



Home Program Matching in Neurosurgical Residency Programs: A 7-Year Study

Albert Antar¹, James Feghali¹, Wuyang Yang¹, Elizabeth E. Wicks¹, Shahab Aldin Sattari¹, Sean Li², Timothy F. Witham¹, Henry Brem¹, Judy Huang¹

OBJECTIVE: The objective of the study was to determine home program matching percentage (staying in a program affiliated with one's medical school) for each neurosurgical residency program in the United States. Secondly, it was to elucidate both program-level and resident characteristics associated with home program matching.

METHODS: Demographic and bibliometric characteristics were collected for 1572 residents in U.S.-based and Accreditation Council for Graduate Medical Education—accredited neurosurgery programs over the 2014–2020 match period using publicly available websites. Program characteristics were collected, including number of clinical faculty, top 20 Doximity research ranking, top 10 Doximity reputation ranking, top 10 *U.S. News* department ranking, affiliation with a *U.S. News* top 10 medical school, and geographic region. Programs were ranked according to home program matching percentage, and associations were statistically evaluated.

RESULTS: The average home program matching percentage per residency was 18.6%. NewYork-Presbyterian/Columbia retained the largest percentage of its own medical students with a home program matching percentage of 57.14%. From the resident frame of reference, only a higher preresidency H-index (3.7 ± 4.0 vs. 3.2 ± 3.7 , $P = 0.033$) was significantly associated with home program matching. From a program perspective, program size (standardized $\beta = 0.234$, $P = 0.006$), Doximity research (standardized

$\beta = 0.206$, $P = 0.031$), Doximity reputation (standardized $\beta = 0.196$, $P = 0.040$), and *U.S. News* program rankings (standardized $\beta = 0.200$, $P = 0.036$) were all significantly associated with home program matching. Overall home program matching percentage remained relatively constant over the 2014–2020 time period.

CONCLUSIONS: The results of this study delineate home program matching patterns on a program-by-program level for U.S. neurosurgical residency programs.

INTRODUCTION

The 7 years of neurosurgical residency rank among the most difficult of any postgraduate medical subspecialty training. How medical students rank residency programs and how residency programs rank students are also complex and multifaceted.^{1,2} Aside from impressive academic credentials,³ medical students must also garner strong letters of recommendation⁴ and connect with supportive mentors.⁵ The presence of a home program in promoting medical student recruitment into neurosurgery is critical.⁶ This may be because a home program allows medical students to become more familiar with the field, connect with supportive mentors, and engage in research.^{7,8} Equally as important, however, is the ability of a neurosurgery program to become more familiar with its own medical students and potentially give preference to its own students in the match.

Key words

- Education
- Home program
- Recruitment
- Research
- Residency

Abbreviations and Acronyms

A.O.A.: Alpha Omega Alpha Honor Medical Society
IMG: International medical graduate
M.D.: Doctor of Medicine
M.P.H.: Master of Public Health
M.S.: Master of Science
PGY: Postgraduate year

Ph.D.: Doctor of Philosophy

USMLE: United States Medical Licensing Examination

From the ¹Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, Maryland; and ²Pratt School of Engineering, Duke University, Durham, North Carolina, USA

To whom correspondence should be addressed: Judy Huang, M.D.
 [E-mail: jhuang24@jhmi.edu]

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Home program matching may be beneficial for medical students by allowing them to continue working with previously established mentors, further on-going research from the medical school, and develop stronger ties to the communities in which they practice. For residency programs, matching home program students may provide similar benefits in addition to training residents whose skills and abilities are personally known to the faculty. Critically, however, home program matching may also stymie the diversity of the resident cohort. Research by Kim et al. demonstrates the profound impact diverse neurosurgeons can have by sharing different perspectives to advance the field, connecting with a broad patient population, and championing equity.⁹ Moreover, neurosurgery has traditionally lacked a diverse workforce, and while recent efforts have been made to increase diversity, this remains a crucial unmet need.^{10,11}

Home program preference has been studied in other competitive fields.^{12,13} For example, Narang et al. showed that in dermatology, 29.8% of applicants in a 6-year cohort matched into their home residency program.¹² Furthermore, 62.8% matched in their home region. In otolaryngology, Johnson et al. found that 20.9% of the residents in their cohort matched at a home program affiliated with their medical school and 58.4% matched in their home region.¹³

While this home program preference is documented across multiple specialties, less is known about home program matching patterns in neurosurgery. In this study, we analyzed 113 U.S. neurosurgery residency programs, comprising 1572 residents from the 2014–2020 match cohort, to determine which programs matched the highest proportion of their own medical students to their home program, while evaluating resident-level and program-level characteristics associated with home program matching.

