JNS

CLINICAL ARTICLE

J Neurosurg 134:295–303, 2021

Impact of master's degree attainment upon academic career placement in neurosurgery

*Adham M. Khalafallah, MD, Adrian E. Jimenez, BS, Rafael J. Tamargo, MD, Timothy Witham, MD, Judy Huang, MD, Henry Brem, MD, and Debraj Mukherjee, MD, MPH

Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, Maryland

OBJECTIVE Previous authors have investigated many factors that predict an academic neurosurgical career over private practice, including attainment of a Doctor of Philosophy (PhD) and number of publications. Research has yet to demonstrate whether a master's degree predicts an academic neurosurgical career. This study quantifies the association between obtaining a Master of Science (MS), Master of Public Health (MPH), or Master of Business Administration (MBA) degree and pursuing a career in academic neurosurgery.

METHODS Public data on neurosurgeons who had graduated from Accreditation Council for Graduate Medical Education (ACGME)–accredited residency programs in the period from 1949 to 2019 were collected from residency and professional websites. Residency graduates with a PhD were excluded to isolate the effect of only having a master's degree. A position was considered "academic" if it was affiliated with a hospital that had a neurosurgery residency program; other positions were considered nonacademic. Bivariate analyses were performed with Fisher's exact test. Multivariate analysis was performed using a logistic regression model.

RESULTS Within our database of neurosurgery residency alumni, there were 47 (4.1%) who held an MS degree, 31 (2.7%) who held an MPH, and 10 (0.9%) who held an MBA. In bivariate analyses, neurosurgeons with MS degrees were significantly more likely to pursue academic careers (OR 2.65, $p = 0.0014$, 95% CI 1.40–5.20), whereas neurosurgeons with an MPH (OR 1.41, $p = 0.36$, 95% CI 0.64–3.08) or an MBA (OR 1.00, $p = 1.00$, 95% CI 0.21–4.26) were not. In the multivariate analysis, an MS degree was independently associated with an academic career (OR 2.48, $p = 0.0079$, 95% CI 1.28–4.93). Moreover, postresidency *h* indices of 1 (OR 1.44, $p = 0.048$, 95% CI 1.00–2.07), 2–3 (OR 2.76, $p = 2.01 \times 10^{-8}$, 95% CI 1.94–3.94), and ≥ 4 (OR 4.88, $p < 2.00 \times 10^{-16}$, 95% CI 3.43–6.99) were all significantly associated with increased odds of pursuing an academic career. Notably, having between 1 and 11 months of protected research time was significantly associated with decreased odds of pursuing academic neurosurgery (OR 0.46, $p = 0.049$, 95% CI 0.21–0.98).

CONCLUSIONS Neurosurgery residency graduates with MS degrees are more likely to pursue academic neurosurgical careers relative to their non-MS counterparts. Such findings may be used to help predict residency graduates' future potential in academic neurosurgery.

https://thejns.org/doi/abs/10.3171/2019.9.JNS192346

KEYWORDS academic career; neurosurgery; residency; master's degree

Neurosurgical residency programs have a vested interest in producing future faculty members who will continue to advance the field through innovative research.[9] Determining the factors that predict a career in academic neurosurgery can help improve mentoring of residents and guide training programs in improving their curricula.[9] Various studies have investigated factors that are associated with neurosurgery residents' choice of an academic career versus another professional trajectory, such as attainment of a Doctor of Philosophy (PhD) degree, number of peer-reviewed publications, and subspecialty fellowship completion.[2–7,9,11,12] Specifically, a study by Choi et al. revealed that a greater proportion of Doctor of Medicine (MD)–PhD neurosurgeons held academic appointments than MD-only neurosurgeons ($p < 0.001$) and that MD-PhD neurosurgeons were more likely to re-

ABBREVIATIONS ACGME = Accreditation Council for Graduate Medical Education; DO = Doctor of Osteopathic Medicine; MBA = Master of Business Administration; MD = Doctor of Medicine; MPH = Master of Public Health; MS = Master of Science; PhD = Doctor of Philosophy.

SUBMITTED August 27, 2019. **ACCEPTED** September 30, 2019.

INCLUDE WHEN CITING Published online December 6, 2019; DOI: 10.3171/2019.9.JNS192346.

* A.M.K. and A.E.J. share first authorship.

ceive NIH funding ($p < 0.001$) than were MD-only neurosurgeons.[4] This research points toward the importance of considering higher degrees other than MD degrees when studying predictors of academic career placement in neurosurgery. Importantly, there has been no published research to date on whether attainment of a master's degree is associated with a career in academic neurosurgery. Quantifying this association was the primary goal of the present study. Establishing another variable associated with an academic career could be useful to residency programs in further improving their ability to identify potential future academic neurosurgeons.[3,6,9,11] Such data may also be informative for medical students and trainees considering a career in academic neurosurgery.

We hypothesized that obtaining a master's degree would be positively associated with a career in academic neurosurgery. In order to test this hypothesis, we gathered information on practicing neurosurgeons' sex, career choice, degrees obtained, medical school attended, residency program attended, and years spent in residency at ACGME-accredited residency programs.

