Attitudes and opinions of US neurosurgical residents toward research and scholarship: a national survey

*Michael Karsy, MD, PhD, MSc,¹ Fraser Henderson Jr., MD,² Steven Tenny, MD, MPH, MBA,³ Jian Guan, MD,¹ Jeremy W. Amps, MD,⁴ Allan H. Friedman, MD,⁵ Alejandro M. Spiotta, MD,² Sunil Patel, MD,² John R. W. Kestle, MD,¹ Randy L. Jensen, MD, PhD,¹ and William T. Couldwell, MD, PhD¹

¹Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, Salt Lake City, Utah; ²Department of Neurosurgery, Medical University of South Carolina, Charleston, South Carolina; ³Division of Neurosurgery, University of Nebraska Medical Center, Omaha, Nebraska; ⁴Department of Neurosurgery, Cleveland Clinic, Cleveland, Ohio; and ⁵Department of Neurosurgery, Duke University, Durham, North Carolina

OBJECTIVE The analysis of resident research productivity in neurosurgery has gained significant recent interest. Resident scholarly output affects departmental productivity, recruitment of future residents, and likelihood of future research careers. To maintain and improve opportunities for resident research, the authors evaluated factors that affect resident attitudes toward neurosurgical research on a national level.

METHODS An online survey was distributed to all US neurosurgical residents. Questions assessed interest in research, perceived departmental support of research, and resident-perceived limitations in pursuing research. Residents were stratified based on number of publications above the median (AM; ≥ 14) or below the median (BM; < 14) for evaluation of factors influencing productivity.

RESULTS A total of 278 resident responses from 82 US residency programs in 30 states were included (a 20% overall response rate). Residents predominantly desired future academic positions (53.2%), followed by private practice with some research (40.3%). Residents reported a mean $\pm$ SD of 11 ± 14 publications, which increased with postgraduate year level. The most common type of research involved retrospective cohort studies (24%) followed by laboratory/bench-top (19%) and case reports (18%). Residents as a group spent on average 14.1 ± 18.5 hours (median 7.0 hours) a week on research. Most residents (53.6%) had ≥ 12 months of protected research time. Mentorship (92.4%), research exposure (89.9%), and early interest in science (78.4%) had the greatest impact on interest in research while the most limiting factors were time (91.0%), call scheduling (47.1%), and funding/grants (37.1%). AM residents cited research exposure ($p = 0.003$), neurosurgery conference exposure ($p = 0.02$), formal research training prior to residency ($p = 0.03$), internal funding sources ($p = 0.05$), and software support ($p = 0.02$) as most important for their productivity. Moreover, more productive residents applied and received a higher number of $< \$10,000$ and $\geq \$10,000$ grants ($p < 0.05$). A majority of residents (82.4%) agreed or strongly agreed with pursuing research throughout their professional careers. Overall, about half of residents (49.6%) were encouraged toward continued neurosurgical research, while the rest were neutral (36.7%) or discouraged (13.7%). Free-text responses helped to identify solutions on a departmental, regional, and national level that could increase interest in neurosurgical research.

CONCLUSIONS This survey evaluates various factors affecting resident views toward research, which may also be seen in other specialties. Residents remain enthusiastic about neurosurgical research and offer several solutions to the ever-scarce commodities of time and funding within academic medicine.

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KEYWORDS neurosurgery; residency; research; academic medicine; career

ABBREVIATIONS AM = number of publications above the median; BM = number of publications below the median; HHMI = Howard Hughes Medical Institute; IQR = interquartile range; NREF = Neurosurgery Research and Education Foundation; PGY = postgraduate year; RUNN = Resident Update in Neuroscience for Neurosurgeons.

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* M.K. and F.H. contributed equally to this work.

RESearch productivity in neurosurgery, with its capacity to improve patients' lives, remains an important and timely topic. Multiple publications have evaluated and ranked the scholarly production of neurosurgical programs.^{1,5,11,12,14,15,22,23,26} Scholarly output affects program accreditation, program reputation, grants, future resident recruitment, and academic promotion. In addition, bibliometrics in neurosurgery are increasingly reported. Publications by residents, attendings, and entire programs have been quantified to understand the overall academic output of neurosurgery. A recent literature review of factors affecting resident choices in academic medicine careers suggested a lack of clarity in understanding resident career choices and recommended further study.²

Multiple studies have supported the idea that resident productivity correlates strongly with overall neurosurgical department productivity.^{10,22} Applicants to neurosurgery remain academically competitive among the pool of medical students as assessed by mean board scores, scholastic performance, and research productivity.¹⁹ However, the effect of neurosurgical training on the research endeavors and future career aspirations of residents remains unknown. The factors that affect scholarship on a departmental and national level have not yet been explored. We sought to survey US neurosurgical residents regarding interest in research, limitations of pursuing research, and potential methods for improving overall resident research.