METHODS

Resident Cohort

A list of Accreditation Council for Graduate Medical Education–accredited residency training programs in neurosurgery was obtained from the American Association of Neurological Surgeons neurosurgical residency training program directory. Canadian programs were excluded. The publicly available websites of the included U.S. programs were accessed on February 2021 in order to acquire a complete list of current residents (postgraduate year [PGY]1 until PGY7), which, in general, reflected successfully matched medical school applicants in neurosurgery over the 2014–2020 match periods who have not dropped out of residency.

Variables Collected for Residents

This project involved the creation of an institutional review board–approved database of residents and U.S. medical schools. For every resident, demographic information was collected, including gender, residency program name, PGY, medical school name and year of graduation, international medical graduate (IMG) status, degrees obtained (M.D. or equivalent, M.S. or equivalent, M.P.H., Ph.D.), and Alpha Omega Alpha Honor Medical Society (A.O.A) membership (<https://www.alphaomegalpha.org/#gsc.tab=0>). Website information was supplemented with publicly available data from Google Scholar, LinkedIn, Doximity, and Docinfo.

Bibliometrics were additionally accrued for each resident, by utilizing the author search tool in Web of Science (Clarivate Analytics, Philadelphia, PA, USA). The total number of published papers and abstracts, citations, and H-index was collected at the preridency (by end of medical school) and current time points. The H-index is a metric that measures both the productivity and citation impact of an author's publications. It is calculated by measuring the maximum value of h such that the author has published h publications that have been cited h times. Broadly, it is used throughout academia to measure an author's research impact and is frequently used in the promotion of faculty and in the procurement of research funding.^{14,15} If publications had different names belonging to the same author, Web of Science allowed the merging of multiple author profiles.

Home program matching was defined as a resident currently training at a program affiliated with the medical school of origin. Programs were considered affiliated with a medical school if there was a publicly available declaration of such affiliation on the residency program or medical school website with medical students scheduled to rotate at these programs as part of their curriculum. A complete program-affiliated medical school list is provided in **Supplementary Table 1**.

Statistical Analysis

Statistical analyses were conducted using SPSS software (version 25.0; SPSS Inc., Chicago, IL, USA) with statistical significance set at $P < 0.05$. The analysis consisted of 2 parts: the evaluation of resident-level characteristics that predict home program matching (staying in a program affiliated with one's medical school) and the analysis of residency program–level characteristics associated with home program matching percentage (percentage of current residents who came from an affiliated medical school). χ^2 and independent t-tests were used to study associations between resident-level characteristics and home program matching while excluding IMG residents. In the event that several significant factors were identified, a subsequent multivariable logistic regression was planned. The home program matching percentage was then calculated for every program while excluding programs without an affiliated medical school (Barrow Neurological Institute, Inova Fairfax Hospital, and the National Institutes of Health neurosurgery residency programs). Programs were ranked according to home program matching percentage, and linear regression was utilized to evaluate associations between program characteristics and home program matching.

RESULTS

The complete cohort consisted of 1572 residents at 113 academic U.S. programs. After excluding IMG residents and residents with incomplete data from the resident-level analysis, the final cohort consisted of 1438 residents. A summary of resident characteristics is provided in **Table 1**. Gender, entry-level academic degrees, and A.O.A membership were not associated with home program matching. Moreover, the home program matching ratio was relatively constant over the 2014–2020 time period (2014: 21%, 2015: 26%, 2016: 19%, 2017: 21%, 2018: 21%, 2019: 23%, and 2020: 22%; $P = 0.764$) as shown in **Figure 1**. A higher preridency

Table 1. Comparisons Between Home Program Matched and Other Matched Residents (n = 1438 U.S. Graduates)

