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# Impact of international research fellows in neurosurgery: results from a single academic center

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**OBJECTIVE** International research fellows have been historically involved in academic neurosurgery in the United States (US). To date, the contribution of international research fellows has been underreported. Herein, the authors aimed to quantify the academic output of international research fellows in the Department of Neurosurgery at The Johns Hopkins University School of Medicine.

**METHODS** Research fellows with Doctor of Medicine (MD), Doctor of Philosophy (PhD), or MD/PhD degrees from a non-US institution who worked in the Hopkins Department of Neurosurgery for at least 6 months over the past decade (2010–2020) were included in this study. Publications produced during fellowship, number of citations, and journal impact factors (IFs) were analyzed using ANOVA. A survey was sent to collect information on personal background, demographics, and academic activities.

**RESULTS** Sixty-four international research fellows were included, with 42 (65.6%) having MD degrees, 17 (26.6%) having PhD degrees, and 5 (7.8%) having MD/PhD degrees. During an average 27.9 months of fellowship, 460 publications were produced in 136 unique journals, with 8628 citations and a cumulative journal IF of 1665.73. There was no significant difference in total number of publications, first-author publications, and total citations per person among the different degree holders. Persons holding MD/PhDs had a higher number of citations per publication per person ($p = 0.027$), whereas those with MDs had higher total IFs per person ($p = 0.048$). Among the 43 (67.2%) survey responders, 34 (79.1%) had nonimmigrant visas at the start of the fellowship, 16 (37.2%) were self-paid or funded by their country of origin, and 35 (81.4%) had mentored at least one US medical student, nonmedical graduate student, or undergraduate student.

**CONCLUSIONS** International research fellows at the authors' institution have contributed significantly to academic neurosurgery. Although they have faced major challenges like maintaining nonimmigrant visas, negotiating cultural/language differences, and managing self-sustainability, their scientific productivity has been substantial. Additionally, the majority of fellows have provided reciprocal mentorship to US students.

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**KEYWORDS** international research fellow; global neurosurgery; mentorship; postgraduate research training

The United States (US) has been the leading country in the number of neurosurgical research publications,[1–3] which has driven the influx of international postdoctoral research fellows to US neurosurgical departments for further research training. The importance of global talent recruitment to academic and clinical medicine has been mentioned by many authors in the literature;[4–9] yet most references were in the form of personal perspective or qualitative evaluations. The scientific contribution of international research fellows as a cohort has been underreport-

**ABBREVIATIONS** MD = Doctor of Medicine; PhD = Doctor of Philosophy; US = United States.

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ed. Likewise, detailed and quantified depictions of career pathways and academic or educational contributions of international research fellows in the US have been scarce.

In this study, we aimed to analyze the academic and educational output, origin, career pathways, and subjective experiences of international research fellows in a single neurosurgical department at a large academic institution. Our goal was to evaluate the scientific contributions of the international research fellows to the neurosurgical field, explore their career pathways, reveal potential hardships, and report their subjective evaluation of the fellowship experience. We hypothesized that international research fellows have significant impacts on academic neurosurgery centers, making important academic and educational contributions during their fellowships regardless of their basic science or clinical research background.

## Methods

### Definition of Study Population

For this study's purpose, we aimed to include international research fellows within the Department of Neurosurgery at The Johns Hopkins University School of Medicine for the past decade (2010–2020). In our department, postgraduate visiting scholars from outside the US are generally appointed "postdoctoral fellows." We included "research fellows" with at least 6 months of appointment in their position in our department with at least one dedicated research mentor. "International research fellow" was defined as an individual obtaining a doctoral degree (Doctor of Medicine [MD], Doctor of Philosophy [PhD], or MD/PhD) from a non-US institution before or after their research fellowship. Persons who were US citizens but holding an MD or PhD granted by a non-US institution were also classified as international research fellows. Fellows were included if they were initially recruited before 2010 but their position in the department continued after 2010. Persons who only completed a clinical fellowship without a dedicated research fellowship were excluded.

All international research fellows in our department are credentialed through our institutional academic program managers. The list of eligible candidates for our study was obtained from our credentialing administrators. Information regarding eligibility was confirmed through official institution websites, faculty mentors, or survey results.

### General and Academic Variable Definition and Collection

Academic and career information can be easily obtained through mentors, administrative data, and institutional or corporation websites of current positions. For academic output, metrics included were each fellow's total number of publications, h-index, citations, journals in which they published, as well as the journal's impact factor for each publication. For the rate of research output, we used fellow-years, which is similar to the concept of patient-years, as the rate is calculated by dividing the total number of publications by the product of the number of fellows and number of years in our department as a research fellow.

All publications included in this study were limited to those produced during the research fellowship time in our department. In order to accrue publications with a Johns Hopkins affiliation, 1- and 2-year grace periods following the fellowship end date were given for the inclusion of clinical and basic science publications, respectively. Lists of publications were queried from the MEDLINE database. Citations and h-indices for those specific publications were calculated using the Scopus database. Journal impact factors were retrieved from the 2020 version of "InCites Journal Citation Reports" from Web of Science. For a descriptive report, the cumulative journal impact factor was used, which was calculated as the sum of all impact factors of each journal in which each paper had been published. The total impact factor of each fellow was calculated in the same way. Publications summarized by a per-fellow basis might have duplicates because, in some situations, multiple research fellows were involved in one publication. To remove this bias, we also analyzed all unique publications produced by all fellows in the past decade.