Methods

Survey Design

A survey was designed to analyze resident opinions toward research in neurosurgery residency. Research was defined as the pursuit of new knowledge or the improved application of existing knowledge. Study data were collected and managed using the Research Electronic Data Capture (REDCap) tool (version 7.0.19). Questions were generated and evaluated via a pilot survey administered to the neurosurgical residents at the University of Utah and Medical University of South Carolina. Feedback on questions was obtained from residents, senior neurosurgical faculty (J.W.A., A.H.F., A.M.S., S.P., J.R.W.K., R.L.J., W.T.C.), course directors at the Resident Update in Neuroscience for Neurosurgeons (RUNN; A.H.F.), members of the Council of State Neurosurgical Societies (S.T., J.W.A.), and research committee members of the Society of Neurological Surgeons (E. Antonio Chiocca, MD, PhD). For the pilot survey, 13 resident responses were obtained over 40 questions (Supplemental Material 1). This pilot question sample was then expanded to a list of 58 questions (Supplemental Material 2). Free-response prompts were available to provide comments not otherwise captured in the survey. The survey was disseminated to 109 programs via an emailed link to the residency program coordinators and a reminder sent to program directors 2 weeks later. The data collection period was from August 25, 2017, until September 25, 2017. The survey was anonymous, and participants received a \$15 Amazon gift card at the completion of the survey.

Analysis

Survey results were classified as demographic variables, research experiences prior to or during residency, details of presented research at conferences, research funding, limiting factors in residency, and programmatic support of research. A free-text response was used to evaluate potential solutions to the limitation. Several bibliometric parameters were assessed from prior studies. Mean resident h-index for a program, the mean number of resident publications on Scopus by program, and program rank by resident h-index were acquired from a 2017 study by Sarkiss et al.²² Program rank by faculty h-index and the total number of faculty were assessed by a 2014 study from Khan et al.¹² The h-index defines a scholar as someone who has published h papers with at least h number of citations, thus reflecting both the number of publications and theoretical value of those publications. Published parameters from these studies were entered for each resident depending on their stated program. Several newer residency programs did not have available bibliometric variables. Residents were also characterized by the number of self-reported peer-reviewed publications to assess factors affecting publication rate. Those with numbers of publications above the median (AM; ≥ 14 publications) were compared with those with below the median (BM; < 14 publications). For evaluation of opinions along a 5-tier response (strongly disagree, disagree, neutral, agree, and strongly agree), responses were weighted to allow comparison of AM and BM residents by t-test.

The survey data were compiled at the end of data collection, anonymized, and analyzed using SPSS (version 20.0, IBM). Means $\pm$ standard deviations and percentages were generated for continuous and discrete variables where appropriate. Continuous variables were compared via Student t-test or linear regression and discrete variables were analyzed by chi-square test or Fisher's exact test. Median values were evaluated by the Mann-Whitney U-test. A predetermined p value < 0.05 was considered statistically significant.

Results

Demographics

From a total of 281 responses obtained from 82 US residency programs in 30 states resulting in a 20% response rate, the results were narrowed to 278 responses because 3 surveys were duplicated. The geographic location of residency programs with respondents is shown in Fig. 1 and represents a national distribution of programs. The distributions of responses by postgraduate year (PGY), subspecialty goal, and future practice preference are shown in Table 1.

Residents were divided into two groups (AM vs BM) to assess factors affecting scholarly productivity (Table 1). A total of 146 BM residents and 132 AM residents were identified. A higher proportion of later PGY levels were noted in the AM group compared with the BM group ($p = 0.02$). No difference in subspecialty interest ($p = 0.87$) was noted between the groups. The AM residents were more likely to prefer an academic career ($p = 0.0001$), train in the West and Northeast ($p = 0.03$), and have recent publications ($p = 0.0001$). Unsurprisingly, AM residents also

FIG. 1. Representative map of US neurosurgical residency programs with survey responses. A map of 82 US residency programs with at least 1 resident who responded to the survey is shown. Specific numbers of respondents from different programs are not shown. In some locations, multiple institutions may have responded to the survey but are only represented by 1 star. Figure is available in color online only.

had a higher average h-index ($p = 0.0001$), and a higher number of papers listed in Scopus ($p = 0.0001$). AM residents were in programs with a larger number of faculty ($p = 0.0001$), a higher median program rank by resident h-index ($p = 0.0001$), and a higher median program rank by faculty H-index ($p = 0.0001$).