Characteristic	Other	Home Program Matched	P Value
Female sex	234 (21)	63 (20)	0.770
Ph.D. degree	116 (10)	37 (12)	0.457
M.S. degree	85 (8)	23 (7)	0.888
M.P.H. degree	25 (2)	6 (2)	0.735
A.Ω.A member	333 (30)	94 (30)	0.915
Match year			0.764
2014	163 (15)	44 (14)	
2015	169 (15)	59 (19)	
2016	172 (15)	41 (13)	
2017	155 (14)	41 (13)	
2018	156 (14)	41 (13)	
2019	154 (14)	45 (14)	
2020	155 (14)	43 (14)	
Preresidency number of publications and abstracts	7.8 ± 11.6	8.9 ± 12.6	0.129
Preresidency number of citations	125.7 ± 331.7	145.4 ± 286.0	0.340
Preresidency H-index	3.2 ± 3.7	3.7 ± 4.0	0.033*

A.Ω.A, Alpha Omega Alpha Honor Medical Society.
*P < 0.050.

H-index was significantly associated with home program matching ($P = 0.033$). No multivariable analysis was conducted given the presence of only one significant univariate factor.

After excluding 3 programs without an affiliated medical school, there were 110 residency programs included in the program-level analysis. Average home program matching per residency was

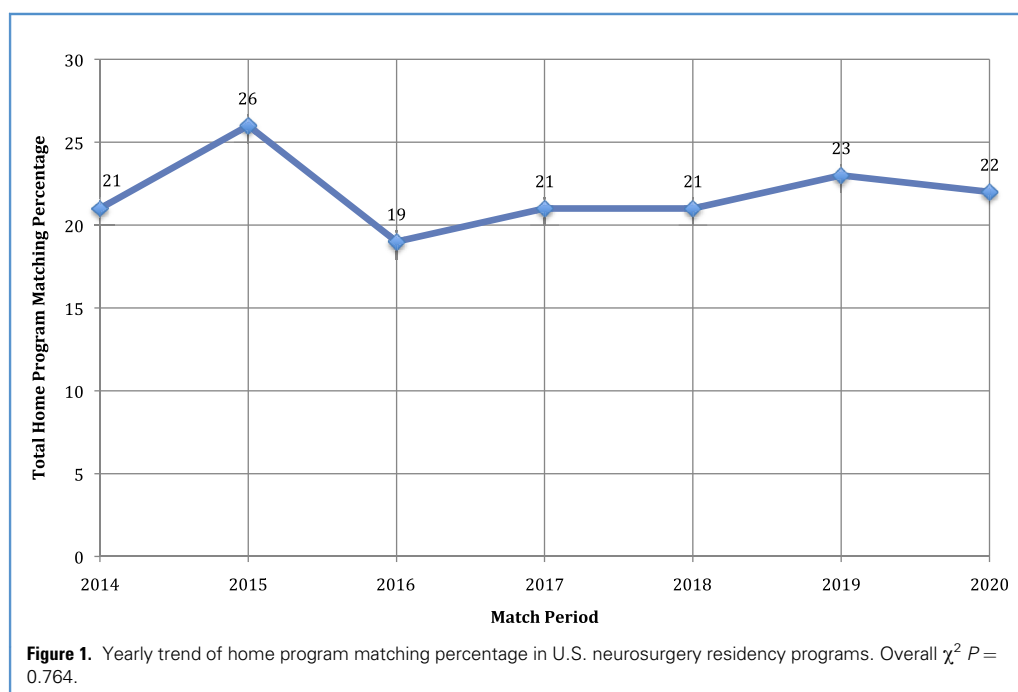


Table 2. Neurosurgery Residency Programs Ranked by Home Program Matching Percentage