### Survey Data Collection

Surveys were sent to all candidates using the best available current contact information. The survey was conducted through Qualtrics. The survey consisted of 5 sections (demographics, department-related questions, academic contributions, after research fellowship, and subjective questions) with a total of 69 questions designed to provide detailed demographic, academic, and educational information, as well as subjective data for evaluation of the overall research fellowship experience. Of note, self-funding has been prohibited for postdoctoral positions by our institution policy since July 2016. Therefore, self-funding as source of support in the survey questionnaire only applied to research fellows before implementation of this policy.

### Statistical Analysis

All study candidate data were de-identified by the first author (W.Y.) and analyzed. General and academic information were compared between fellows holding different degrees (MD vs MD/PhD vs PhD). A chi-square test was used for categorical variables, and an ANOVA test was used for continuous variables. All continuous variables were reported as both mean ± standard deviation and median with range. Statistical significance was defined as $p < 0.05$, and p values were reported as two-sided. All analyses were performed using R statistical software (version 4.0.2, R Foundation for Statistical Computing). Information visualization was performed using Microsoft PowerPoint and Google Visualization API.[6]

## Results

### General Information, Demographics, and Career Pathway After Fellowship

This study was approved by our institutional review board as exempt status. A total of 64 international research fellows who had obtained their doctoral degrees from 22 non-US countries were identified using the aforementioned criteria. Twenty-three unique mentors were involved in mentoring the departmental fellows, and 7 faculty mentored 3 or more international fellows, with 1 faculty serving as a mentor for 19 fellows. Among the research fellows included in our study, 42 (65.6%) were male, and

**TABLE 1. Summary of countries in which advanced degrees were obtained by international fellows**

| Country | Overall (n = 64) | MD (n = 42) | MD/PhD (n = 5) | PhD (n = 17) |
|---|---|---|---|---|
| Mexico | 11 (17.2) | 9 (21.4) | 1 (20.0) | 1 (5.9) |
| China | 9 (14.1) | 5 (11.9) | 3 (60.0) | 1 (5.9) |
| Israel | 5 (7.8) | 5 (11.9) | 0 (0) | 0 (0) |
| Spain | 5 (7.8) | 3 (7.1) | 0 (0) | 2 (11.8) |
| Italy | 4 (6.3) | 3 (7.1) | 0 (0) | 1 (5.9) |
| Japan | 3 (4.7) | 3 (7.1) | 0 (0) | 0 (0) |
| Netherlands | 3 (4.7) | 1 (2.4) | 1 (20.0) | 1 (5.9) |
| Thailand | 3 (4.7) | 1 (2.4) | 0 (0) | 2 (11.8) |
| Brazil | 2 (3.1) | 0 (0) | 0 (0) | 2 (11.8) |
| Colombia | 2 (3.1) | 2 (4.8) | 0 (0) | 0 (0) |
| Egypt | 2 (3.1) | 2 (4.8) | 0 (0) | 0 (0) |
| England | 2 (3.1) | 1 (2.4) | 0 (0) | 1 (5.9) |
| Greece | 2 (3.1) | 1 (2.4) | 0 (0) | 1 (5.9) |
| Hungary | 2 (3.1) | 2 (4.8) | 0 (0) | 0 (0) |
| Iran | 2 (3.1) | 1 (2.4) | 0 (0) | 1 (5.9) |
| Lebanon | 2 (3.1) | 2 (4.8) | 0 (0) | 0 (0) |
| Canada | 1 (1.6) | 0 (0) | 0 (0) | 1 (5.9) |
| France | 1 (1.6) | 0 (0) | 0 (0) | 1 (5.9) |
| Germany | 1 (1.6) | 0 (0) | 0 (0) | 1 (5.9) |
| Poland | 1 (1.6) | 0 (0) | 0 (0) | 1 (5.9) |
| Syria | 1 (1.6) | 1 (2.4) | 0 (0) | 0 (0) |

Values expressed as number (%).

the distribution of types of degrees for MD, MD/PhD, and PhD was 42 (65.6%), 5 (7.8%), and 17 (26.6%), respectively. Detailed information regarding the distribution of degrees with respect to countries is depicted in Table 1. Of the 22 countries granting the advanced degree, the top 5 countries of origin with the most international research fellows were Mexico (11 [17.2%]), China (9 [14.1%]), Israel (5 [7.8%]), Spain (5 [7.8%]), and Italy (4 [6.3%]). A world map representation of all the fellows is illustrated in Fig. 1.

With regard to home university (n = 54), Erasmus University Rotterdam in the Netherlands contributed 3 graduates (5.6%), 8 universities contributed 2 graduates each (Khon Kaen University, Peking Union Medical College, Tehran University of Medical Sciences, Tel Aviv University, University of Barcelona, University of Guadalajara, University of Padua, and University of Valencia), and the rest of the universities (n = 45) contributed 1 graduate each.

Average duration of fellowship was 27.9 months, with MD (23.9 ± 15.5 months) degree holders having a significantly shorter stay ($p = 0.048$) than MD/PhD (39.6 ± 34.4 months) and PhD (34.6 ± 19.0 months) degree holders. Among graduated fellows, 34 (53.1%) stayed in the US, 28 (43.8%) returned to their home country, and 2 (3.1%) went to another country. Thirty-nine (60.9%) graduates remained in the field of neurosurgery, with 14 (21.9%) becoming attendings, 13 (20.3%) gaining acceptance into a clinical fellowship or residency training program, and 12 (18.8%) becoming either a research fellow or a research associate at the time of data collection. Of note, 9 (14.1%) matched into US neurosurgery programs, including 5 (7.8%) who matched into our neurosurgery residency program. Other career specialties or pathways are illustrated in a river plot in Fig. 2.