Publications and Research Time

The distribution of research project types is shown in Fig. 2A. Residents had written a mean of 11 ± 14 papers (median = 7) by the time of the survey (25th interquartile range [IQR] = 3, 75th IQR = 15; Fig. 2B). The number of resident publications correlated positively with PGY level ($\beta = 1.7$, $R = 0.23$, $p < 0.0001$, linear regression; Fig. 2C). There were a number of outliers in terms of both publication number and research time. Eleven residents, exclusively later-stage residents ($\geq$ PGY4) had > 39 publications (2 standard deviations from the mean). Residents spent on average 14.1 ± 18.5 self-reported hours (median = 7.0) per week on research (Fig. 2D). Most residents (53.6%) stated they had ≥ 12 months of protected research time (Fig. 2E). A distribution of hours spent on research per week and total number of publications shows a strong positive correlation ($\beta = 0.132$, $R = 0.22$, $p = 0.03$, linear regression; Fig. 2F). AM residents spent a significantly greater number of hours on research than BM residents (18.5 ± 21.0 vs 10.2 ± 14 , $p = 0.0001$; Table 2). There was no difference in the number of dedicated research months ($p = 0.11$), with 51.5% of AM residents and 58.9% of PM residents having ≥ 12 months of protected time.

Research Resources, Presentations, and Funding

Resident responses regarding research experiences, research presentation, and success with funding were collected to evaluate where residents learned the scientific process and where avenues for improvement could be found (Table 2). Categories were not mutually exclusive and single residents could have obtained multiple avenues of research experience. Among all factors, rates of completion of a dedicated research year ($p = 0.001$), research fellowships ($p = 0.0001$), and postdoctoral fellowships ($p = 0.0001$) were significantly higher among AM residents. Residents without formal graduate research training were significantly more likely to be in the BM group ($p = 0.002$). AM residents reported a higher number of presentations at national ($p = 0.0001$), regional ($p = 0.0001$), and international ($p = 0.0001$) meetings. Similarly, AM residents had greater numbers of submitted ($p = 0.0001$) and received ($p = 0.0001$) grants for $< \$10,000$ as well as submitted ($p = 0.0001$) and received ($p = 0.0001$) grants for $\geq \$10,000$. Whereas approximately half of residents (49.6%) were more enthusiastic to pursue research since starting residency, the other half were either unchanged (36.7%) or discouraged (13.7%); no significant difference in attitude was observed between the AM and BM groups.

Limiting Factors in Neurosurgical Resident Research

Important factors limiting resident research as well as residency program initiatives to improve research endeavors were explored by simple “yes” and “no” responses (Table 3). The 3 factors cited as most important in af-

TABLE 1. Distribution of neurosurgery resident respondents

Variable	All Residents (n = 278)	BM Residents (n = 146)	AM Residents (n = 132)	p Value
PGY				0.02
1	49 (17.6)	32 (21.9)	17 (12.9)	
2	41 (14.7)	23 (15.8)	18 (13.6)	
3	42 (15.1)	28 (19.2)	14 (10.6)	
4	45 (16.2)	28 (19.2)	17 (12.9)	
5	52 (18.7)	18 (12.3)	34 (25.8)	
6	30 (10.8)	10 (6.8)	20 (15.2)	
7	19 (6.8)	7 (4.8)	12 (9.1)	
Current subspecialty interest				0.87
Spine	68 (24.5)	38 (26.0)	30 (22.7)	
Tumor/neurooncology	61 (21.9)	29 (19.9)	32 (24.2)	
Endovascular	43 (15.5)	21 (14.4)	22 (16.7)	
Pediatric	35 (12.6)	19 (13.0)	16 (12.1)	
Functional	32 (11.5)	17 (11.6)	15 (11.4)	
Skull base	32 (11.5)	17 (11.6)	15 (11.4)	
Trauma/critical care	5 (1.8)	3 (2.1)	2 (1.5)	
Peripheral nerve	2 (0.7)	2 (1.4)	0 (0.0)	
Current practice type interest				0.0001
Academics	148 (53.2)	59 (40.4)	89 (67.4)	
Private practice w/ some research	112 (40.3)	74 (50.7)	38 (28.8)	
Private practice	15 (5.4)	11 (7.5)	4 (3.0)	
Other	3 (1.1)	2 (1.4)	1 (0.8)	
Region				0.03
Midwest	87 (31.3)	52 (35.6)	35 (26.5)	
Southeast	80 (28.8)	47 (32.2)	33 (25.0)	
Northeast	78 (28.1)	37 (25.3)	41 (31.1)	
West	24 (8.6)	7 (4.8)	17 (12.9)	
Mountain	9 (3.2)	3 (2.1)	6 (4.5)	
Author of publication last yr	223 (80.2)	99 (67.8)	124 (93.9)	0.0001
Mean resident h-index $\pm$ SD	2.6 $\pm$ 2.3	2.2 $\pm$ 1.5	3.0 $\pm$ 1.7	0.0001
Mean no. of Scopus documents $\pm$ SD	7.8 $\pm$ 6.2	6.0 $\pm$ 5.5	9.7 $\pm$ 7.0	0.0001
Median program rank by resident h-index	35	50	25	0.0001
Median program rank by faculty h-index	47	52	23	0.0001
Mean no. of faculty $\pm$ SD	12.9 $\pm$ 12.0	13.3 $\pm$ 5.5	16.2 $\pm$ 5.2	0.0001