Rank	Program	Home Program Matching Percentage
1	NewYork-Presbyterian/Columbia	57.14
2–3	Loma Linda University	50.00
	Louisiana State University/New Orleans	
4	Georgetown University	46.15
5	Cleveland Clinic	45.45
6–7	National Capital Consortium	42.86
	Southern Illinois University	
8	Indiana University	42.11
9	University of Tennessee/Memphis	40.00
10	Henry Ford Hospital	38.46
11–12	Massachusetts General Hospital	38.10
	Washington University	
13	Tufts Medical Center	37.50
14	Rutgers New Jersey	36.84
15	Montefiore Medical Center	36.36
16	NewYork-Presbyterian/Cornell	35.71
17–19	Johns Hopkins University	33.33
	New York University	
	Philadelphia College	
20–21	Case Western Reserve	31.25
	University of Texas/San Antonio	
22–24	University of Cincinnati	30.77
	University of Maryland	
	University of Nebraska	
25	Penn State	29.41
26–35	Emory University	28.57
	Louisiana State University/Shreveport	
	Medical University of South Carolina	
	St. Louis University	
	Stanford University	
	Temple University	
	Thomas Jefferson University	
	University of Kentucky	
	University of North Carolina	
	Vanderbilt University Medical Center	
36	University of South Florida	26.67
37–39	Albany Medical Center	25.00
	Ascension Providence Hospital/MSUCHM	
	Ohio State University	
Continues		

Table 2. Continued

Rank	Program	Home Program Matching Percentage
40	Jackson Memorial Medical Center	23.81
41	University of Virginia	22.73
42–45	New York Medical College	22.22
	University of Mississippi	
	University of Texas/Houston	
	University of Texas/Southwestern	
46–49	Mount Sinai	21.43
	University of Minnesota	
	Virginia Commonwealth University	
	Yale University	
50	University of California/San Diego	20.00
51–53	Duke University Hospital	19.05
	University of California/San Francisco	
	University of Pennsylvania	
54	SUNY Buffalo	17.65
55	Baylor College of Medicine	17.39
56	Tulane University	16.67
57	Mayo Clinic	16.00
58–60	Allegheny General Hospital	15.38
	Methodist Hospital	
	University of Rochester	
61	University of Florida/Gainesville	15.00
62–70	University of Alabama	14.29
	University of Arizona	
	University of Iowa	
	University of Kansas	
	University of Louisville	
	University of Pittsburgh	
	University of Southern California	
	University of Texas/Galveston	
	University of Vermont	
71–72	Long Island Jewish	13.33
	University of Wisconsin/Madison	
73–74	University of Utah	12.50
	West Virginia University	
75	University of Michigan	11.76
76	Advocate BroMenn Medical Center	11.11
77	Oregon Health & Science University	10.53
78	Cedars-Sinai Medical Center	10.00
Continues		

Table 2. Continued

Rank	Program	Home Program Matching Percentage
79–81	Brigham and Women's Hospital	9.52
	University of California/Los Angeles	
	University of Washington	
82–87	Loyola University	9.09
	Medical College of Wisconsin	
	Northwestern University	
	SUNY Syracuse	
	University of Illinois at Chicago	
	University of Illinois/Peoria	
88–89	University of California/Davis	7.69
	Wake Forest University	
90	University of Colorado	7.14
91–110	Beth Israel Deaconess Medical Center	0
	Brown University	
	Carilion Clinic - Virginia Tech	
	Carolinas Medical Center	
	Dartmouth-Hitchcock	
	Desert Regional Medical Center	
	Geisinger Health System	
	George Washington University	
	Mayo Clinic Jacksonville	
	Medical College of Georgia	
	Rush University	
	Spectrum Health/Michigan State University	
	Texas A&M	
	University of Arkansas	
	University of California/Irvine	
	University of Chicago	
	University of Massachusetts	
	University of Missouri/Columbia	
	University of Oklahoma	
	William Beaumont Hospital	

18.6%. Residency ranking by home program matching percentage from highest to lowest is provided in Table 2. Programs that had the same home program matching percentage were grouped together in alphabetical order. The top 3 programs had at least half of their residents coming from an affiliated medical school, and the top 19 programs had at least a third of their residents coming from an affiliated medical school. A univariate linear regression of factors associated with home program matching

percentage is provided in Table 3. The number of clinical faculty, presence of an IMG, geographic region, and affiliation with a top 10 U.S. News–ranked medical school were not associated with home program matching percentage. Home program matching for different regions in the United States was in increasing order: West (14.2% \pm 12.3%), Midwest (18.8% \pm 14.5%), South (19.8% \pm 13.8%), and Northeast (21.1% \pm 14.4%). Program size (standardized β = 0.234, P = 0.006), Doximity research (standardized β = 0.206, P = 0.031), Doximity reputation (standardized β = 0.196, P = 0.040), and U.S. News program rankings (standardized β = 0.200, P = 0.036) were all significantly associated with home program matching.

