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CLINICAL ARTICLE

Characteristics and career outcomes of Neurosurgery Research and Education Foundation research fellowship recipients

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OBJECTIVE The American Association of Neurological Surgeons (AANS) Neurosurgery Research and Education Foundation (NREF) provides ongoing competitive research fellowships for residents and young investigators. The authors sought to determine the characteristics and career tracks of award recipients.

METHODS The authors analyzed characteristics and academic productivity parameters of NREF resident and young investigator awardees in the United States and Canada from 1983 to 2017. Data were extracted from the NREF database and online resources (Web of Science, NIH reporter).

RESULTS In total, 224 research grants were awarded to 31 women (14%) and 193 men (86%) from 1983 to 2017. Neuro-oncology (36%) was the most common research category. Sixty percent of awardees were in training and most resident award winners were in postgraduate year 5 (37%). Forty-nine percent of all awardees had an additional postgraduate degree (PhD 39%, Master's 10%) with a significantly higher number of PhD recipients being from Canada in comparison to any US region ($p = 0.024$). The Northeastern and Southeastern United States were the regions with the highest and lowest numbers of award recipients, respectively. More than one-third (40%) of awardees came from institutions that have a National Institute of Neurological Disorders and Stroke Research Education Grant (NINDS R25) for neurosurgical training. Awardees from NINDS R25–funded programs were significantly more likely to go on to receive funding from the National Institutes of Health (NIH) (40.4% vs 26.1%; $p = 0.024$). The majority of recipients (72%) who were no longer in training pursued fellowships, with a significant likelihood that fellowship subspecialty correlated with NREF research category ($p < 0.001$). Seventy-nine percent of winners entered academic neurosurgery practice, with 18% obtaining the position of chair. The median h-index among NREF winners was 11. NIH funding was obtained by 71 awardees (32%) with 36 (18%) being a principal investigator on an R01 grant from the NIH Research Project Grant Program.

CONCLUSIONS The majority of AANS/NREF research award recipients enter academics as fellowship-trained neurosurgeons, with approximately one-third obtaining NIH funding. Analysis of this unique cohort allows for identification of characteristics of academic success.

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KEYWORDS academic neurosurgery; NIH; NREF; AANS; surgeon-scientist; clinician-scientist; research fellowship; career

Research productivity as measured by publications and extramural funding is a main component of success in academic medicine, including surgical disciplines. Obtaining National Institutes of Health (NIH) funding remains a gold standard of academic success in biomedical research, but such funding has continued to decline. Early-career physician-scientists are the group most vulnerable to having difficulty obtaining NIH funding.[5] Surgeon-scientists face further unique challenges given that the need to maintain surgical skills requires significant clinical time compared to other specialties. Furthermore, the length of time between medical and graduate research training to first faculty position is prolonged in surgical training.[14]

NIH funding to academic surgeons has continued to decline relative to funding to nonsurgeons.[12] Many sur-

ABBREVIATIONS AANS = American Association of Neurological Surgeons; NIH = National Institutes of Health; NINDS R25 = National Institute of Neurological Disorders and Stroke Research Education Grant; NREF = Neurosurgery Research and Education Foundation; PI = principal investigator; R01 = grant from the NIH Research Project Grant Program.

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TABLE 1. Neurosurgical programs with an NINDS R25

Neurosurgical Programs With NINDS R25
Baylor
Duke
Emory
Harvard (Massachusetts General, Brigham)*
Stanford
University of Alabama
University of California Los Angeles
University of California San Francisco
University of Michigan
University of Southern California
University of Texas Southwestern
University of Washington
Washington University, St. Louis
Yale

* For analysis purposes, Massachusetts General and Brigham are considered as separate programs, but per the NINDS R25 website (https://www.ninds.nih.gov/Funding/Training-Career-Awards/Institutional-Awards/R25-Awardees), they are combined into Harvard Medical School.