Data are reported as number (%) unless otherwise indicated. Boldface type indicates statistical significance.

fecting an interest in research were mentorship (92.4%), research exposure (89.9%), and early interest in science (78.4%). For AM residents, research exposure ($p = 0.003$), neurosurgery conference exposure ($p = 0.02$), and formal research training prior to residency ($p = 0.03$) were more important than they were for BM residents. The programmatic factors that were more likely to be cited by residents in the AM group included internal departmental funding ($p = 0.05$) and software support ($p = 0.02$).

Residents were asked to select from a list the three most limiting factors for their future research opportunities in residency. Time (91.0%), call scheduling (47.1%), and funding/grants (37.1%) were the most commonly selected choices. AM and BM residents agreed that time ($p = 0.4$) and call schedules ($p = 0.96$) were important limiting

factors. Interestingly, funding/grants ($p = 0.02$) was more likely cited as a critical factor by AM residents. Difficulty in finding novel research topics was more likely in the BM residents ($p = 0.02$). No differences in other factors were identified.

Opinions Regarding Resident Research in Neurosurgery

Resident perceptions toward research and overall interest were evaluated on a five-tier scale (Fig. 3). A total of 82.4% of residents agreed or strongly agreed with interest in pursuing research throughout their professional careers. Most (87.4%) agreed with wanting to present research at local or national meetings. Most residents (72.7%) also agreed that a strong research foundation in residency would help with landing a job as an attending physician,

TABLE 2. Research experiences and exposure

Variable	All Residents (n = 278)	BM Residents (n = 146)	AM Residents (n = 132)	p Value
Research/scholarly hrs/wk	14.1 ± 18.5	10.2 ± 14.9	18.5 ± 21.0	0.0001
Research experience				
Research/clinical training courses (e.g., AANS/CNS, RUNN course, Boot Camp)	120 (43.2)	56 (38.4)	64 (48.5)	0.09
Cadaver courses	113 (40.6)	54 (37.0)	59 (44.7)	0.2
Clinical science research conference	105 (37.8)	50 (34.2)	55 (41.7)	0.2
Basic science research conference	82 (29.5)	40 (27.4)	42 (31.8)	0.4
Dedicated research year	83 (29.9)	31 (21.2)	52 (39.4)	0.001
Online videos	67 (24.1)	32 (21.9)	35 (26.5)	0.4
No formal graduate research training	109 (39.2)	76 (52.1)	39 (29.5)	0.002
Graduate Masters degree	49 (17.6)	21 (14.4)	28 (21.2)	0.1
Research fellowship (e.g., HHMI, NIH)	45 (16.2)	12 (8.2)	33 (25.0)	0.0001
Graduate doctoral degree	25 (9.0)	14 (9.6)	11 (8.3)	0.7
Postdoctoral fellowship	26 (9.4)	4 (2.7)	22 (16.7)	0.0001
Research presentations				
Local institution	210 (75.5)	106 (72.6)	104 (78.8)	0.2
Regional meetings	157 (56.5)	67 (45.9)	90 (68.2)	0.0001
National meetings	201 (72.3)	84 (57.5)	117 (88.6)	0.0001
International meetings	63 (22.7)	20 (13.7)	43 (32.6)	0.0001
Research funding				
Applied for neurosurgical research grant (value <\$10,000)	70 (25.2)	15 (10.3)	55 (41.7)	0.0001
Received neurosurgical research grant (value <\$10,000)	29 (10.4)	5 (3.4)	24 (18.2)	0.0001
Applied for neurosurgical research grant (value ≥\$10,000)	58 (20.9)	14 (9.6)	44 (33.3)	0.0001
Received neurosurgery research grant (value ≥\$10,000)	31 (11.2)	6 (4.1)	25 (18.9)	0.0001
Attitude toward research in neurosurgery during residency?				0.2
Encouraged	138 (49.6)	66 (45.2)	72 (54.5)	
Neutral	102 (36.7)	57 (39.0)	45 (34.1)	
Discouraged	38 (13.7)	23 (15.8)	15 (11.4)	

CNS = Congress of Neurological Surgeons.