## Scientific Output of International Fellows

Table 2 summarizes the research output of international fellows by degree. During a total of 146.98 fellow-years, the 64 fellows were involved in 460 unique publications with a cumulative journal impact factor of 1665.73 and total citations of 8628, translating to a rate of 3.13 publications per fellow per year, 11.64 impact factors per fellow per year, and 58.70 citations per fellow per year. Articles were published in 136 unique journals. The top 10 journals with the most published papers are depicted in Fig. 3. There were no differences among the different degree holders in terms of total number of publications, first-author publications, or total citations. However, MD/PhD holders appeared to have higher average citations per publication per person (55.2 ± 48.9 citations) than the other two degree holders ($p = 0.027$), likely due to longer average publication lifetimes (duration between data collection and publication date), whereas MD holders had higher cumulative journal impact factors than the other degree holders ($p = 0.048$). Number of publications with number of citations in each year is illustrated in Fig. 4. An overview of academic productivity regarding first-author papers is provided in Supplementary Table 1.

## Survey Results

Among the 64 fellows who received the survey, 43

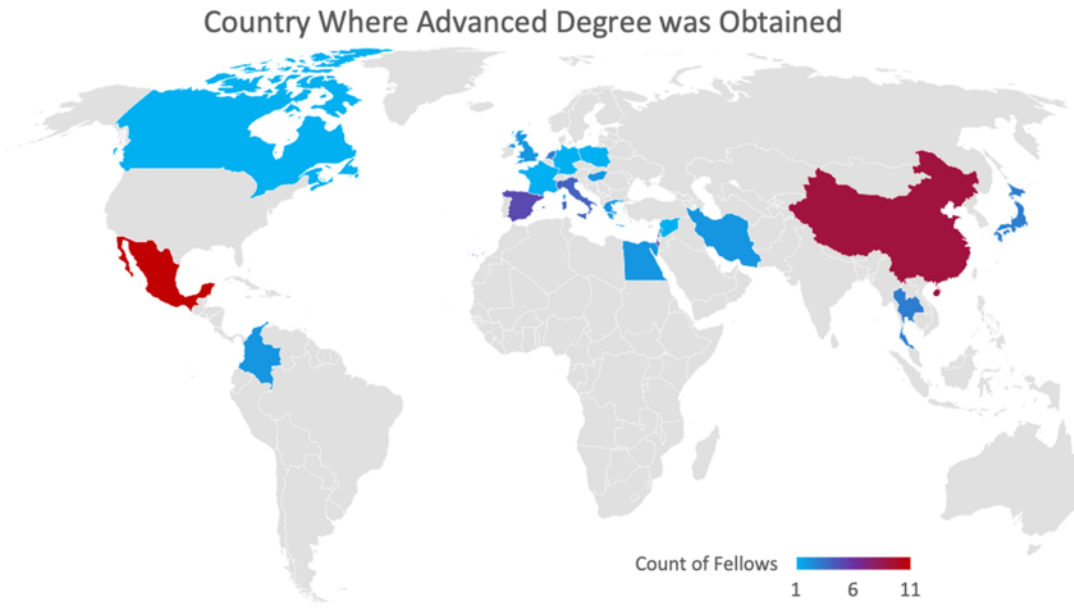


**FIG. 1.** World map of distribution of countries in which degrees were obtained. *Red* represents the highest number of fellows in a single country, whereas *blue* represents the lowest number and *purple* represents the number that is between *blue* and *red* regarding the number of fellows. Figure is available in color online only.