TABLE 2. States by geographical region

Northeast	Southeast	Midwest	West
Connecticut	Alabama	Illinois	Alaska
Delaware	Arkansas	Indiana	Arizona
District of Columbia	Florida	Iowa	California
Maine	Georgia	Kansas	Colorado
Maryland	Kentucky	Michigan	Hawaii
Massachusetts	Louisiana	Minnesota	Idaho
New Hampshire	Mississippi	Missouri	Montana
New Jersey	North Carolina	Nebraska	Nevada
New York	South Carolina	North Dakota	New Mexico
Pennsylvania	Tennessee	Ohio	Oregon
Rhode Island	Virginia	Oklahoma	Texas
Vermont	West Virginia	South Dakota	Utah
		Wisconsin	Washington
			Wyoming

gical specialties have implemented research fellowships during postgraduate training and early career development in order to support the next generation of surgeon-scientists.[6,13,15] Formal research training appears to correlate with future research productivity and funding.[11]

The American Association of Neurological Surgeons (AANS) Neurosurgery Research and Education Foundation (NREF) has awarded research fellowship grants to residents and young investigators since 1983. In this study, we reviewed the characteristics and career outcomes of fellowship award recipients from the United States and Canada. These data will aid in elucidating what factors lead to research success among academic neurosurgeons.

Methods

Data Collection

Recipients of NREF research grants and young clinician investigator awards between the years of 1983 and 2017 (N = 213) were characterized based on data found in online resources. Parameters of interest included time of award in relation to progression through residency training, research productivity, and indicators of career development such as appointment at an academic institution and NIH funding after winning an award.

Characteristics upon receipt of award were recorded, including status as resident or attending physician, affiliated program, research category, and project mentor. Information regarding the affiliated program and mentor was provided by the AANS. Completion of additional degrees (PhD and/or Master's) by the awardee was also recorded, along with whether or not the project mentor was a neurosurgeon and/or had obtained a PhD. Of note, Master's degrees included were those pertaining to medicine, health, and/or research, including Master's of Public Health (MPH) and Master's of Science (MS), but not Master's of Business Administration (MBA) or Juris Doctor (JD). Whether or not awardees were from programs with a National Institute of Neurological Disorders and Stroke Research Education Grant (NINDS R25) as of 2017 was recorded. The 15 neurosurgical programs with an NINDS R25 at the time of data collection are listed in Table 1. The neurosurgical training program location was recorded as Canada or US region (Northeast, Southeast, Midwest, or West), which was determined using the US Census Bureau (https://www.census.gov/geo/reference/webatlas/regions.html) and American Association of Geographers (http://www.aag.org/membership/regional_divisions) definitions of different regions in the United States. States comprising each of these 4 regions are listed in Table 2.

Projects were categorized into 7 groups: functional, neuro-oncology/skull base, pediatrics, spine, trauma/critical care/intensive care, vascular, and general neuroscience/neurosurgery. Research on the topics of peripheral nerves, pain, and epilepsy was included in the functional category. Oncology projects dealing with pediatric tumors were classified in the pediatric category.

Research productivity was determined using the Web of Science Citation Tools. We recorded the number of publications both at the time of award receipt and at the end of residency, along with each awardee's current Hirsch index (h-index), also generated by use of Web of Science tools.

Career development of award recipients was assessed based on fellowship completion, academic position, and chair appointment postresidency. Type of fellowship was placed into one of 7 categories: functional/epilepsy, neuro-oncology/skull base, pediatrics, spine/peripheral nerve, trauma/critical care/intensive care, vascular (both open cerebrovascular and endovascular), and other. If an academic position was held at any point after graduation from residency, appointment as assistant professor, associate professor, or professor was recorded.