Data are reported as number (%) unless otherwise indicated. Boldface type indicates statistical significance.

and 77.3% enjoyed participating in peer-reviewed research. A majority of residents (91.4%) stated that clinical research or basic science research (85.6%) was important in advancing neurosurgery. Overall, 75.9% agreed they would like to do more clinical research while only 40.6% stated they would like to do more basic science research.

Local institutional factors were assessed. Over half (57.2%) of respondents agreed they had an adequate physical workspace for pursuing a research interest, and 78.8% reported that their program or department supported their research endeavor. Surprisingly, residents were divided regarding the role of funding as a major barrier to research: a total of 4.7% strongly disagreed, 28.1% disagreed, 32.0% were neutral, 25.9% agreed, and 8.3% strongly agreed that funding would be a major issue for future research. Residents were also split regarding time commitments, as 10.1% strongly disagreed, 30.2% disagreed, 27.3% were neutral, 28.4% agreed, and 2.9% strongly agreed that they have adequate time for research. Two-thirds of residents (64.4%) agreed that important research could be performed in a private practice setting,

and 70.7% agreed that important research could be done in all academic settings.

Comparison of AM and BM residents showed significant differences in their desire to continue research professionally ($p = 0.003$) or present research at local/national meetings ($p = 0.02$) and in their views toward the importance of research in future employment ($p = 0.01$). In addition, AM residents were more interested in peer-reviewed ($p = 0.001$) and specifically neurosurgical ($p = 0.007$) research than BM residents. Importantly, AM residents significantly felt their programs supported their research compared with BM residents ($p = 0.04$).

Free-Response Questions

Free-response questions served as a platform to identify issues affecting resident research as well as solutions to limiting factors (Table 4). Several themes from a regional/national standpoint included improvements in collaboration, funding, data management, training/mentorship, regulatory/paperwork, and overall neurosurgical publications.

TABLE 3. Limiting factors in neurosurgical resident research

Limiting Factor	All Residents (n = 278)	BM Residents (n = 146)	AM Residents (n = 132)	p Value
Important factors affecting interest in research				
Mentorship	257 (92.4)	130 (89.0)	127 (96.2)	0.07
Research exposure	250 (89.9)	123 (84.2)	127 (96.2)	0.003
Early interest in science	218 (78.4)	107 (73.3)	111 (84.1)	0.09
Interaction w/ my peers	214 (77.0)	109 (74.7)	105 (79.5)	0.6
Specific patient questions arising during practice	201 (72.3)	101 (69.2)	100 (75.8)	0.5
Neurosurgery conference exposure	185 (66.5)	86 (58.9)	99 (75.8)	0.02
Formal research training prior to residency	164 (59.0)	77 (52.7)	87 (65.9)	0.03
Mandated residency requirements	132 (47.5)	70 (47.9)	62 (47.0)	0.98
Program support				
Conference/travel support	234 (84.2)	122 (83.6)	112 (84.8)	0.8
Protected research time	196 (70.5)	104 (71.2)	92 (69.7)	0.8
Access to medical students &/or undergraduates	179 (64.4)	94 (64.4)	85 (64.4)	0.99
Internal funding sources	126 (45.3)	57 (39.0)	69 (52.3)	0.05
Clinical study coordinator	124 (44.6)	58 (39.7)	66 (50.0)	0.09
Collaborative agreements w/ other researchers	121 (43.5)	61 (41.8)	60 (45.5)	0.5
Software support	99 (35.6)	43 (29.5)	56 (42.4)	0.02
Time to obtain additional degrees/training	90 (32.4)	42 (28.8)	48 (36.4)	0.2
Academic editor	85 (30.6)	44 (30.1)	41 (31.1)	0.9
Medical illustrator	74 (26.6)	34 (23.3)	40 (30.3)	0.2
3 most limiting factors in pursuing research interest				
Time	253 (91.0)	131 (89.7)	122 (92.4)	0.4
Call schedule	131 (47.1)	69 (47.3)	62 (47.0)	0.96
Funding/grants	103 (37.1)	45 (30.8)	58 (43.9)	0.02
Administrative assistance (e.g., clinical coordinator, biostatistician, editor)	100 (36.0)	48 (32.9)	52 (39.4)	0.3
Regulatory paperwork (e.g., IRB, IACUC, FDA)	52 (18.7)	22 (15.1)	30 (22.7)	0.1
Finding novel research topics	52 (18.7)	35 (24.0)	17 (12.9)	0.02
Lack of participating students or residents	36 (12.9)	15 (10.3)	19 (14.4)	0.3
Lack of interest	30 (10.8)	19 (13.0)	11 (8.3)	0.2
Training in the scientific method	26 (9.4)	17 (11.6)	9 (6.8)	0.2
Institutional support	24 (8.6)	17 (11.6)	7 (5.3)	0.06
Departmental encouragement	14 (5.0)	7 (4.8)	7 (5.3)	0.8

IACUC = Institutional Animal Care and Use Committee.