DISCUSSION

This study quantifies, on a granular level, how U.S. neurosurgical residency programs retain their own home program medical students as residents. Across the 110 residency programs studied, home program matching varied greatly. NewYork-Presbyterian/Columbia retained the largest percentage of its own medical students with 57.14% of its residents earning an M.D. from Columbia University Vagelos College of Physicians and Surgeons. Notably, 20 residency programs had no residents from their own medical school. On average, home program matching for an individual residency program was 18.6%—nearly on par with the field of otolaryngology (20.9%) but significantly lower than the field of dermatology (29.8%).^{12,13} This rate remained nearly constant for the match cohorts from 2014–2020 (P = 0.764).

From the medical student perspective, only a higher pre-residency H-index was associated with remaining at one's home program (3.7 \pm 4.0 vs. 3.2 \pm 3.7, P = 0.033). Other factors, such as an applicant's gender, other advanced degrees (Ph.D., M.S., M.P.H.), or A.O.A status, were not associated with remaining at one's affiliated residency program. This was in contrast to the results of Wadhwa et al., who found in the 2018 neurosurgery intern class that research productivity, defined by the number of publications, did not correlate with matching at one's home program (χ^2 = 0.54, P = 0.46).¹⁶ In our 7-year cohort, we found that research productivity when defined by the H-index and not the number of publications or abstracts (7.8 \pm 11.6 vs. 8.9 \pm 12.6, P = 0.129) was significantly associated with matching at one's home program, suggesting that the quality of research may be more important than the quantity. Still, the results of Wadhwa et al. must be analyzed in the context of their small sample size of one PGY.¹⁶

From the perspective of the residency program, the most important factor for predicting home program matching was the number of available residency positions. A highly ranked department, whether by research or reputation, was also important. For instance, a top 20 Doximity (2021) research ranking was significantly associated with home program matching (β 7.5 [0.7, 14.4], P = 0.031), as was a top 10 U.S. News program ranking (β 7.9 [0.5, 15.2], P = 0.036) and a top 10 Doximity (2021) reputation ranking (β 9.9 [0.5, 19.3], P = 0.040). Based on the magnitude of standardized β values, the number of available residency positions was most correlated with home program matching. This made sense: a residency program with more available positions can both match

Table 3. Analysis of Residency-Level Associated Factors with Home Program Matching Percentage (n = 110 Programs)

Variable	β [95% CI]	P Value
Number of clinical faculty	0.1 [−0.1, 0.4]	0.210
Program size (# of residents)	0.7 [0.2–1.1]	0.006*
Presence of IMG resident	−1.9 [−7.2, 3.4]	0.478
Top 20 Doximity research programs (2021)†	7.5 [0.7, 14.4]	0.031*
Top 10 Doximity reputation programs (2021)†	9.9 [0.5, 19.3]	0.040*
Top 10 <i>U.S. News</i> programs (2014–2020)†	7.9 [0.5, 15.2]	0.036*
Top 10 <i>U.S. News</i> 2014–2020 affiliated medical schools	5.4 [−1.8, 12.7]	0.138
Regions (West as reference)		
Midwest	4.6 [−4.3, 13.4]	0.307
South	5.6 [−2.8, 14.0]	0.188
Northeast	6.9 [−1.9, 15.7]	0.121

CI, confidence interval; IMG, international medical graduate.
 * $P < 0.050$.
 †Standardized β values: 0.234 for program size, 0.206 for top 20 Doximity research programs, 0.196 for top 10 Doximity reputation programs, and 0.200 for top 10 *U.S. News* rankings.

home program students who they are familiar with and critically increase the diversity of their program by recruiting medical students from other institutions. The size of the neurosurgery department (by faculty) did not correlate with home program matching, in agreement with the analysis done by Falcone who found that in general surgery, department size was also not correlated with home program matching.¹⁷ Quite surprisingly, the presence of an IMG resident also did not correlate with less home program matching; originally we postulated that neurosurgery departments with IMGs may be more open to accepting medical students from nonaffiliated medical schools for residency training. In addition, affiliation with a top 10 *U.S. News*–ranked medical school did not correlate with home program matching.

