionally, our study may also be helpful for further investigating how undergraduate, medical school, and residency training environments influence future surgical subspecialists' career trajectory.

DECLARATION OF COMPETING INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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