Data are reported as number (%) unless otherwise indicated. Boldface type indicates statistical significance.

From a departmental standpoint, residents identified needs as resources for paperwork and data management, mentorship, funding, and time. Some residents requested changes in departmental attitudes toward research to encourage further research opportunities.

Discussion

Residents and practicing neurosurgeons share the conviction that clinical and basic science research underlies advancement of the field of neurosurgery, yet the means to that end continue to be debated. Although the underlying motivators of an individual's scientific curiosity may ultimately remain as varied as the individuals themselves, strategic interventions at the national or programmatic level may potentiate or dampen an individual's academic

flame (Table 5). The results of this study confirm that residents enjoy participating in peer-reviewed research, and they possess a desire to continue pursuing it during their careers. Overall, half (49.6%) of residents were encouraged toward pursuing research during their residency, the other half were either neutral (36.7%) or discouraged (13.7%) toward pursuing research. The three top limiting factors for resident research included adequate time, call scheduling, and funding. AM residents reported a greater number of devoted research hours weekly and more grant funding (external and internal grants), presentation of research, mentorship, and research exposure (prior to residency and during residency).

Research Productivity

Sarkiss et al.²² published a key study on neurosurgi-

FIG. 3. Multiple-choice responses to agreement statements. Resident opinions for various question prompts were elicited on a 5-tier scale: strongly agree, agree, neutral, disagree, and strongly disagree. AM (triangle) and BM (inverted triangle) resident averages were compared by assigning weights of 0, 25, 50, 75, and 100 for respective responses, which were compared by t-test. *Significant difference at $p < 0.05$. Figure is available in color online only.

cal research evaluating 1352 neurosurgical residents in 105 programs, comparing resident and faculty h-indices. Residents published a total of 2.9 first-author papers with a mean h-index of 2.47 and 7.6 documents in Scopus. Our results showed that residents published an average of 11 papers, suggesting that coauthored papers are a predominant part of resident portfolios. The top three subspecialties among resident publications (vascular, spine, and oncology) also correlated with the top three subspecialty career interests. Sarkiss et al. showed that larger program size and greater faculty and resident productivity each individually correlated with overall academic departmental productivity and ranking. Funding and research opportunities may be more available at larger programs. Sarkiss et al. showed that productivity between residents and faculty at the top-20 ranked programs did not correlate with the overall group or bottom-20 ranked programs. This suggested that residents were possibly involved in research independently or with nonneurosurgical faculty.

Some, but not all, studies have correlated residency research publication with further academic pursuits. Crowley et al.⁵ tracked 717 neurosurgical graduates between 1985 and 1990 and evaluated those that later pursued academic careers or were promoted to professor, chairs, or chiefs of neurosurgery compared with other neurosurgical careers. This study showed that those pursuing academics had a higher number of total publications (5.1 vs 1.9, $p < 0.001$) and first-author publications (3.0 vs 1.0, $p < 0.001$) during residency. Program size (≥ 2 graduates/year) correlated with an academic career but not professorship or serving as a chair/chief. Further studies in neurosurgery and other medical fields have shown a correlation between publication during residency and future academic productivity.^{16–18,24,28} However, this correlation between publication and future academic pursuits has not been shown in all studies, including for neurosurgical residents.^{13,21} Daniels et al.⁷ demonstrated that publications during residency, an h-index of ≥ 2 achieved during residency, and devoted