Receipt of NIH funding was determined using the NIH Research Portfolio Online Reporting Tools (https://projectreporter.nih.gov/reporter.cfm) provided by the US government. Receipt of any NIH grant was recorded as

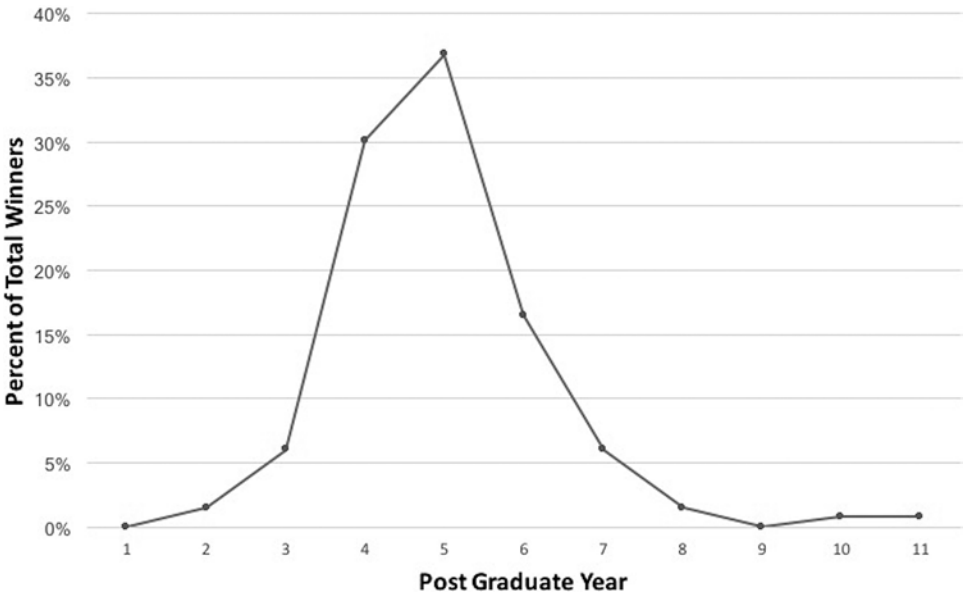

FIG. 1. Distribution of NREF award winners by postgraduate year at the time of winning the award. Award recipients in postgraduate years 1–7 are residents; those in postgraduate year ≥ 8 are new investigators.

well if an R01 award from the NIH Research Project Grant Program (R01) was granted to the awardee as either the principal investigator (PI) or a co-investigator.

AANS member data were obtained as a surrogate for the national neurosurgery population to determine an estimated percentage of neurosurgeons in academic practice (those who won the award were excluded to obtain this estimation).

Statistical Analysis

Data analysis was performed using IBM SPSS version 24.0 for Mac (IBM Corp.). The Kolmogorov-Smirnov test was used to evaluate for normality of distribution of data. It was determined the data are not normally distributed; therefore, nonparametric tests were used for analysis when appropriate. Chi-square test of independence, Mann-Whitney U test, and Kruskal-Wallis tests were used when appropriate.

Results

Award Recipient Demographics

In total, 224 awards were given between 1983 and 2017, with 6 recipients winning the award twice. There were winners from 66 different institutions. Thirty-one awardees were female (14%) and 193 were male (86%). Ten percent and 39% of award recipients had a Master's or PhD, respectively, in addition to an MD. Sixty percent of awardees were in training at the time of the award as opposed to 40% who had completed training and were considered young investigators. Research fellowship participants who were residents at the time of the award were most likely to be in postgraduate year 5 (37%). The distribution of award winners by postgraduate year is shown in Fig. 1.

Recipients were mostly from the Northeastern (35%) and Western (22%) regions of the United States. The top 5 NREF awards producers were the University of Toronto, University of California San Francisco, Johns Hopkins, Massachusetts General, and Duke University. NINDS R25–funded programs for research education for neurosurgery trainees represented only 23% of institutions with award winners, yet 40% of all awardees were from these institutions.