Methods

Data Set Creation

Using publicly available data, we created a database of all neurosurgeons who had graduated from Accreditation Council for Graduate Medical Education (ACGME)–accredited residency programs in the period from 1949 through 2019. Alumni information was identified predominantly from residency program websites. This information was verified and supplemented with an individual internet search for each alumna or alumnus; this internet search was conducted through online search engines (e.g., Google) and professional websites (e.g., LinkedIn).

Variables

The collected data for each individual included degrees obtained, sex, medical school name, medical school graduation year, name of residency program, residency graduation year, typical residency length, actual time spent in residency, months of protected research time during residency, current position, publication number, number of citations, and total *h* index after residency. For this study, "during residency" refers to publications and citations that were listed on Web of Science during the years a given alumnus was undergoing residency training. "After residency" refers to publications and citations listed on Web of Science for the years after a graduate had completed their residency training. Data were additionally stratified into whether the residency program was one of the top-20 residency programs according to *U.S. News & World Report* and Doximity rankings and whether that residency program was associated with a *U.S. News* top-20 medical school for research. A position was considered "academic" if it was affiliated with a neurosurgery residency program; other positions were considered nonacademic.

Statistical Analysis

Data were collected using Microsoft Excel (version 2016, Microsoft Corp.). Statistical analyses were conducted using SPSS version 25 (IBM Corp.). A chi-square test was used for categorical variables; when such variables did not meet the assumptions of minimum expected frequencies, Fisher's exact test was used.

The data were analyzed in two phases: Bivariate analyses determined associations between independent and dependent variables. Data were evaluated for skewness and kurtosis to determine normality. The Mann-Whitney U-test was used for variables containing two groups. The Kruskal-Wallis test was used for variables containing more than two groups. For associations between variables that met this bivariate level of significance, least-squares multiple regression analyses were computed. Odds ratios and 95% confidence intervals were calculated from multivariate logistic regression analyses. Covariates with a bivariate level of significance of $p < 0.10$ were included in multivariate logistic regression analyses. Values of $p < 0.05$ were considered statistically significant, and p values were reported as two-sided.

Results

Characteristics of Neurosurgeons

We built a database of 1387 neurosurgeons who had graduated from 85 ACGME-accredited residency programs within North America from 1949 through 2019. We excluded current fellows (n = 24), neurosurgeons who had attained a PhD (n = 188), and physicians for whom we were missing data for any of the variables we sought to analyze (n = 35). Thus, 1140 neurosurgeons were included in the final analysis. The cohort consisted of 994 (87.2%) male and 146 (12.8%) female neurosurgeons. The 1140 alumni in our database completed residency training between 1964 and 2019, with 1045 (91.7%) graduating after 2004. Of the total number of neurosurgeons included in our study, 469 (41.1%) were classified as holding an academic position. While 95.6% of the neurosurgeons in our cohort were MDs, the data set included 50 (4.4%) neurosurgeons who were Doctors of Osteopathic Medicine (DOs). Master's degrees were pursued by 88 (7.7%) neurosurgeons. Of these, 47 (4.1%) held a Master of Science (MS) degree, 31 (2.7%) held a Master of Public Health (MPH) degree, and 10 (0.9%) held a Master of Business Administration (MBA) degree (Table 1). None of the neurosurgeons in our database held multiple master's degrees (e.g., attained both an MS and an MPH).

Residency Program Characteristics

The distribution of neurosurgeons according to the length of their residency is presented in Table 1: 894 (78.4%) neurosurgeons completed a 7-year residency training and 246 (21.6%) completed a 6-year training program. After ranking residency programs according to both the *U.S. News* and Doximity national rankings, we found that 397 neurosurgeons trained in a top-20 residency program according to *U.S. News*, 360 trained in a top-20 residency program according to Doximity, and 390 trained in a residency program that is affiliated with a top-20 research medical school according to *U.S. News*. In considering protected research time, we found that 188 (16.5%) neurosurgeons had ≥ 24 months, 772 (67.7%) had

12–23 months, 87 (7.6%) had 1–11 months, and 93 (8.2%) did not have any protected research time during their residency.