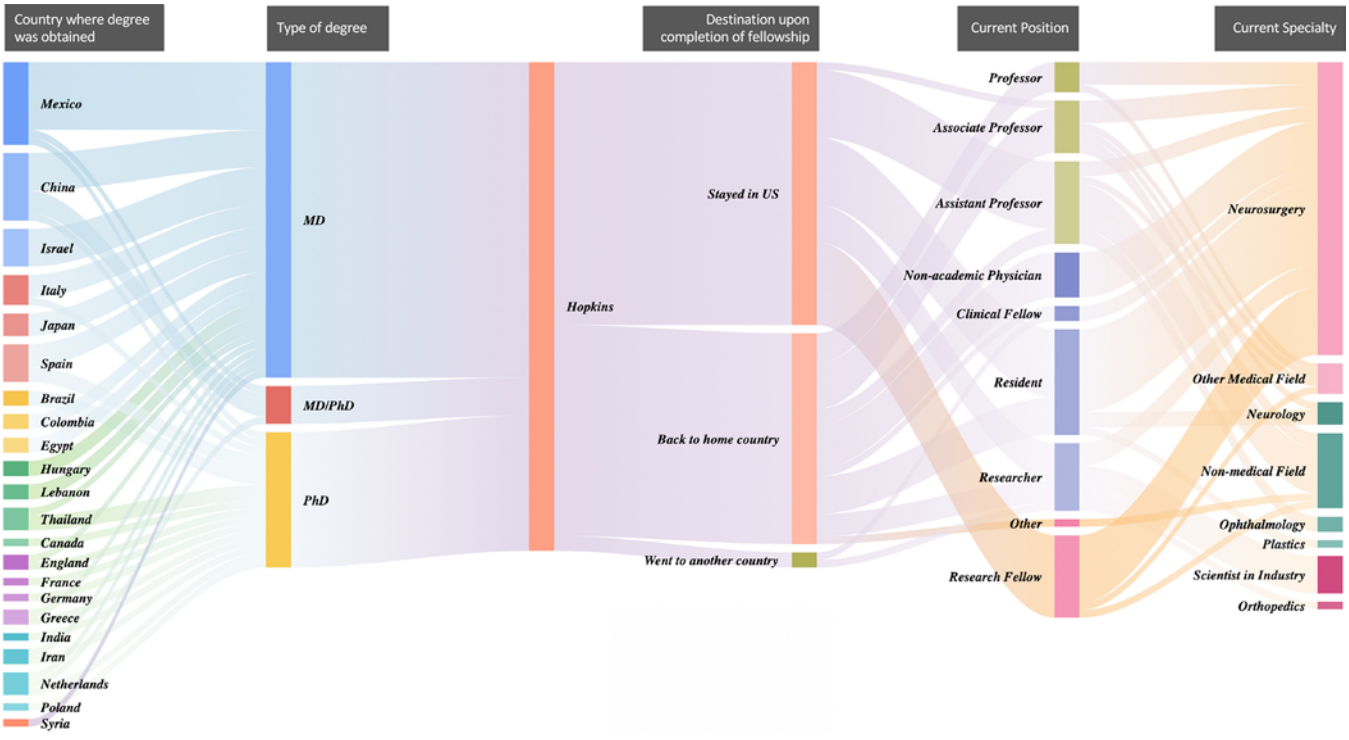


**FIG. 2.** A river plot of career development with a focus on destination after the research fellowship was completed. The plot demonstrates that despite heterogeneous backgrounds in terms of country of origin and clinical or basic science training, most individuals achieved academic success after research fellowship training, with approximately one-third being assistant professor to professor in different academic specialties. This plot also shows that around half of neurosurgery research fellows remained in the field to continue to contribute. Figure is available in color online only.

**TABLE 2. Comparison of academic productivity parameters among different degree holders**

| Parameter | Overall (n = 64) | MD (n = 42) | MD/PhD (n = 5) | PhD (n = 17) | p Value |
|---|---|---|---|---|---|
| Fellowship duration in mos | | | | | 0.048* |
| Mean (SD) | 27.9 (18.9) | 23.9 (15.5) | 39.6 (34.4) | 34.6 (19.0) | |
| Median [min, max] | 24.1 [5.97, 94.0] | 17.2 [5.97, 61.1] | 23.7 [11.1, 94.0] | 25.3 [6.00, 66.6] | |
| No. of publications per person† | | | | | 0.331 |
| Mean (SD) | 8.58 (12.6) | 10.3 (14.9) | 5.60 (5.37) | 5.24 (5.13) | |
| Median [min, max] | 4.00 [0, 73.0] | 4.50 [0, 73.0] | 3.00 [2.00, 15.0] | 4.00 [0, 17.0] | |
| First-author publications per person† | | | | | |
| Mean (SD) | 2.67 (5.05) | 3.36 (6.00) | 1.40 (1.52) | 1.35 (1.97) | 0.329 |
| Median [min, max] | 1.00 [0, 25.0] | 1.00 [0, 25.0] | 1.00 [0, 4.00] | 1.00 [0, 7.00] | |
| Total citations per person† | | | | | 0.164 |
| Mean (SD) | 165 (269) | 172 (295) | 349 (385) | 92.1 (93.7) | |
| Median [min, max] | 54.5 [0, 1230] | 32.5 [0, 1230] | 139 [15.0, 848] | 77.0 [0, 287] | |
| Average citations per publication per person† | | | | | 0.027* |
| Mean (SD) | 21.2 (30.0) | 17.6 (26.6) | 55.2 (48.9) | 19.9 (27.2) | |
| Median [min, max] | 9.34 [0, 136] | 4.95 [0, 112] | 46.3 [5.00, 136] | 10.0 [0, 116] | |
| h-index of publications† | | | | | 0.911 |
| Mean (SD) | 3.92 (3.90) | 3.98 (4.33) | 5.00 (4.06) | 3.47 (2.65) | |
| Median [min, max] | 2.50 [0, 18.0] | 2.00 [0, 18.0] | 3.00 [2.00, 12.0] | 3.00 [0, 8.00] | |
| Total impact factor per person† | | | | | 0.048* |
| Mean (SD) | 32.3 (40.2) | 36.0 (46.6) | 23.5 (20.5) | 25.6 (23.8) | |
| Median [min, max] | 15.6 [0, 168] | 14.0 [0, 168] | 19.0 [9.86, 59.4] | 16.3 [0, 72.9] | |
| Maximum impact factor per person† | | | | | 0.985 |
| Mean (SD) | 8.20 (10.9) | 8.31 (12.6) | 7.41 (2.75) | 8.16 (7.36) | |
| Median [min, max] | 5.24 [0, 74.7] | 4.85 [0, 74.7] | 6.77 [4.00, 10.3] | 6.57 [0, 30.0] | |
| Impact factor per publication per person† | | | | | 0.740 |
| Mean (SD) | 3.70 (2.98) | 3.05 (2.27) | 4.49 (1.20) | 5.08 (4.26) | |
| Median [min, max] | 3.14 [0, 16.3] | 2.56 [0, 9.29] | 3.96 [3.40, 6.38] | 4.08 [0, 16.3] | |

* Statistical significance ($p < 0.05$).

† Only publications produced during research fellowship at our department were included, with a grace period of 1 year for clinical research and 2 years for basic science research.

responded to the survey (67.2%). As indicated in Table 3, most fellows (25 [58.1%]) were recruited by a mentor, by an acquaintance of the mentor, or through part of their structured training (within either their medical program or their research program). Twelve (27.9%) fellows sought the position independently, whereas 6 (14.0%) listed "other" for method of establishing contact with their mentors.

The majority of fellows (31 [72.1%]) started on an exchange visitor visa (J-1; Table 3). At the end of the fellowship, most remained on the same visa (23 [53.5%]), whereas the other 8 J-1 visa holders converted to a permanent resident (n = 5), a nonimmigrant worker visa (n = 1), or an other/unknown visa type (n = 2). Among the 43 respondents, 14.0% (n = 6) were self-funded through the fellowship period, whereas 21 (48.8%) held an employed position funded by the mentor. Only 16 (37.2%) fellows were funded by grants from the country of origin or US grants. Most fellows met with mentors for at least 4 hours per month (35 [81.4%]), and most (19 [44.2%]) were involved in both clinical and basic science research.