The top 3 research categories for projects were neuro-oncology, functional/epilepsy, and spine/peripheral nerve (Fig. 2). Fifty percent of research mentors were neurosurgeons, with 39% of mentors having a PhD. The mean (SD) number of publications at the time of award receipt was 12.4 (22.36). The median number of publications at the time of the award was 8 (IQR 3–15). For award winners who won as residents, the mean number of publications at the time of award was 9 (11.72) (median 6, IQR 2–10). For those who won after residency, young investigators had a mean of 17.8 (31.89) publications (median 12, IQR 6–21).

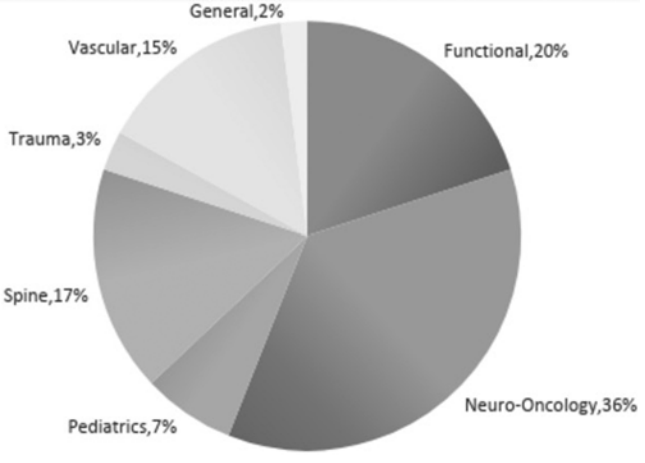

FIG. 2. Research category at time of award. Neuro-oncology, functional, and spine comprised 73% of the award categories.

Career Outcomes

At the time of data collection, 198 NREF research fellows had completed residency training. In total, 142 research fellows (72% of those out of training) went on to complete 157 subspecialty fellowships, with 15 fellows completing 2 fellowships each. Oncology, spine/peripheral nerve, and vascular were the most common fellowships pursued (21%, 22%, and 18%, respectively). Seventy-nine percent of award recipients who had completed training by the time of data collection entered academic positions. Of the fellowship participants who entered academics, most neurosurgeons were assistant professors (43%) or full professors (40%). Thirty-five neurosurgeons (18%) became chairs of academic departments. Seventy-one (32%) fellowship recipients obtained NIH funding, with 36 (18%) being PIs on an R01. The median h-index of award recipients at the time of data collection was 16 (IQR 14). There were no significant differences in career outcomes based on sex.

We also analyzed the correlation between the number of publications and h-index at the time of award receipt and the number of winners at the academic institutions of the recipients: 1 to 5 winners, 6 to 10 winners, or 11 to 15 winners. Winners were categorized based on whether they were residents or attendings when they won the NREF award. With respect to mean number of publications, there were no significant differences among both resident and attending winners with respect to the academic institution. However, for resident winners, the mean h-index was higher for winners at academic institutions with programs with a greater number of overall resident NREF award winners ($p = 0.001$) (Fig. 3).

Effect of Research Category

Award winners were, across all research categories, significantly more likely to have completed or entered a fellowship in the same area in which they were doing research at the time they received the award ($p < 0.001$). Research category was not associated with whether the winner was involved in academics. Significantly more winners involved in vascular research than in other research categories achieved full professor status (67.9%; $p = 0.011$) and became department chairs (34.3%; $p = 0.012$). Following vascular research, the highest percentage of winners who became chairs were involved in neuro-oncology (17.3%), spine/peripheral nerve (16.2%), or functional/epilepsy (7.1%) research. No winner whose research category was pediatrics or trauma/critical care became a chair.

Effect of an Additional Postgraduate Degree

Additional degrees as they relate to research productivity were analyzed. Not all additional postgraduate degrees were obtained before the NREF award, as certain candidates did pursue these degrees during residency. There were 38.6% and 10.4% of award winners that had PhD and Master's degrees, respectively. Award winners from Canada were significantly more likely to have a PhD than those from all US regions combined (17.4% vs 5.1%; $p = 0.024$). Additionally, award winners from the Northeast were significantly less likely than those from other US regions to have a PhD (25.6% vs 38.7%; $p = 0.024$).