Finally, we did not find any correlation between home program matching and geographical region, implying that the degree of home program matching is equitable across geographic regions. Previous literature suggests that medical students are more likely to match in their home region.¹⁸ While our data suggest that each region has some degree of home program matching, it also indicates that no one region has it more than another. Future research should aim to investigate and quantify the extent to which medical students are more likely to match into neurosurgical residency programs in their region, aside from those affiliated with their respective medical schools.

Research in other competitive specialties, such as general surgery,¹⁷ plastic surgery,¹⁹ and otolaryngology,²⁰ supports the notion that home program preference from the perspective of the residency program may largely stem from a familiarity with the applicants whether through engaging in research or via clinical rotations. Since neurosurgical residency is long and arduous and the cost of selecting a poorly performing resident may be greater than the benefit of selecting a highly performing resident, programs have a stronger incentive to select students who they are familiar with as opposed to selecting applicants

who may have stronger applications but are not personally known to the program. Still, it was interesting to observe that despite the long residency commitment of 7 years in neurosurgery and the anecdotal importance of applicant familiarity, the degree of home program matching was less than that observed in other specialties with a shorter training time such as otolaryngology and dermatology, which may highlight the importance of away subinternships in promoting familiarity with outside medical students. Future research should aim to evaluate whether the COVID-19 pandemic influenced the degree of home program matching given the absence of away rotations during that application cycle. In plastic surgery, for example, Asadourian et al. found that the rates of home program preference in 963 residents were significantly higher in 2021 during the COVID-19 pandemic than the rates in 2015–2020 (36.0% vs. 24.1%, $P = 0.019$).¹⁹ The authors suggested that this was because the ability of students to rotate at other programs for subinternships was severely curtailed during the pandemic, leading programs to prioritize students they were already familiar with. Other research in plastic surgery also demonstrates that almost half of students match at a program with which they did a clinical rotation, highlighting the importance of familiarity in the match process.^{21,22}

With regard to factors that affect home program matching in other fields, Falcone found that in general surgery, states with ≤ 2 medical schools had higher rates of home program matching than states that had > 2 medical schools (30.1% \pm 18.4% vs. 22.6% \pm 13.5%, $P = 0.04$).¹⁷ There, the author postulates that geographically isolated medical schools are less likely to have students rotate for away subinternships, leading them to prefer students from their affiliated medical school, with whom they are more familiar. Moreover, in general surgery, survey data of program directors and others involved in resident selection by Makdissi et al. demonstrated that home program preference was

rated as 2.46 of 5 on the Likert Scale, between “somewhat important” and “important.”²³ In otolaryngology, surveys distributed to fourth-year medical students by Wang et al. found that applicants with either a home program or otolaryngology staff at their institution had higher match rates ($P = 0.037$) than students without any otolaryngology staff at their home institution.²⁰ Applicants without home programs also went on more away rotations than did students with home programs (mean: 2.5 ± 0.5 vs. 1.7 ± 0.07 , $P = 0.0002$) but received the same number of interviews (home program median: 16.5, staff only median: 17.5, and no home program or staff median: 15.0; $P = 0.438$). Other factors, such as United States Medical Licensing Examination (USMLE) scores and number of publications, were not significantly different between the 2 groups. Taken together, this suggests that familiarity, by way of an away rotation or a home program, is significantly correlated with matching.

Overall, our analysis suggests that medical students with significant research productivity and large, highly ranked residency programs by reputation and research exhibit the largest home program and home student preference. This may occur for several reasons. First, academically inclined students may prefer their own home programs after having developed mentors or research projects at that institution, and they may desire to continue these relationships or scholarly work throughout residency. Students may also believe that their home program will rank them more favorably and so may rank their home institution highly in order to ensure a successful match. Medical students may also have developed personal ties in the city or state where they attend medical school, further influencing their preference for remaining there. Residency programs may prefer home program students primarily because of familiarity with the applicant, whether through clinical rotations or research. Secondly, some residency programs may also rank affiliated medical students more favorably if they believe that these students are more likely to rank the associated program highly due to a perceived home program preference, especially if the associated program is highly ranked.