For educational output, 33 (76.7%) fellows mentored at least one US medical student, 28 (65.1%) mentored at least one US nonmedical graduate student, and 31 (72.1%) mentored at least one US undergraduate student. Stratified educational contributions of international fellows by degree type are summarized in Table 4.

### Subjective Evaluation of Experience

Subjective evaluation of the research fellow experience was also surveyed. Among the 43 survey responders, 40 (93.0%) responded to > 80% of the subjective questions. Among these 40 responders, 31 (91.2%) of 34 nonimmigrant visa holders subjectively evaluated the level of ease in securing a visa. When graded on a level of 0–10, with 10 being the easiest or best experience, fellows reported an average score of 8.9 ± 1.6 regarding whether the fellow experience helped with their career, a score of 8.5 ± 2.3 regarding whether the mentor was approachable or easy to work with, a score of 9.1 ± 1.6 regarding whether the mentor was supportive of their academic activity, and a score of 5.7 ± 3.0 regarding whether obtaining fellowship fund-

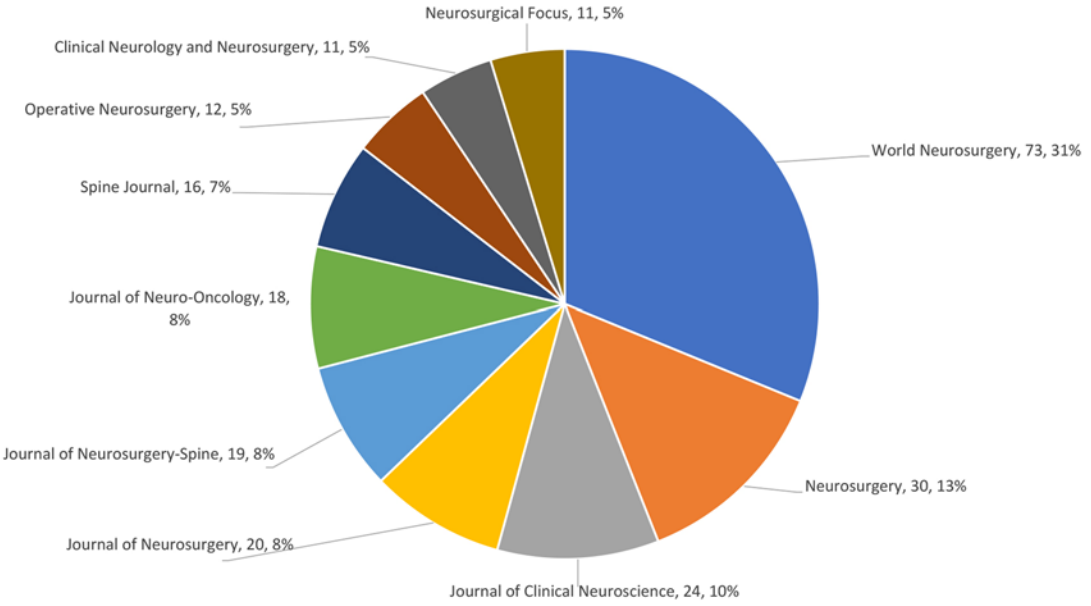


**FIG. 3.** Pie chart of top 10 journals with the most papers published by international research fellows. Figure is available in color online only.

ing was easy. The score for whether it was easy to secure a visa to work in the US was 6.7 ± 2.9.

## Discussion

### Summary of Critical Findings in the Study

This study featured the productive academic and educational output, career progression, and challenges of international research fellows in the field of neurosurgery through their experience in a single neurosurgical department during a 10-year period. We found that international research fellows typically held their research positions for 2–3 years, and approximately half remained in the US to continue their careers. Additionally, they achieved an average rate of around 3 publications per fellow per year, and each publication generated an average of 60 citations