Bivariate Analyses

We first sought to determine the residency program and individual neurosurgeon characteristics associated with an academic neurosurgery career choice by using bivariate analyses (Table 2). Such factors included training at a residency program listed as a *U.S. News* top-20 program (OR 2.50, $p < 0.00001$, 95% CI 1.94–3.24). Similar findings were also statistically significant according to Doximity top-20 residency program rankings (OR 2.41, $p < 0.00001$, 95% CI 1.86–3.14). The ranking of residencies according to their affiliations with top-20 research medical schools also demonstrated statistical significance (OR 2.83, $p < 0.00001$, 95% CI 2.18–3.67). Overall length of residency training ($p = 0.14$) was not predictive of an academic career. However, having either 12–23 months (OR 1.68, $p = 0.033$, 95% CI 1.03–2.81) or ≥ 24 months (OR 3.75, $p < 0.00001$, 95% CI 2.14–6.70) of protected research time during residency was associated with a higher likelihood of pursuing an academic job. Notably, having 1–11 months of protected research time was significantly associated with a lower likelihood of pursuing an academic career (OR 0.43, $p = 0.031$, 95% CI 0.19–0.95). At the individual neurosurgeon level, we found that neurosurgeons with a postresidency *h* index of 1 (OR 1.65, $p = 0.0049$, 95% CI 1.15–2.38), 2–3 (OR 3.13, $p = 5.04 \times 10^{-11}$, 95% CI 2.20–4.47), or ≥ 4 (OR 6.23, $p < 0.00001$, 95% CI 4.37–8.94) were all significantly more likely to pursue an academic career than neurosurgeons with a postresidency *h* index of 0. Holding an MD degree was statistically significant in predicting an academic career choice (OR 2.91, $p = 0.0018$, 95% CI 1.41–6.59) relative to holding a DO degree. Overall, male sex ($p = 0.087$) was not a significant predictor of academic career placement.

In our database, 420 (39.9%) neurosurgeons without any type of master's degree held academic positions, while 632 (60.1%) neurosurgeons without master's degrees held nonacademic positions. Among the physicians with an MS degree, 30 (63.8%) held academic positions and 17 (36.2%) held nonacademic positions. Among those with MPH degrees, 15 (48.4%) held academic positions compared to 16 (51.6%) who held nonacademic positions. Among physicians with an MBA, 4 (40.0%) were academic neurosurgeons while 6 (60.0%) held nonacademic positions. While attaining an MS was statistically significant (OR 2.65, $p = 0.0014$, 95% CI 1.40–5.20), holding an MPH ($p = 0.36$) or an MBA ($p = 1.00$) was not a statistically significant predictor of pursuing an academic career. Various characteristics specific to the subset of neurosurgeons in our database with master's degrees are listed in Table 3. As shown in the table, the only statistically significant association is that between the type of master's degree and sex ($p = 0.015$).

To verify the results reported by Choi et al. in their investigation of the impact of obtaining a PhD on academic career placement, we also created a separate cohort of alumni that included neurosurgeons with PhD degrees and excluded those with master's degrees (n = 1222) to study the effect of PhD attainment on career choice in isolation. Using Fisher's exact test, we found that attainment of a PhD was significantly positively associated with a career in academic neurosurgery (OR 2.58, $p = 1.71 \times 10^{-8}$, 95% CI 1.83–3.67).

TABLE 1. Summary of demographics among 1140 neurosurgeons

Variable	No. (%)
Sex	
Male	994 (87.2)
Female	146 (12.8)
Residency graduation yr	
≤2004	95 (8.3)
2005–2009	383 (33.6)
2010–2014	473 (41.5)
≥2015	189 (16.6)
Residency program length in yrs	
6	246 (21.6)
7	894 (78.4)
Top-20 residency program per *U.S. News*	
Yes	397 (34.8)
No	743 (65.2)
Top-20 residency program per Doximity	
Yes	360 (31.6)
No	780 (68.4)
Residency programs affiliated w/ a top-20 research medical school	
Yes	390 (34.2)
No	750 (65.8)
Protected research time in mos	
0	93 (8.2)
1–11	87 (7.6)
12–23	772 (67.7)
≥24	188 (16.5)
Postresidency *h* index	
0	423 (37.1)
1	233 (20.4)
2–3	231 (20.3)
≥4	253 (22.2)
Medical degree	
MD	1090 (95.6)
DO	50 (4.4)
Master's degree	
None	1052 (92.3)
MS	47 (4.1)
MPH	31 (2.7)
MBA	10 (0.9)

Multivariate Analysis

To assess whether these characteristics would stand alone as independent predictive factors of academic career choice, we conducted a multivariate analysis using a logis-