Findings emerging from this study may be of interest to several groups but particularly to medical students applying into neurosurgery. For example, these data may influence how applicants rank neurosurgery residency programs by considering how strongly it appears that a residency program prefers its own students. This may also impact how students structure their away rotations. For instance, a medical student from an affiliated department that does not appear to have a strong preference for its home students may consider going on more away rotations to programs that also do not have a strong preference for their affiliated medical students. This may allow those other departments to gain more familiarity with the applicant. Students from medical schools with a high home program matching ratio may consider going on fewer away rotations if they already have a strong preference for their home program, thereby incurring less financial burden. In addition, these data may be of use to students in the process of choosing to attend medical school, if they already have a strong inclination to pursue neurosurgery. In particular, it may enable them to select a medical school affiliated with a neurosurgery department that strongly favors its own medical students. Finally, this analysis may be of use to medical school staff or program directors, to gauge how their home program

preference, if any, aligns with that of other programs around the nation and to make changes if they see fit. Further research should focus on how a changing residency application landscape through the COVID-19 pandemic, pass/fail USMLE step 1, and virtual interviews affects the significance of home program preference for both applicants and residency programs. Analysis of applicant-specific characteristics such as USMLE scores and subinternship performance may also represent worthwhile avenues for further research.

Limitations

Our data provide a better understanding of home program matching in neurosurgical training programs. Still, there are several limitations. For example, our data shows the percentage of residents who trained at an affiliated medical school. They do not, however, indicate how each residency program ranked its own medical students, how affiliated medical students ranked their home program, or applicant-specific characteristics, such as USMLE step 1 scores. Nonetheless, we believe that by using a 7-year cohort, these “personal preference” effects that may vary year-to-year for different programs are minimized. Another limitation is that our data does not truly represent the 2014–2020 match cohorts because some residents may have dropped out during residency. Another small percentage of residents may also have matched in positions beyond PGY-1, perhaps from the same institution. These distinctions were not made as match lists for each medical school for each year were not available. Finally, our research only examined individual home program preference and its variation among different geographical regions, rather than matching in a program within the same geographical region as one’s medical school. Given the absence of data regarding the hometown of every resident, this other anecdotally influencing geographic factor could not be evaluated. Further survey-type research should aim to investigate whether medical students are more likely to match in their home region in the field of neurosurgery. Moreover, using larger data sets to negate stochastic effects that may predominate in small sample sizes and evaluating longer-range time trends represent avenues for further research in this topic.

CONCLUSION

This study is the first to characterize how home program preference varies on a granular level for neurosurgical residency programs in the United States. The most important factor associated with medical students remaining at their home program was research productivity as defined by a high preresidency H-index. The most important factor associated with residency programs retaining their own medical students is the number of available residency positions. This analysis may aid medical students in deciding how to rank residency programs and in strategizing their away rotations. It may also help medical school staff and residency program directors investigate trends that they may or may not have been aware of and to implement changes in their selection process if desired or necessary.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Albert Antar: Writing — original draft, Writing — review & editing, Methodology, Formal analysis, Investigation, Data curation. **James Feghali:** Writing — original draft, Writing — review & editing, Methodology, Software, Formal analysis, Investigation. **Wuyang Yang:** Writing — review & editing, Software, Formal analysis, Investigation. **Elizabeth E. Wicks:** Investigation, Data curation,

Writing — review & editing. **Shahab Aldin Sattari:** Investigation, Writing — review & editing. **Sean Li:** Investigation, Data curation, Writing — review & editing. **Timothy F. Witham:** Writing — review & editing, Supervision. **Henry Brem:** Writing — review & editing, Supervision. **Judy Huang:** Writing — review & editing, Supervision, Project administration.

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SUPPLEMENTARY DATA

Supplementary Table 1. Affiliated Medical Schools by U.S. Neurosurgery Residency Programs