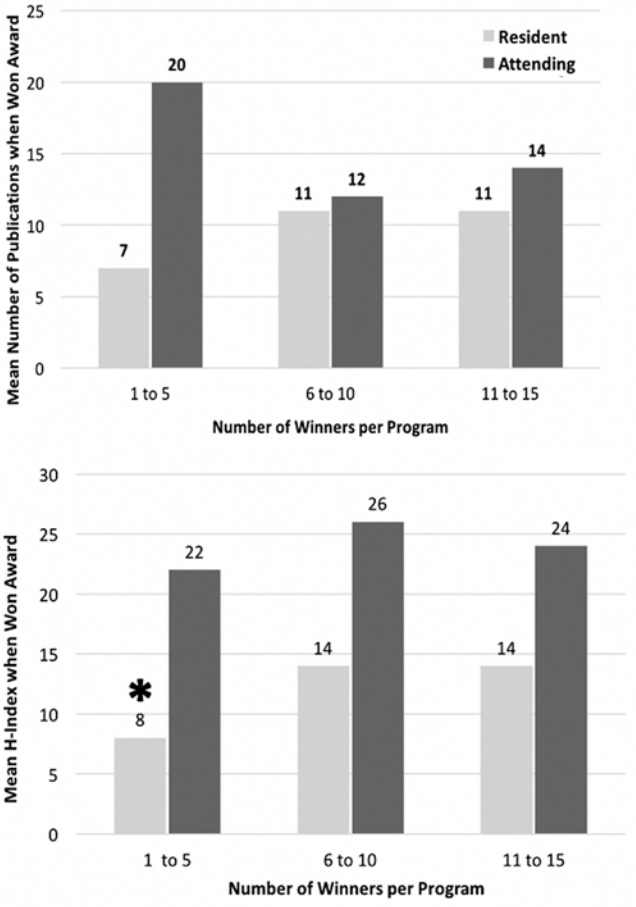

FIG. 3. Relationship between mean publication number (**upper**) and h-index (**lower**) at the time of award and the number of awardees at the institution. *$p < 0.05$.

Winners with a PhD were more likely than other winners to be involved in academics (86.7% vs 74.6%; $p = 0.039$). Winners with Master's degrees were equally as likely to be involved with academics as other winners. Winners with a Master's degree were significantly more likely to become chairs of a program or department (39.1% vs 13.2%; $p < 0.001$). The presence of an additional postgraduate degree did not increase the likelihood of having an R01 or other NIH funding later in life. There was no difference in the median number of publications between winners based on whether the winner had a Master's or PhD.

Effect of Program Region

Several regional variations were noted. Although there are a statistically similar number of neurosurgery programs in each of the 4 US regions and Canada, there were significantly fewer winners compared with the number of programs in the Southeast region ($p < 0.001$) (Fig. 4). More than half of all winners went on to pursue fellowship training, but there were regional variations noted. Winners from Canada were significantly more likely to pursue fellowships (90.0%), those from the Northeast and West were the least likely to pursue fellowships (55.1%, 57.4%), and those from Southeast and Midwest were less likely than those from Canada but more likely than those from the