TABLE 2. Bivariate analysis of academic career choice among 1140 neurosurgeons

Characteristic	No. (%)		p Value	OR	95% CI
	Academic Position	Nonacademic Position			
Sex					
Male	399 (40.1)	595 (59.9)	0.087	0.73	0.51–1.05
Female	70 (47.9)	76 (52.1)			
Residency program length in yrs					
6	91 (37.0)	155 (63.0)	0.14	0.80	0.59–1.08
7	378 (42.3)	516 (57.7)			
Top-20 residency program per *U.S. News*					
Yes	221 (55.7)	176 (44.3)	4.52×10^{-13}*	2.50	1.94–3.24
No	248 (33.4)	495 (66.6)			
Top-20 residency program per Doximity					
Yes	201 (55.8)	159 (44.2)	1.26×10^{-11}*	2.41	1.86–3.14
No	268 (34.4)	512 (65.6)			
Residency program affiliated w/ a top-20 research medical school					
Yes	225 (57.7)	165 (42.3)	4.74×10^{-16}*	2.83	2.18–3.67
No	244 (32.5)	506 (67.5)			
Protected research time in mos					
0	27 (29.0)	66 (71.0)	—	Reference	—
1–11	13 (14.9)	74 (85.1)	0.031*	0.43	0.19–0.95
12–23	315 (40.8)	457 (59.2)	0.033*	1.68	1.03–2.81
≥24	114 (60.6)	74 (39.4)	6.34×10^{-7}*	3.75	2.14–6.70
Postresidency *h* index					
0	103 (24.3)	320 (75.7)	—	Reference	—
1	81 (34.8)	152 (65.2)	0.0049*	1.65	1.15–2.38
2–3	116 (50.2)	115 (49.8)	5.04×10^{-11}*	3.13	2.20–4.47
≥4	169 (66.8)	84 (33.2)	$<2.2 \times 10^{-16}$*	6.23	4.37–8.94
Medical degree					
MD	459 (42.1)	631 (57.9)	0.0018*	2.91	1.41–6.59
DO	10 (20.0)	40 (80.0)			
Master's degree					
None	420 (39.9)	632 (60.1)	—	Reference	—
MS	30 (63.8)	17 (36.2)	0.0014*	2.65	1.40–5.20
MPH	15 (48.4)	16 (51.6)	0.36	1.41	0.64–3.08
MBA	4 (40.0)	6 (60.0)	1.00	1.00	0.21–4.26

* Statistical significance ($p < 0.05$).

tic regression model (Table 4). We chose our covariates by including the statistically significant characteristics from our bivariate analysis. The selected model consisted of top-20 residency program status, residency programs affiliated with a top-20 research medical school, protected research time, postresidency *h* index, medical degree status, and an MS degree. The results of our logistic regression demonstrated that attainment of an MS degree is independently predictive of an academic career choice (OR 2.48, p = 0.0079, 95% CI 1.28–4.93). Similarly, having a postresidency *h* index of 1 (OR 1.44, p = 0.048, 95% CI 1.00–2.07), 2–3 (OR 2.76, $p = 2.01 \times 10^{-8}$, 95% CI 1.94–3.94), or ≥ 4 (OR 4.88, p < 0.00001, 95% CI 3.43–6.99) also independently predicted an academic neurosurgical career. Conversely, protected research time of only 1–11 months had a negative correlation with academic career choice (OR 0.46, p = 0.049, 95% CI 0.21–0.98). No other statistically significant characteristics on bivariate analysis were significant in the multivariate analysis. A graphic representation of the odds ratio and 95% confidence interval calculated for each covariate in the multivariate analysis is displayed in Fig. 1. Given our finding that an MS degree is independently associated with academic career choice, we tracked the residency graduation years for neurosurgeons in our database who hold an MS degree. Our findings are displayed in Fig. 2, which shows that there have been more residency graduates in recent years who have obtained an MS in addition to their medical degree, with the greatest number of MS neurosurgeons in our database completing residency between 2008 and 2012.

TABLE 3. Demographics for neurosurgeons with a master's degree

Characteristic	No. (%)			p Value*
	MS Degree	MPH Degree	MBA Degree	
Total no. of neurosurgeons	47 (100.0)	31 (100.0)	10 (100.0)	—
Sex				
Male	43 (91.5)	21 (67.7)	7 (70.0)	0.015†
Female	4 (8.5)	10 (32.3)	3 (30.0)	
Residency program length in yrs				
6	10 (21.3)	8 (25.8)	1 (10.0)	0.66
7	37 (78.7)	23 (74.2)	9 (90.0)	
Top-20 residency program per *U.S. News*				
Yes	19 (40.4)	11 (35.5)	3 (30.0)	0.86
No	28 (59.6)	20 (64.5)	7 (70.0)	
Top-20 residency program per Doximity				
Yes	19 (40.4)	11 (35.5)	3 (30.0)	0.86
No	28 (59.6)	20 (64.5)	7 (70.0)	
Residency program affiliated w/ a top-20 research medical school				
Yes	17 (36.2)	13 (41.9)	3 (30.0)	0.82
No	30 (63.8)	18 (58.1)	7 (70.0)	
Protected research time in mos				
0	6 (12.8)	2 (6.5)	1 (10.0)	0.96
1–11	4 (8.5)	1 (3.2)	0 (0.0)	
12–23	28 (59.6)	23 (74.2)	8 (80.0)	
≥24	9 (19.1)	5 (16.1)	1 (10.0)	
Postresidency *h* index				
0	9 (19.1)	10 (32.3)	2 (20.0)	0.10
1	12 (25.5)	10 (32.3)	1 (10.0)	
2–3	9 (19.1)	4 (12.9)	2 (20.0)	
≥4	17 (36.2)	7 (22.6)	5 (50.0)	
Medical degree				
MD	43 (91.5)	31 (100.0)	9 (90.0)	0.23
DO	4 (8.5)	0 (0.0)	1 (10.0)	

* p values were obtained using Fisher's exact test for categorical variables and the Kruskal-Wallis test for continuous variables.
† Statistical significance ($p < 0.05$).