TABLE 4. Direct written responses from residents discussing needed support

Category	Responses
Regional/national aspects	
Collaboration	"Ability to do research at other institutions" "Creation of broad collaborative initiatives between institutions" "Greater inter-institutional research collaborations and data sharing possibilities" "Organizational-led research initiatives for residents" "I think more meeting time focused on getting residents together to discuss their research may help foster collaboration and shared ideas looking into careers" "Protected time for research; senior resident sharing research with juniors" "Ability to have a protected research space and protected time with good collaboration with local university"
Funding	"Better NIH funding from the government" "Conference travel funds" "More grant opportunities" "NREF is the only option that exists for the funding of neurosurgery residents and more of the funding is being funneled to young attendings, which is really putting current residents at a distinct disadvantage" "My hope would be that in the future we follow the HHMI approach and fund the applicant, not the project. Or, in the least, expand our funding mechanisms to favor resident-driven projects. Seed grants, to be used for material support rather than salaries, are another option. These could be much smaller than the salary support for an NREF but have a tremendous impact" "Junior-level funding opportunities" "Small grants (\$5,000 or less)"
Data management	"Access to the neurosurgical outcomes databases" "More consortiums of centers to pool clinical data" "A database to help have easy access to patient information" "More longitudinal databases to pick and choose from"
Training/mentorship	"Research training at national conferences, additional research courses/webinars/material to improve training with methodology, grantsmanship, improved understanding about the direction that careers with neurosurgical research can take" "Organized courses on writing grants" "RUNN-type meetings" "Statistics workshops, coding workshops, Photoshop/Illustrator workshops, grant-writing courses" "Online resource for connecting with neurosurgical mentors across different institutions"
Regulatory/paperwork	"...collaboration with other labs/hospitals that have already approved research projects may make [IRB approval] easier"
Publication	"Higher barrier for bull**** research, and lower emphasis on quantity throughput. Then we could focus energies on fewer, high-quality studies"
Departmental aspects	
Departmental resources	"Medical writer to hold us accountable and teach us how to begin to publish" "Administrative assistance that will help with documentation, finances, etc." "A coordinator to help with the paperwork and regulator issues" "A devoted research coordinator. Someone to help recruit and consent participants, help collect data" "Academic editor and biostatistician" "I have experienced 3 institutions during my residency (my residency, enfolded fellowship, and post-residency fellowship). By FAR the most helpful resources to productivity are the presence of an editor and medical illustrator! Hands down" "There is little time to efficiently go through data and statistics without the appropriate staff to help"
Mentorship	"Clinical and basic science faculty mentors who can act as clearinghouses for projects and ideas" "... someone who knows how to apply for grants and plan prospective research" "More introductory lectures/meetings for people who are entering residency who are entirely new to research. Basics like: how to engage in meaningful research? What are grants and how do they work? What are some good mentored opportunities for those new to research? etc." "Specific research mentors to help devise research ideas and put together timelines. Currently, everything is very relaxed and informal and thus a lot of good project ideas fall through the cracks"
Funding	"Resources to get funding for small projects" "Funding, opportunity, time"

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TABLE 4. Direct written responses from residents discussing needed support

Category	Responses
Departmental aspects (<i>continued</i>)	
Time	"Time to go to conferences" "Academic days during junior residency" "Truly protected research time" "I will be continuing to pursue research during the protected research years; however, dedicated time during junior residency would better facilitate continued research endeavors" "Longitudinal research time (e.g., 1–2 days over 2–3 years rather than 1 year of dedicated research), department faculty involvement and encouragement of research endeavors. Funding sources" "More administrative assistance given the overall demands of our clinical/operative duties" "Time and clinical obligations are the most limiting steps in a research setting early on but are also non-negotiable components of a neurosurgical residency"
Attitude	"Change in attitude. Tell[ing] us to do it for years, hasn't happened, still take same approach" "My department has been and continues to encourage my research interests and provides me with sufficient time and resources to invest in my research"

pre-residency research time predicted a postresidency academic career. The number of pre-residency publications was not predictive of an academic career.

Research Limiting Factors

Although it is clear that there are limiting factors for resident research, there are also possible solutions. Jagannathan et al.¹⁰ suggested that the creation of an 80-hour work week has limited time to devote to scholarly activities. This study showed that when comparing resident abstract presentation to the AANS annual meeting, the number of abstracts submitted by residents decreased from 345 abstracts in 2002 to 218 abstracts in 2007 ($p < 0.05$). Besides the limitation of available time and call schedules, funding and formalized training in the research process may have played a role in the lower number of abstract presentations. Funding has clearly been shown to impact research output but remains a significant challenge.^{9,25,27} Formal research training may be a more rectifiable issue. Eastwood et al.⁸ published a guide for improving resident academic pursuits. Strategies to improve research included a series of seminars and one-on-one tutorials with academic editors as well as training on the scientific publishing process. Such interventions could be easily replicated at other departments or at a national level. In addition, formalized research training during neurosurgical residency might improve critical analysis of the literature, which could improve overall clinical training for all residents. Mentor-

ship, as shown by our study, is critical to guiding residents, increasing opportunities, and likely fostering interest in research during residency. Lastly, pre-residency training is important in fostering future scholarship. Choi et al.⁴ suggested that neurosurgical residents with doctoral training were more likely to hold academic medicine positions and to have received funding from the NIH. Our study suggests that postdoctoral training and other research fellowship training (e.g., Howard Hughes Medical Institute [HHMI], NIH) may be helpful in encouraging research endeavors. Formalized research education might not only help with resident education but also provide a holdover value for practicing neurosurgeons as they critically assess which new technologies and studies have really passed the rigor of proper evaluation.