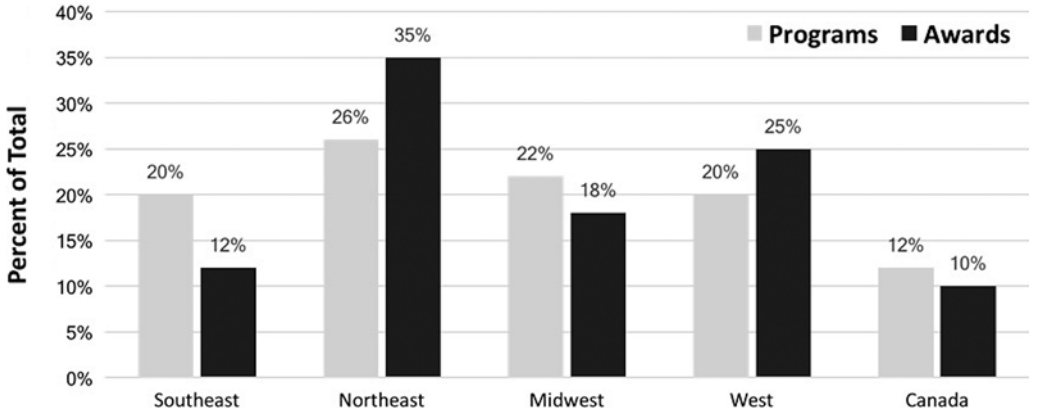

FIG. 4. Percentage of programs compared with percentage of winners per each US geographical region and Canada. There are statistically similar numbers of programs per region ($p = 0.006$); however, there are significantly fewer award winners from the Southeastern United States compared with other regions ($p < 0.001$).

Northeast or West to pursue fellowships (67.9%, 79.5%; $p = 0.008$). There was a trend for award winners from Canada (90.5%) to go into academics more than winners from any other region; however, this difference did not reach statistical significance. Significantly more winners from Canada had a PhD than those from the Northeast (68.2% vs 28.2%; $p = 0.012$). Award winners from the Southeast (42.9%), West (42.9%), and Midwest (33.3%) were not significantly more likely than those from other regions to have a PhD. Winners from the West were significantly more likely than winners from the Northeast to have a mentor with a PhD (76.8% vs 50.0%; $p = 0.025$). Award winners from Canada (70.0%), the Midwest (56.4%), and the Southeast (51.9%) were not significantly more likely than other winners to have a mentor with a PhD.

Award winners from the West and Southeast were significantly more likely to have come from programs with an NINDS R25 (66.1%, 57%; $p < 0.001$) compared with those from the Northeast (32.1%) and the Midwest (27.5%). Award winners from Canada (50.0%), the West (26.8%), and the Northeast (24.4%) were significantly more likely to have come from a top-tier academic program ($p < 0.001$). Award winners from the Southeast and the West were significantly more likely to receive NIH funding than those from Canada (46.4% and 46.4% vs 4.5%; $p = 0.002$). Those from the Northeast (26.9%) and Midwest (25.6%) were not significantly more likely than those from other regions to receive NIH finding. Award winners from the Southeast were significantly more likely than winners from Canada to go on to become a PI on an R01 (32.1% vs 4.5%; $p = 0.04$). Award winners from the West (21.4%), Midwest (15.4%), and Northeast (11.5%) were not significantly more likely than other winners to become a PI on an R01. Of note, unless they have United States citizenship or dual Canadian/United States citizenship, not all neurosurgeons from Canada are eligible for US federally funded awards, including both NIH and R01 funding, which may contribute to artificially lower percentages of this funding being awarded to those from Canada.

Effect of Mentor and Program Characteristics

Mentors who were neurosurgeons were significantly less likely to have a PhD than other mentors (39.6% vs 79.6%; $p < 0.001$). Award winners with neurosurgeon mentors were equally as likely as other winners to receive NIH funding or an R01 grant. Award winners with PhD mentors were significantly less likely to receive an R01 grant as a PI (10.9% vs 22.1%; $p = 0.027$), but they were equally likely to receive NIH funding.

Award winners from neurosurgical programs with an NINDS R25 were significantly less likely to pursue academics than other award winners (59.6% vs 78.9%; $p = 0.002$), but they were significantly more likely to go on to receive NIH funding (40.4% vs 26.1%; $p = 0.024$). Winners from NINDS R25 institutions were equally as likely as other winners to receive R01 grants, and there were also no differences in the rates of pursuing fellowship, having a neurosurgeon or PhD mentor, or becoming chairman among those from programs with an NINDS R25 and those without.