Discussion

Our study of 1140 neurosurgeons who graduated from residency training programs from 1964 to 2019 demonstrated that MS degrees are associated with increased odds of pursuing an academic career. Of note, although attending a top-20 residency program (per *U.S. News* or Doximity criteria), having 12–23 months of protected research time during residency, and having an MD (versus a DO) degree all seemed to be positive predictors of an academic career on bivariate analysis, these relationships no longer held in the multivariate analysis. Logistic regression analysis demonstrated that having an MS degree and having a postresidency *h* index of 1, 2–3, or ≥ 4 were all significantly positively associated with academic career placement in both bivariate and multivariate analyses.

Programmatic Predictors of an Academic Career

With residency programs seeking to develop and mentor academic neurosurgeons, much research has been undertaken to determine predictors of academic career placement in neurosurgery. Brem and Amundson have written about the experience at Johns Hopkins University School of Medicine, where large numbers of medical students have chosen to pursue careers in academic neurosurgery due in part to the department's efforts to provide extensive research and clinical opportunities longitudinally throughout medical school and residency in a supportive and collegial environment.[2] This model of early and longitudinal support of academic interests within neurosurgery has been replicated at several institutions across the country. Notably, Agarwal et al. studied institutional efforts at Rutgers New Jersey Medical School to improve medical student recruitment into the field. These authors found that the initiatives implemented at Rutgers led to a large increase in the number of medical students matching successfully into neurosurgery.[1] Another study by Kashkoush et al. documented the impact of a Neurosurgery In-

TABLE 4. Multivariate analysis of academic career choice among 1140 neurosurgeons

Characteristic	p Value*	OR	95% CI
Top-20 residency program per *U.S. News*			
Yes	0.34	1.19	0.83, 1.70
No			
Top-20 residency program per Doximity			
Yes	0.37	1.18	0.82, 1.68
No			
Residency program affiliated w/ a top-20 research medical school			
Yes	0.071	1.47	0.97, 2.25
No			
Protected research time in mos			
0			
1–11	0.049†	0.46	0.21, 0.98
12–23	0.55	1.18	0.69, 2.06
≥24	0.057	1.86	0.99, 3.56
Postresidency *h* index			
0			
1	0.048†	1.44	1.00, 2.07
2–3	2.01×10^{-8}†	2.76	1.94, 3.94
≥4	$<2.00 \times 10^{-16}$†	4.88	3.43, 6.99
Medical degree			
MD	0.78	1.12	0.51, 2.63
DO			
MS degree			
Yes	0.0079†	2.48	1.28, 4.93
No			

* p values were obtained using Fisher's exact test.
† Statistical significance (p < 0.05).

terest Group (NSIG) at the University of Pittsburgh School of Medicine. Formation of the NSIG increased medical student exposure to neurosurgery, student engagement in scholarly activity, and the number of students matriculating into neurosurgical residencies.[8] Additionally, a recent survey of program directors from across the country demonstrated that institutions with early preclinical exposure opportunities for medical students, active neurosurgery interest groups, student research opportunities, and formal mentorship programs led more students to match into neurosurgery as compared to institutions without these opportunities.[10]

Campbell et al. measured the academic productivity of medical schools and residency programs in order to infer the influence of training experiences on the choice of a career in academic neurosurgery.[3] Analyzing data from 986 faculty members and 97 academic neurosurgery departments, the authors demonstrated that graduates of Columbia University chose to enter academic neurosurgery more frequently than graduates from other medical schools and that the University of Pittsburgh's residency training program produced the highest number of academics.[3] Such findings seem to point toward unique environments and initiatives within specific medical schools and residency programs that are supportive of budding careers in academia.

Individual Predictors of an Academic Career

The investigation of individual predictors of an academic neurosurgical career has spanned from preresidency board exam scores to intraresidency factors. For instance, Gelinne et al. showed that a career in academic neurosurgery was associated with a slightly higher United States Medical Licensing Exam (USMLE) Step I score, although this score did not predict eventual academic rank or research productivity.[7] Given that we only utilized publicly available online sources, we were unable to capture this type of data for our subjects. Additionally, Choi and colleagues found that a greater proportion of MD-PhD neurosurgeons had academic appointments compared to their MD-only counterparts, and they concluded that MD-PhD training may predict academic research careers.[4] To verify these results using our own database, we created a separate cohort of neurosurgeons that included only those with PhD degrees (n = 1222). We excluded from this cohort those physicians who had obtained master's degrees, in order to investigate the relationship between PhD and career choice in isolation, since our results demonstrated that MS degrees are significantly associated with academic career choice. In a bivariate analysis, we found that attainment of a PhD degree was significantly associated with higher odds of pursuing an academic career (OR 2.58, $p = 1.71 \times 10^{-8}$, 95% CI 1.83–3.67). Therefore, our results validate Choi et al.'s findings regarding the impact of obtaining a PhD upon academic career placement. It is notable that obtaining an MS had a similarly positive impact upon academic career placement as compared to obtaining a PhD degree, despite the often fewer years needed to obtain an MS degree.