Residents provided direct responses highlighting some of the many solutions to current research problems. Several common themes emerged, including collaboration, funding, data management, training/mentorship, regulatory/paperwork, and publication. Programs and attending physicians can work on actively pursuing collaboration with residents and modeling good collaboration with other colleagues. Although faculty with active laboratories may be able to better guide research endeavors with residents and influence research attitudes, faculty at all levels can serve as mentors. The creation of additional subspecialty registries could engage interested residents at different institutions to help with data management and analysis,

TABLE 5. Survey conclusions

1. Program directors & chairs can implement strategies to minimize the 3 top limiting factors for resident research, which included adequate time, call scheduling, & funding/grants, while improving factors to promote research, such as faculty mentorship & exposure to research. Additional access to resources (e.g., database support, biostatisticians, medical editor) may help in the setting of limited time available for resident research.
2. National leaders should recognize that nonacademic neurosurgeons, i.e., those in private practice, may nonetheless wish to remain actively involved in research efforts that advance the field.
3. Academic departments w/ residency programs must hire & cultivate faculty who are themselves academically productive & committed to mentorship.
4. Resident neurosurgeons have a desire for cross-institutional collaboration. This is already facilitated in part by programs including RUNN & the resident Boot Camps, but a collaborative national or international platform remains to be established.

while building collaboration. The Young Neurosurgeons Committee would be an ideal level for organizing collaborative efforts for residents across institutions. Other potential environments where resident research can be fostered could include the junior resident boot camps, the RUNN course, and other resident courses. The British Neurosurgical Trainee Research Collaborative is one example of how collaboration is conducted successfully.³ It is also apparent that neurosurgeons of the next generation do not observe a sharp distinction between academic and privately practicing physicians; leaders of the field should utilize new mechanisms to harness research interests in neurosurgeons who may otherwise launch careers in a private practice setting.

Funding is a challenge at any level of research. National efforts to raise research funding via the Neurosurgery Research and Education Foundation (NREF) have been very successful. Increased opportunity for smaller grants, higher risk projects, and junior residents would be potential avenues that could pay dividends in encouraging resident research and opening opportunities for a wider range of residents. Improvement of resident research training on a national perspective could include resident seminars and courses on grant writing, forming an academic career, statistical analysis, scientific writing, and other relevant topics. Even if the pursuit of research interests and scholarship is not in the interest of every resident or residency program, the potential for learning the scientific method and critical appraisal of the literature is beneficial to all physicians.

The challenge in finding a balance between clinical and research endeavors is not new or unique to the field of neurosurgery.^{6,20} From a departmental standpoint, avenues for improving resident research are suggested. Additional departmental resources (i.e., clinical coordinator, databases, academic editors, biostatisticians) are critical as residents reported that time and clinical responsibilities are predominant limiting factors. Internal funding sources and small grants for junior residents are additional resources residents identify as important. Mentorship is crucial for residents to understand how to apply for funding, formulate research ideas, and draft manuscripts. Encouragement from departments, including support for conferences, protected research time, and high expectations, are also important factors.

Study Limitations

Some study limitations for this project should be addressed. Although the overall response to the survey was positive, multiple residency programs did not have responses and the overall response rate was 20%. Regardless, because the questions were intended to examine both individual and programmatic factors, even one response from a program would provide an idea about the available resources. Responses to the survey may have been biased toward individuals more interested in research. Further follow-up with respondents and tracking of career direction would be helpful in evaluating research career aspirations. Resident research publications were self-reported and not verified, thus creating a potential recall/reporting bias. In addition, although the number of papers was quan-

tified and presentation at conferences was evaluated, the number of abstracts and conference presentations were not counted. Number of publications is certainly a narrow measure of scholarly performance, as with any bibliometric measure, but can serve as a metric for future comparisons. Resident publication number did increase with PGY level as expected, and only a handful of outliers were identified, suggesting that self-reporting may be reasonably accurate. Our intention with the survey was not to rank programs against one another, thus limiting comparison of ranking to previous studies. We believe this ranking is detrimental to scholarly pursuits in neurosurgery, and we instead suggest that improvement of resident research can be achieved at all programs.

Conclusions

This study helps to identify resident-identified individual and programmatic factors affecting neurosurgical resident research. Factors both encouraging and limiting research are delineated. In addition, suggestions for improvement at national, regional, and departmental levels are suggested.

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Author Contributions

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Correspondence

Michael Karsy: University of Utah, Salt Lake City, UT. neuropub@hsc.utah.edu.