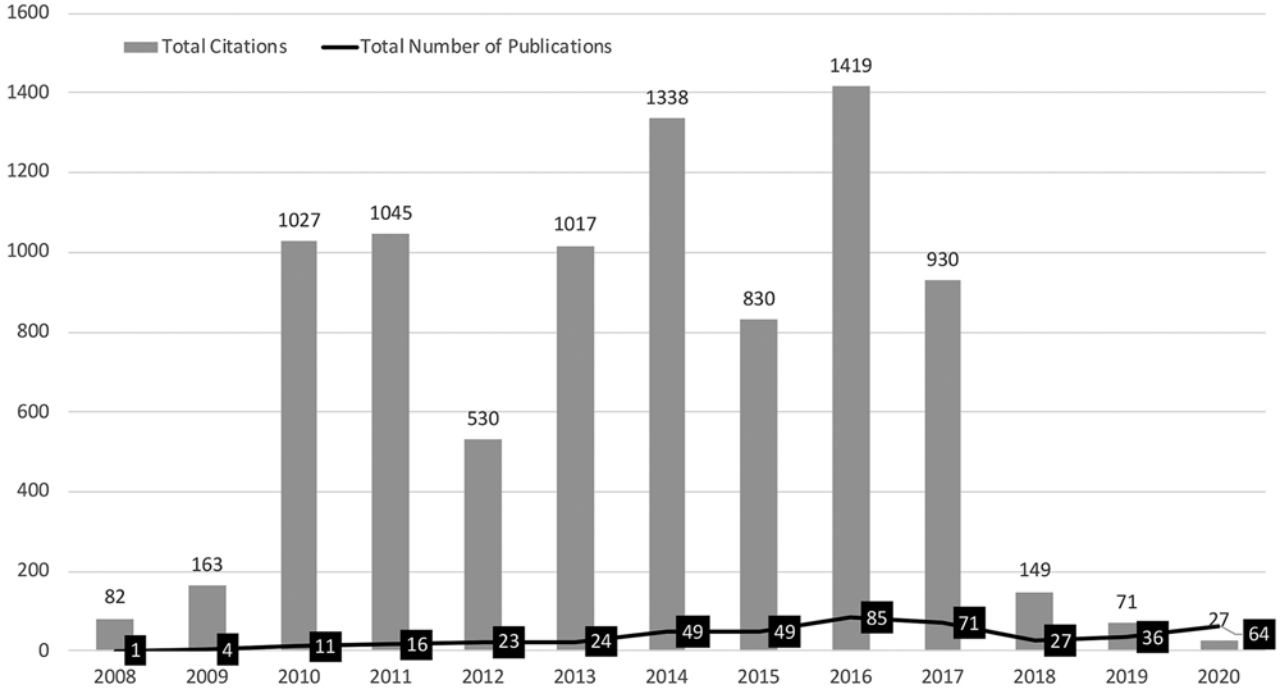


**FIG. 4.** Bar and line graphs of distribution of publications and citations over the years.

**TABLE 3. General information for international research fellows based on survey results**

| Variable | Overall (n = 43) | MD (n = 31) | MD/PhD (n = 4) | PhD (n = 8) |
|---|---|---|---|---|
| How was mentor contacted | | | | |
| Part of rotation in home country program | 4 (9.3) | 4 (12.9) | 0 (0) | 0 (0) |
| Introduced to mentor through acquaintance | 15 (34.9) | 13 (41.9) | 0 (0) | 2 (25.0) |
| Through collaborations on projects | 3 (7.0) | 2 (6.5) | 1 (25.0) | 0 (0) |
| Was reached out to by mentor for recruitment | 3 (7.0) | 1 (3.2) | 1 (25.0) | 1 (12.5) |
| Contacted mentor by myself | 12 (27.9) | 7 (22.6) | 2 (50.0) | 3 (37.5) |
| Other | 6 (14.0) | 4 (12.9) | 0 (0) | 2 (25.0) |
| Visa status at start of fellowship | | | | |
| F1 OPT (student visa on temporary working permission) | 2 (4.7) | 2 (6.5) | 0 (0) | 0 (0) |
| J-1 (exchange visitor) | 31 (72.1) | 23 (74.2) | 4 (100) | 4 (50.0) |
| H-1B (nonimmigrant worker) | 1 (2.3) | 0 (0) | 0 (0) | 1 (12.5) |
| Permanent resident | 3 (7.0) | 2 (6.5) | 0 (0) | 1 (12.5) |
| US citizen | 3 (7.0) | 3 (9.7) | 0 (0) | 0 (0) |
| Other | 3 (7.0) | 1 (3.2) | 0 (0) | 2 (25.0) |
| Visa status at end of fellowship | | | | |
| J-1 (exchange visitor) | 23 (53.5) | 18 (58.1) | 3 (75.0) | 2 (25.0) |
| H-1B (nonimmigrant worker) | 3 (7.0) | 2 (6.5) | 0 (0) | 1 (12.5) |
| Permanent resident | 9 (20.9) | 5 (16.1) | 1 (25.0) | 3 (37.5) |
| US citizen | 3 (7.0) | 3 (9.7) | 0 (0) | 0 (0) |
| Other | 4 (9.3) | 2 (6.5) | 0 (0) | 2 (25.0) |
| Unknown | 1 (2.3) | 1 (3.2) | 0 (0) | 0 (0) |
| Funding | | | | |
| Funded through country-of-origin grants | 12 (27.9) | 10 (32.3) | 1 (25.0) | 1 (12.5) |
| Funded through US grants | 4 (9.3) | 2 (6.5) | 1 (25.0) | 1 (12.5) |
| Paid fellowship or funded by mentor | 21 (48.8) | 13 (41.9) | 2 (50.0) | 6 (75.0) |
| Self-funded | 6 (14.0) | 6 (19.4) | 0 (0) | 0 (0) |
| Monthly meeting w/ mentors | | | | |
| <1 hr | 2 (4.7) | 0 (0) | 0 (0) | 2 (25.0) |
| 1–2 hrs | 1 (2.3) | 1 (3.2) | 0 (0) | 0 (0) |
| >2–3 hrs | 4 (9.3) | 1 (3.2) | 1 (25.0) | 2 (25.0) |
| >3–4 hrs | 1 (2.3) | 1 (3.2) | 0 (0) | 0 (0) |
| >4–5 hrs | 9 (20.9) | 6 (19.4) | 0 (0) | 3 (37.5) |
| >5–10 hrs | 11 (25.6) | 8 (25.8) | 3 (75.0) | 0 (0) |
| >10 hrs | 15 (34.9) | 14 (45.2) | 0 (0) | 1 (12.5) |
| Type of research involved | | | | |
| Clinical | 9 (20.9) | 9 (29.0) | 0 (0) | 0 (0) |
| Basic science research (including engineering research) | 15 (34.9) | 6 (19.4) | 2 (50.0) | 7 (87.5) |
| Both | 19 (44.2) | 16 (51.6) | 2 (50.0) | 1 (12.5) |

OPT = optional practical training.
Values expressed as number (%).

to date. We compared the demographics and academic productivity among different degree holders, and fellows with an MD/PhD had the highest average citation per publication per fellow, whereas MDs had the highest total impact factor. Otherwise, PhD, MD, and MD/PhD degree holders attained similar accomplishments on first-author publications, total citations, h-indices of publications, and average impact factors per publication per person. Despite coming from different backgrounds, most fellows pursued careers in the field of neurosurgery and continued to advance our field through clinical or academic contributions.