In a separate study, McClelland noted that preresidency publication number was associated with residents' eventual choice of an academic career.[11] However, a subsequent study by Daniels et al. found that preresidency publication number did not predict academic career placement.[6] Importantly, Daniels et al. used a much larger sample size (n = 949) than McClelland (n = 422). Additionally, Daniels and colleagues employed multivariate regression models to analyze their data, while McClelland used only a chi-square test for nominal data.[6,11] In addition to their findings on the influence of preresidency publication number, Daniels et al. also found that having two or more publications during residency and having devoted research time before residency were both associated with attaining an academic position.[6]

Focusing on factors during neurosurgery residency, Crowley et al. found that total number of publications during training, number of first-author publications during training, and residency program size were predictive of residents choosing an academic career.[5] These findings are confirmed by our results, as we found that the number of publications during residency for neurosurgeons in academic positions was significantly higher (median = 7)

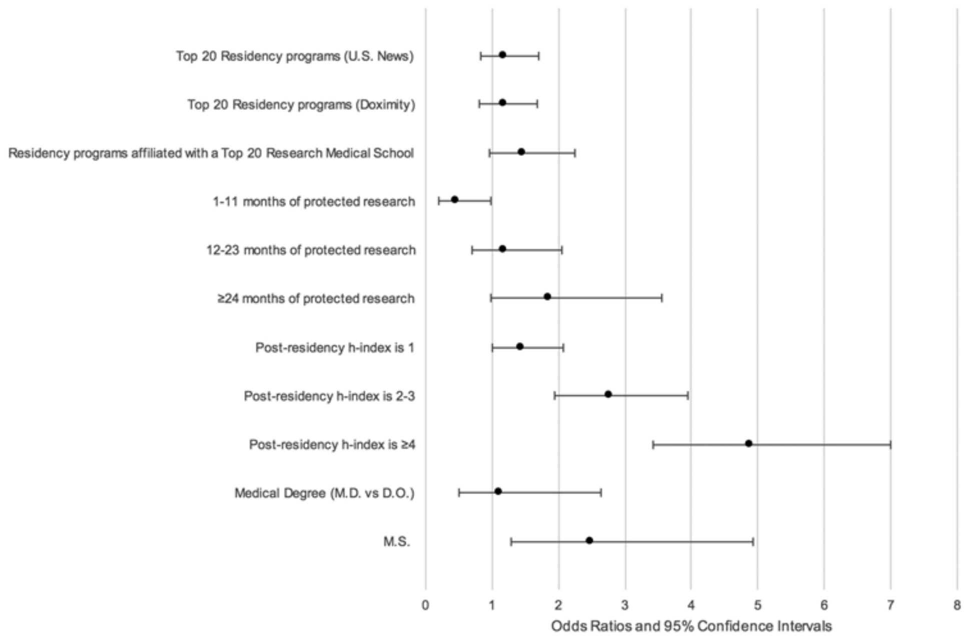

FIG. 1. The *dot*s on the plot represent odds ratios, and the *horizontal error bars* represent 95% confidence intervals.

than the number of publications during residency for neurosurgeons in nonacademic positions (median = 2, $p < 2.2 \times 10^{-16}$).

In 2007, Lawton and colleagues retrospectively reviewed the applications, interview evaluations, and residency performance reviews of graduates from the neurological surgery program at the University of California, San Francisco.[9] By examining many different factors, such as American Board of Neurological Surgery (ABNS) written board exam scores, publication number, and personal demographics, these authors found that favorable evaluations during junior ($p = 0.04$) and chief ($p = 0.03$) residency years, as well as the pursuit of a subspecialty fellowship ($p = 0.006$), were the only factors predictive of an academic career.[9] Like us, they also found that female graduates are just as likely as their male counterparts to pursue academic career paths. Our study differed in finding significantly higher odds of attaining an academic career with a master's degree, whereas the Lawton series demonstrated no significant association between additional degrees and academic career placement. This discrepancy may be due, in part, to the fact that Lawton et al. analyzed 54 neurosurgeons as compared to the 1140 analyzed in our study. Additionally, Lawton and colleagues only considered graduates from one residency program, whereas we studied graduates from 85 different programs from across the country. The different sample sizes between the studies and our more diverse cohort may account for some of the differing results. Importantly, the Lawton study also found no association between number of publications and academic career choice. In contrast, we found a significant difference between total publication number in residents pursuing an academic career (median = 18) versus those in nonacademic positions (median = 5, $p < 2.2 \times 10^{-16}$). Again, this discrepancy may be due in part to our much larger sample size including graduates from a wide variety of residency programs.