Pursuit of an Academic Neurosurgery Career

At the time of this analysis, 26 award winners were still in residency and the other 198 had completed residency. The following comparisons were done for those who had completed residency only. There were 79.3% of residency-graduated award winners who pursued academics. There was no significant difference in those who chose to do fellowships in terms of pursuing or being involved with academics. Award winners with a neurosurgery mentor were less likely to pursue or be involved in academics (42.7% vs 73.2%; $p = 0.001$). There was no difference regarding entry into academics based on whether the research mentor held a PhD. Winners in academics were significantly more likely to receive NIH funding (42.0% vs 7.3%; $p < 0.001$). There were 18% of winners in academics who received an R01 grant as a PI, whereas none of the winners who were not in academics received an R01 grant. There were also 18% of winners in academics who went on to be chairs, and as expected, no winner not in academics became chair. Winners who became chairs were significantly more likely to receive NIH funding (60.0% vs 29.4%; $p = 0.001$) and have received an R01 as a PI (37.1% vs 14.1%; $p < 0.001$).

NREF Award Status of Neurosurgeons in Academic Careers

As stated above, there are 224 NREF award winners in this study. We used the number of AANS members who have not won an NREF award (5354) to make estimates regarding the number of neurosurgeons in academic practice who have not received an award, although not all practicing neurosurgeons are AANS members and not all AANS members qualify for the NREF awards. According to these estimates, NREF award winners comprise only 4% of current AANS members. In addition, a significantly higher percentage of NREF award winners versus AANS members who have not won an NREF award are MDs who also have a PhD (38.4% vs 6.6%; $p < 0.001$) or Master's (10.3% vs 1.4%; $p < 0.001$), and a significantly higher percentage of award winners listed an academic title (70.5% vs 14.8%; $p < 0.001$). Among those who listed an academic title, a significantly higher percentage of NREF award winners were professors compared with AANS members who have not won an NREF award (43% vs 20.5%; $p < 0.001$).

Discussion

Metrics of academic success among surgeon-scientists are a conglomerate of multiple measurements which include factors such as publication productivity and external research funding. A nationwide evaluation of departments of surgery demonstrated a correlation between increased academic productivity and faculty members with advanced graduate degrees, increased publications and citations, and NIH funding.[16] In neurosurgery, participation in a research-based fellowship is a method to promote an academic career with translational research.[17]

Multiple surgical specialties have funded research fellowship opportunities for residents and young investigators. In general, in the specialties of surgery, orthopedics, otolaryngology, plastic surgery, vascular surgery, and oral maxillofacial surgery, formal research training provided through specialty-specific foundation funding correlated with greater success in obtaining NIH funding and a higher chance of entering academic surgery.[1,3,6,8–11] Therefore, we hypothesized that NREF funding would correlate with greater academic success among neurosurgeon award recipients. To our knowledge this type of analysis has yet to be completed in the neurosurgical specialty.

NREF award recipients did enter academics at a higher rate than the general AANS membership, with more than 70% entering academics. Nearly 20% of recipients became neurosurgery chairs, and these individuals had a significantly higher likelihood of receiving NIH funding and being a PI on an R01. Recent characteristics of current neurosurgical chairs demonstrate a trend toward hiring professors who had previously obtained extramural funding.[4] Our data indicate that receiving an NREF award may be a predictor of entering and remaining in academic neurosurgery.

We were also interested in the characteristics of NREF recipients. Forty-nine percent of recipients had an additional postgraduate degree (Master's or PhD), with 39% having a PhD. Not all the PhDs were obtained prior to the award, as certain programs, such as the University of Toronto, provide avenues for residents to obtain a PhD during training. In comparison to AANS members at large, NREF awardees had a higher percentage of having a postgraduate degree. We presume there is a correlation between obtaining a postgraduate degree, especially a PhD, and entering a career in academic neurosurgery. Choi et al. reviewed 613 neurosurgery graduates from 1990 to 2012 and found that a higher proportion of neurosurgeons with MD/PhDs entered academics than their MD-only peers. Among academic neurosurgeons, MD/PhDs have a 4-fold higher chance of being awarded an NIH R01.[2] Fifty-year outcomes from integrated MD/PhD training demonstrate that the additional doctoral research training correlates with success in biomedical research in multiple subspecialties.[7] Therefore it is not surprising that NREF recipients have a higher percentage of additional postgraduate degrees, as these individuals comprise a subgroup of neurosurgeons interested in pursuing translational research.