Through survey results, we demonstrated that the reciprocal contribution of these fellows is substantial, as 35 fellows mentored at least one US medical student, nonmedical graduate student, or undergraduate student. We found that most of the survey responders worked on a J-1 visa, which is one of the most restrictive visa types available to foreigners. Through subjective assessment, most fellows rated the overall experience as a fellow in a US neurosur-

**TABLE 4. Educational activities of international research fellows based on survey results**

| Responsibility | Overall (n = 43) | MD (n = 31) | MD/PhD (n = 4) | PhD (n = 8) |
|---|---|---|---|---|
| Mentored medical students | | | | |
| None | 10 (23.3) | 8 (25.8) | 1 (25.0) | 1 (12.5) |
| 1–2 | 7 (16.3) | 5 (16.1) | 1 (25.0) | 1 (12.5) |
| 3–5 | 10 (23.3) | 5 (16.1) | 0 (0) | 5 (62.5) |
| >5 | 16 (37.2) | 13 (41.9) | 2 (50.0) | 1 (12.5) |
| Mentored graduate students | | | | |
| None | 15 (34.9) | 12 (38.7) | 1 (25.0) | 2 (25.0) |
| 1–2 | 15 (34.9) | 9 (29.0) | 2 (50.0) | 4 (50.0) |
| 3–5 | 5 (11.6) | 3 (9.7) | 1 (25.0) | 1 (12.5) |
| >5 | 8 (18.6) | 7 (22.6) | 0 (0) | 1 (12.5) |
| Mentored undergraduate students | | | | |
| None | 12 (27.9) | 10 (32.3) | 1 (25.0) | 1 (12.5) |
| 1–2 | 4 (9.3) | 3 (9.7) | 1 (25.0) | 0 (0) |
| 3–5 | 13 (30.2) | 9 (29.0) | 1 (25.0) | 3 (37.5) |
| >5 | 14 (32.6) | 9 (29.0) | 1 (25.0) | 4 (50.0) |

Values expressed as number (%).

gery department as excellent, but the challenge of securing visa status and funding to cover personal expenses has been notable.

## The Founding of Neurosurgery and International Collaborations

The field of neurosurgery has blossomed from international academic collaborations. The founding father of neurosurgery, Harvey Cushing, worked as an international postdoctoral researcher in Europe for a year before officially starting his career at The Johns Hopkins Hospital.[10] One of his most important discoveries in the field, the Cushing reflex, was formulated through working in the laboratory of the Nobel laureate Theodor Kocher on canine experiments in Bern, Switzerland.[10–15] He was the first American student of the English Nobel laureate Sir Charles Sherrington, and the interaction between these two giants was considered one of the early models of "bench-to-bedside" collaborations.[10,16] Cushing was also inspired by his collaboration with Italian internist Scipione Riva-Rocci, resulting in the earliest advocacy for noninvasive blood pressure measurement in North America. This concept was later incorporated into surgical operations to enable intraoperative vital sign monitoring, arguably one of Cushing's most important contributions to the field of surgery.[10,12] Expectedly, the reciprocal influence of Cushing and the European neurological society was equally significant. As stated by the prominent British neurosurgeon Francis Gillingham, "what Cushing had originally derived from Britain and Europe and continued to derive, he returned a thousand-fold."[17]

Another precedent was set by Professor M. Gazi Yaşargil, generally regarded as the founding father of microsurgery, who, as a neurosurgeon from the University of Zurich, initially arrived in the US as an international scholar to work with Dr. Raymond Donaghy at the University of Vermont. This experience stimulated the development of an entire corpus of microscopic neurosurgical techniques and instruments, which enabled Yaşargil to pioneer the revolution of cerebrovascular neurosurgery.[18–20] During his time at the University of Vermont and later as a professor at the University of Arkansas for Medical Sciences in Little Rock, he mentored and influenced generations of neurosurgeons.

An example in our department of ongoing international collaboration is contributed by Professor Alessandro Olivi. After obtaining his MD at the University of Padova in Italy, he completed his neurosurgical residency at the University of Cincinnati. On completion of his residency, Olivi joined our department initially as a clinical and research fellow specializing in neuro-oncology and was subsequently recruited to faculty, rising through the academic ranks, amassing notable achievements, and mentoring faculty, residents, and students. Since his departure in 2015 to chair a prestigious neurosurgery department in Rome, Italy, he has continued to host our senior neurosurgery residents in elective rotations, who have gained extraordinary experience from their interactions with our Italian neurosurgical colleagues. The significance of transitioning from an international fellow to a mentor in the US and then providing reciprocal mentorship to the next generation is noteworthy.