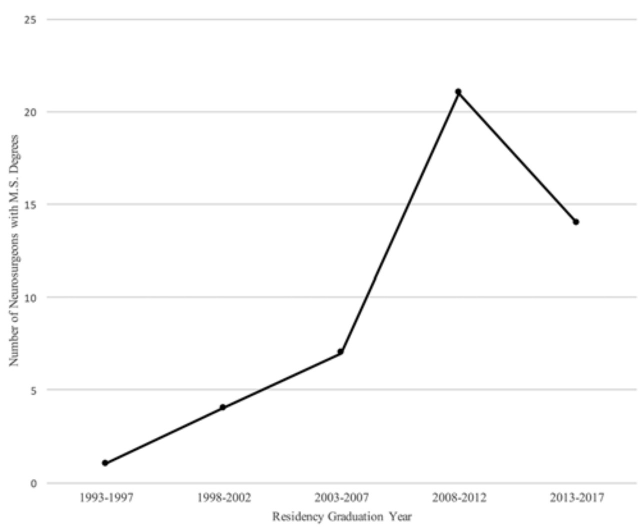

FIG. 2. The *dots* on the line plot represent the number of neurosurgeons with MS degrees who graduated from residency for a given range of years.

Findings of a Large Bibliographic Data Set

The results obtained using our database validate certain conclusions from prior studies. Both Lawton et al. and Daniels et al. concluded that sex was not a statistically significant factor associated with academic career choice, and our results concur.[6,9] We also validated Daniels and colleagues' finding that there is a significantly higher postresidency *h* index in academic neurosurgeons (median = 2) relative to that in nonacademic neurosurgeons (median = 1, $p < 2.2 \times 10^{-16}$).[6]

Most importantly, however, our study builds on this line of research by introducing an additional, novel method of predicting academic career placement. Our results demonstrate that attainment of an MS degree is independently associated with a neurosurgery resident choosing an academic career, while MPH and MBA degrees are not associated with academic employment. Importantly, we did not consider MD-PhD neurosurgeons in our analysis in order to account for the results reported by Choi and colleagues.[4] We also found that having a postresidency *h* index of 1, 2–3, or ≥4 was independently associated with academic career choice. This result was expected and serves to validate our methodology, as increased research output is predicted from neurosurgeons who pursue careers in academic medicine compared to those in nonacademic careers. Additionally, we found in our database that among neurosurgeons with master's degrees, there is a significant association between type of master's degree and sex ($p = 0.015$). Given the small sizes of these cohorts, however, it is difficult to determine the importance of this specific finding. Further research into sex distributions among neurosurgeons with higher degrees may prove informative. By tracking the residency graduation year of alumni in our database, we found that in recent years there has been an increase in the number of neurosurgeons with MS degrees, with the greatest number completing residency between 2008 and 2012. This could be attributable to initiatives on the part of residency programs or medical schools to encourage students and trainees to pursue additional higher degrees, but further investigation is necessary to determine if this observed trend will continue into the future.

An interesting future avenue of research would be why attainment of a master's degree is predictive of an academic career. A possible explanation could be the advanced research training that is required for a student to obtain a master's degree, which could either incline a student toward a research-oriented career or merely serve as an indication of the fact that a given student already has a propensity toward research. A mechanism by which physician-scientists can obtain advanced clinical research training and advanced degrees (such as an MS degree) is the NIH's Clinical and Translational Science Awards (CTSA) Program, specifically the KL2 Career Development Program. Previous research has shown that KL2 scholars at the University of Wisconsin–Madison were cited more often than is the norm for NIH publications.[13] If the neurosurgeons in our study obtained their degrees through the KL2 mechanism, their advanced clinical research training could be a significant factor explaining their higher odds of pursuing an academic career compared to neurosurgeons without MS degrees.

Our study utilizes a large number of residency alumni ($n = 1140$) from 85 different residency programs, allowing our conclusions to be more generalizable than single-institution series. Our study can also be easily reproduced and validated given that we used publically available data. Combined with the predictors established in previous studies, our results may serve to expand the ways in which residency programs determine which trainees have the most potential for pursuing an academic career.

Study Limitations

There are various limitations to this study. First, although we extensively cross-referenced data to ensure their validity and accuracy, data collected from online sources may not necessarily be completely accurate or fully up to date. Second, our definition of an "academic" career in neurosurgery is specific, and it is only based on current employment information. It is possible that other definitions of an academic career, based on factors such as NIH funding, publications, or citations, may lead to different results. Third, our study was a retrospective review, and it would benefit from comparison with and validation via different experimental methods, such as a prospective cohort study examining neurosurgery residents' career choices over time. Fourth, the fact that 91.7% of the graduates in our study completed residency after 2004 is indicative of a skew toward more recent alumni. It is important to note that this is a possible source of selection bias, with earlier graduates possibly self-selecting into having an online presence only if they are in academic neurosurgery. Fifth, the residency program characteristics that we investigated, such as protected research time and national rankings, were obtained via the websites of currently accredited neurosurgery residency programs. Thus, these characteristics would not have as much applicability to neurosurgeons who completed residency training 3 or 4 decades ago, representing another limitation of our study. Sixth, we did not have data on when our alumni obtained their MS degrees, and so our proxy for measuring MS attainment among neurosurgeons over time relied on tracking residency graduation year for the alumni in our database, which may not correspond exactly to the years when these physicians obtained their master's degrees. Lastly, we acknowledge that our study does not include all North American neurosurgery residency programs. The ACGME website (https://apps.acgme.org/ads/Public/Programs/Search?stateId=&specialtyId=35&specialtyCategoryTypeId=&numCode=&city=) currently lists 115 neurological surgery programs. Additionally, a 2012 statement endorsed by the American Association of Neurological Surgeons estimated that there were about 3689 board-certified neurosurgeons currently practicing in the United States (Statement of the American Association of Neurological Surgeons, American Board of Neurological Surgery, Congress of Neurological Surgeons, Society of Neurological Surgeons before the Institute of Medicine on the subject of Ensuring an Adequate Neurosurgical Workforce for the 21st century, December 2012). Given that the number of programs included in our study comprises only 73.9% of these cataloged residency programs and our sample size is only 30.9% of an approximate current number of United States neurosurgeons, these factors would be additional limitations of our data set.