In addition to investigating the characteristics of individual award recipients, we also analyzed institutional factors that could contribute to success. Among the more than 100 academic neurosurgery programs included in our analysis, institutions that had the greatest number of award recipients had neurosurgical training programs with an NINDS R25. In fact, 40% of award recipients came from a program with a current NINDS R25 for neurosurgery residents, which is designed to provide research education. However, as mentioned above, programs with an NINDS R25 represent only 23% of institutions with award winners and an even smaller percentage of all academic neurosurgical institutions. Winners from NINDS R25 programs were significantly more likely to obtain future NIH funding. These findings indicate that having a research education infrastructure at an institution may be an important factor for obtaining extramural grant funding. Neurosurgery programs that hope to increase their research productivity and promote the creation of academic neurosurgeons can consider implementing this necessary infrastructure. Likewise, applicants who are interested in establishing an academic career may seriously consider programs with a track record of producing successful surgeon-scientists.

Through our data analysis, we came upon some other unexpected factors that were suggestive of future career success. Interestingly, significant regional differences were noted. For example, the lowest number of awardees were from the Southeast region, yet these winners were more likely to receive an R01 as a PI than recipients from other regions. Considering that winners from the Southeast were predominately from one institution (i.e., Duke University), this factor may be attributable to the unique mentorship and/or training provided there.

In addition to NIH funding, academic productivity as measured by h-index was analyzed but no significant differences were noted between subgroups. Residents from programs that produced more than 5 winners had a significantly higher h-index at the time of award receipt in comparison to awardees from programs with fewer than 5 winners (Fig. 3). Having a neurosurgeon as a research mentor did not affect subsequent research success. Award recipients did tend to pursue clinical fellowship training in the same field as their translational research. Vascular

surgery subspecialty training was significantly associated with obtaining full professor status and becoming a chair. Our data correlate with a recent report on neurosurgical chairs which also identified the vascular surgery subspecialty as comprising the largest percentage of chairs as of 2016.[4]

Limitations of our study include that it is retrospective in nature and the data were primarily obtained from online resources. Furthermore, Canadian neurosurgeons are able to win the NREF but many do not qualify for NIH funding. Therefore, it is difficult to make direct comparisons between Canadian and American neurosurgeons regarding this parameter. We did not ascertain other forms of national extramural funding outside of the NIH, such as the National Science Foundation or Department of Defense, as those data are not publicly available. In future studies, NREF winners may be contacted to determine total research funding. NIH funding remains the gold standard and therefore the results of our initial study can give insight into funding trends. Furthermore, we attempted to ascertain an estimate of neurosurgeons in academic practice based on AANS membership. However, not all practicing neurosurgeons are AANS members and not all AANS members qualify for the NREF awards.

Conclusions

The NREF has provided research fellowship training to residents and young investigators for 35 years. To our knowledge, this study is the first to analyze career outcomes of this unique cohort. Our data demonstrate that receiving an NREF award correlates with entering academic neurosurgery and receiving NIH funding in the future. This award mechanism is a potential avenue for fostering academic success in neurosurgery.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Rodriguez, Wilson. Acquisition of data: all authors. Analysis and interpretation of data: Rodriguez, Wilson. Drafting the article: Rodriguez, Wilson. Critically revising the article: Rodriguez, Wilson. Reviewed submitted version of manuscript: Rodriguez, Wilson. Approved the final version of the manuscript on behalf of all authors: Rodriguez. Statistical analysis: Wilson. Administrative/technical/material support: Rodriguez, Wilson. Study supervision: Rodriguez, Wilson.

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