## Scientific Productivity of International Research Fellows

Currently, there is no consensus regarding the optimal parameters or formula to evaluate the scientific productivity of an individual. The most frequently utilized indicators of scholarly productivity are number of publications, citations, h-index, journal impact factor, research funding, and degree of coauthorship.[21–26] These indicators are either interpreted independently or included as part of a comprehensive evaluation of the duration of scientific activity or even the salary of the individual.[23] We have highlighted the commonly utilized indicators in this study. However,

it must be emphasized that the benchmarks for the postdoctoral fellow publication rate, citation rate, and journal impact factor are highly variable between different specialties and may significantly differ between clinical and basic science research even within the same specialty.[21,27]

Although no direct comparison was made in this study between international degree holders and US degree holders, it is still apparent that international fellows are capable of thriving with opportunities in academic neurosurgery. Among all indicators, publication rate appears to be the most frequently quoted.[21,23,25,26,28,29] Several studies have addressed the academic productivity of neurosurgery residents, clinical fellows, or neurosurgeons.[25,26,29] However, data on the scientific productivity of research fellows in neurosurgery is almost nonexistent. Publications describing academic output in general medicine can provide a reference context. Rørstad and Aksnes performed a large-scale analysis of all research staff (including research faculty and PhD students) in Norwegian academic institutions and highlighted an average publication rate of 0.28 to 0.97 publications per year in the field of medicine in general, with a rate of 0.43 publications per year for postdoctoral fellows.[30] In a study that included only postdoctoral fellows who were awarded National Research Service Awards, Ross and colleagues noted that 43% of graduates averaged at least one publication per year.[31] In comparison, international research fellows in our department averaged 3.13 publications per year, significantly higher than reported data in other specialties.[24,28–30,32,33] Regarding citations, the overall total citations per fellow in our study was 165. When factoring in the short duration of the fellowship (27.9 months), the rate of citation per publication is comparable to that of National Institutes of Health applicants or grant receivers in other specialties, which also included full professors, as well as chairs or deans.[28,32,33]

The increased scientific productivity of participants in our study and those described in the literature can be partially attributed to the fact that neurosurgery in general is a demanding academic field. In Patience and colleagues' recent work that ranked the citation rate of publications among all scientific categories,[34] both surgery and neuroscience research, which would include the categories of most neurosurgical publications, ranked in the top 10 of all 236 scientific categories.

## Barriers to Success

Barriers to the success of international research fellows in the US are multifold. First, securing a worker visa is required to work as a foreigner in the US, which by itself presents several obstacles. For example, the J-1 visa (exchange visitor visa), the commonly used type in our study, may be given in 1- to 3-year intervals for a maximum of 6–7 years and commonly requires the scholar to return to their home country for at least 2 years before becoming eligible to apply for immigrant status.[35,36] The uncertainty regarding the timing and chances of approval for reentry into their home country was anxiety-provoking for many, especially when it came to attending to family emergencies.[37] Access to governmental and nongovernmental funding for research in the US has become increasingly difficult over the years.[38,39] For example, our study found that 62.8% of fellows were supported during the fellowship at their own expense or through mentor sponsorship, 27.9% were funded through the country of origin, and only 9.3% were funded through US grants. One of the reasons for the difficulty is that many funding programs prohibited the primary investigator or funded personnel from having nonimmigrant status. This can make staying in the US for long-term careers unsustainable for some. Finally, from the mentor and institutional perspectives, accounting for these uncertainties associated with international fellows, the employment of such individuals for research fellowships may be less attractive compared to domestic candidates.

The situation is further complicated by interactions between these challenges and added difficulty from other barriers. A common scenario is a reluctance to employ international fellows because of the risk and prohibitions of funding from the mentor's perspective, which adds financial hardship to these individuals and creates disadvantages in securing a visa or change of status to immigrant status; that is, securing a visa or a change of status will create significant administrative and legal expense, which in turn hinders the chances for employment. This is further compounded by the increased restrictions on visas during the past few years.[37,40] Although we have appreciated notable academic success in our cohort and significant contributions to the field of neurosurgery despite these obstacles, the likelihood of individuals being forced to leave for a position back in their home country or even in another country has been significant.[37,41]

Nevertheless, as indicated by the results of this study, international research fellows have made an important contribution to academic neurosurgery despite facing many challenges and continue to flourish in the US or their respective countries.

## Study Limitations

This study has limitations that need to be clarified for accurate interpretation of the data. First, it is a retrospective review of a cohort, which embodies the limitations of general retrospective studies. We examined the neurosurgery department of a single academic institution, which might introduce selection bias and be less generalizable to other programs. Short-term scholars (< 6 months) were excluded, as there were a significant number of clinical visiting scholars who did not participate in research but were also listed as research fellows. The capability of securing contact information was essential for the inclusion of international fellows; therefore, only the recent decade was chosen as the study period, limiting our sample size. As mentioned, the evaluation of academic productivity in the literature is currently variable, and we have chosen the parameters most frequently used in previously published work. Other types of important scholarly productivity, including participation in book chapters, conferences, teaching, abstract publication, or oral presentations at congresses, were not evaluated. A grace period was given for publications to be eligible for inclusion, but we might still have underreported academic productivity, as many fellows had continued collaboration with members of the department many years after leaving, resulting in subse-

quent publications that may have been inadvertently omitted in this study. Impact factor was only obtained for the current year as opposed to the year of publication, which might not accurately reflect the impact of the journal at the time of publication. The response rate to the survey was 67.2%, which is a relatively high survey response rate, but response bias might exist, as fellows who had a positive experience might be more likely to respond. However, we did observe a wide range of scoring in the subjective evaluation of experience, indicating that even those who had suboptimal experiences also responded to the survey. Finally, no comparison between international and US research fellows was made, as US medical graduates working as research fellows in a clinical department is rare; therefore, we could not generate sufficient numbers to make this comparison. Furthermore, the argument of whether a US or an international research fellow is more productive is beyond the scope of this study.

## Conclusions

The collaboration of global talent in neurosurgery has been both historical and ongoing. Moreover, such efforts have led to substantial academic and educational contributions by all involved. Despite the hardships associated with international status, the production rate of scientific publications and parameters representative of publications contributed by these individuals have exceeded the reported metrics in medicine in general. Our study will provide insight to both future mentors and research fellows regarding possible expectations for achievement.

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## Disclosures

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## Supplemental Information

### Online-Only Content

Supplemental material is available with the online version of the article.

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