Conclusions

For our sample of graduates from ACGME-accredited neurosurgery residency programs, attainment of a master's degree in addition to an MD degree is associated with a career in academic neurosurgery. Considered individually, an MS degree is independently associated with an academic career, whereas MPH and MBA degrees are not.

These results may be useful to residency programs seeking to predict trainees' future potential in academic neurosurgery and for mentoring trainees with an interest in pursuing an academic career.

References

1. Agarwal N, Norrmén-Smith IO, Tomei KL, Prestigiacomo CJ, Gandhi CD: Improving medical student recruitment into neurological surgery: a single institution's experience. **World Neurosurg 80:**745–750, 2013
2. Brem H, Amundson E: Preparing Hopkins medical students for a career in academic neurosurgery. **Surgery 134:**414–415, 2003
3. Campbell PG, Awe OO, Maltenfort MG, Moshfeghi DM, Leng T, Moshfeghi AA, et al: Medical school and residency influence on choice of an academic career and academic productivity among neurosurgery faculty in the United States. Clinical article. **J Neurosurg 115:**380–386, 2011
4. Choi BD, DeLong MR, DeLong DM, Friedman AH, Sampson JH: Impact of PhD training on scholarship in a neurosurgical career. **J Neurosurg 120:**730–735, 2014
5. Crowley RW, Asthagiri AR, Starke RM, Zusman EE, Chiocca EA, Lonser RR: In-training factors predictive of choosing and sustaining a productive academic career path in neurological surgery. **Neurosurgery 70:**1024–1032, 2012
6. Daniels M, Garzon-Muvdi T, Maxwell R, Tamargo RJ, Huang J, Witham T, et al: Preresidency publication number does not predict academic career placement in neurosurgery. **World Neurosurg 101:**350–356, 2017
7. Gelinne A, Zuckerman S, Benzil D, Grady S, Callas P, Durham S: United States Medical Licensing Exam Step I score as a predictor of neurosurgical career beyond residency. **Neurosurgery 84:**1028–1034, 2019
8. Kashkoush A, Feroze R, Myal S, Prabhu AV, Sansosti A, Tonetti D, et al: Fostering student interest in neurologic surgery: The University of Pittsburgh experience. **World Neurosurg 108:**101–106, 2017
9. Lawton MT, Narvid J, Quiñones-Hinojosa A: Predictors of neurosurgical career choice among residents and residency applicants. **Neurosurgery 60:**934–939, 2007
10. Lubelski D, Xiao R, Mukherjee D, Ashley WW, Witham T, Brem H, et al: Improving medical student recruitment to neurosurgery. **J Neurosurg** [epub ahead of print August 9, 2019. DOI: 10.3171/2019.5.JNS1987]
11. McClelland S III: Pre-residency peer-reviewed publications are associated with neurosurgery resident choice of academic compared to private practice careers. **J Clin Neurosci 17:**287–289, 2010
12. Oyesiku NM: Editorial. The impact of PhD training. **J Neurosurg 120:**727–728, 2014
13. Sayavedra N, Hogle JA, Moberg DP: Using publication data to evaluate a Clinical and Translational Science Award (CTSA) career development program: early outcomes from KL2 scholars. **J Clin Transl Sci 1:**352–360, 2017

Disclosures

Dr. Witham is a consultant for DePuy Synthes Spine and Augmedics, has direct stock ownership in Augmedics, and receives support from Eli Lilly and Co. and the Gordon and Marilyn Macklin Foundation for non–study-related clinical or research effort. Dr. Brem is a consultant for AsclepiX Therapeutics, StemGen, InSightec, Accelerating Combination Therapies, Camden Partners, LikeMinds Inc., Galen Robotics Inc., and Nurami Medical and receives support from Arbor Pharmaceuticals Bristol-Myers Squibb and AcuityBio Corp. for non–study-related clinical or research effort.

Author Contributions

Conception and design: Khalafallah, Jimenez. Acquisition of data: Mukherjee, Khalafallah, Jimenez. Analysis and interpretation of data: Mukherjee, Khalafallah, Jimenez. Drafting the article: Mukherjee, Khalafallah, Jimenez. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Statistical analysis: Khalafallah, Jimenez.

Correspondence

Debraj Mukherjee: Johns Hopkins University School of Medicine, Baltimore, MD. dmukher1@jhmi.edu.