Residency Program	Associated Medical School
Advocate BroMenn Medical Center	University of Illinois College of Medicine at Chicago
Albany Medical Center	Albany Medical College
Allegheny General Hospital	Lewis Katz School of Medicine at Temple University, Lake Erie College of Osteopathic Medicine
Ascension Providence Hospital/MSUCHM	Michigan State University College of Osteopathic Medicine
Baylor College of Medicine	Baylor College of Medicine
Beth Israel Deaconess Medical Center	Harvard Medical School
Brigham and Women's Hospital	Harvard Medical School
Brown University	Warren Alpert Medical School of Brown University
Carilion Clinic - Virginia Tech	Virginia Tech Carilion School of Medicine
Carolinas Medical Center	Wake Forest School of Medicine
Case Western Reserve	Case Western Reserve University School of Medicine
	Cleveland Clinic Lerner College of Medicine
Cedars-Sinai Medical Center	David Geffen School of Medicine at University of California, Los Angeles
Cleveland Clinic	Case Western Reserve University School of Medicine
	Cleveland Clinic Lerner College of Medicine
Dartmouth-Hitchcock	Geisel School of Medicine at Dartmouth
Desert Regional Medical Center	University of California, Riverside, School of Medicine
Duke University Hospital	Duke University School of Medicine
Emory University	Emory University School of Medicine
Geisinger Health System	Geisinger Commonwealth School of Medicine
George Washington University	George Washington University School of Medicine
Georgetown University	Georgetown University School of Medicine
Henry Ford Hospital	Wayne State University School of Medicine
Indiana University	Indiana University School of Medicine
Inova Neuroscience & Spine Institute	None
Jackson Memorial Medical Center	University of Miami Miller School of Medicine
Johns Hopkins University	Johns Hopkins University School of Medicine
Loma Linda University	Loma Linda University School of Medicine
Long Island Jewish	Zucker School of Medicine at Hofstra/Northwell
	Albert Einstein College of Medicine
Louisiana State University/New Orleans	Louisiana State University School of Medicine
Louisiana State University/Shreveport	Louisiana State University School of Medicine
Loyola University	Loyola University Chicago Stritch School of Medicine
Massachusetts General Hospital	Harvard Medical School
Mayo Clinic	Mayo Alix School of Medicine
Mayo Clinic Jacksonville	Mayo Alix School of Medicine
Continues	

Supplementary Table 1. Continued

Residency Program	Associated Medical School
Medical College of Georgia	Augusta University Medical College of Georgia
Medical College of Wisconsin	Medical College of Wisconsin
Medical University of South Carolina	Medical University of South Carolina College of Medicine
Methodist Hospital	Texas A&M Health Science Center College of Medicine
Montefiore Medical Center	Albert Einstein College of Medicine
Mount Sinai	Icahn School of Medicine at Mount Sinai
National Capital Consortium	Uniformed Services University
National Institutes of Health	None
New York Medical College	New York Medical College
NewYork-Presbyterian/Columbia	Columbia University Vagelos College of Physicians and Surgeons
NewYork-Presbyterian/Cornell	Weill Cornell Medicine
New York University	New York University School of Medicine
Northwestern University	Northwestern Feinberg School of Medicine
Ohio State University	The Ohio State University College of Medicine
Oregon Health & Science University	Oregon Health & Science University
Penn State	Pennsylvania State University College of Medicine
Philadelphia College	Philadelphia College of Osteopathic Medicine
Rush University	Rush Medical College
Rutgers New Jersey	Rutgers New Jersey Medical School
SUNY Buffalo	Jacobs School of Medicine and Biomedical Sciences
SUNY Syracuse	State University of New York Upstate Medical University
Southern Illinois University	Southern Illinois University School of Medicine
Spectrum Health/Michigan State University	Michigan State University College of Human Medicine
St. Joseph's Hospital (Barrow)	None
St. Louis University	Saint Louis University School of Medicine
Stanford University	Stanford University School of Medicine
Temple University	Lewis Katz School of Medicine at Temple University
Texas A&M	Texas A&M Health Science Center College of Medicine
Thomas Jefferson University	Sidney Kimmel Medical College, Thomas Jefferson University
Tufts Medical Center	Tufts University School of Medicine
Tulane University	Tulane University School of Medicine
University of Alabama	University of Alabama at Birmingham School of Medicine
University of Arizona	University of Arizona College of Medicine Phoenix, University of Arizona College of Medicine, Tucson
University of Arkansas	University of Arkansas for Medical Sciences College of Medicine
University of California/Davis	University of California, Davis, School of Medicine
University of California/Irvine	University of California, Irvine, School of Medicine
University of California/Los Angeles	David Geffen School of Medicine at University of California, Los Angeles
University of California/San Diego	University of California, San Diego, School of Medicine
University of California/San Francisco	University of California, San Francisco, School of Medicine
University of Chicago	University of Chicago, Pritzker School of Medicine
Continues	

Supplementary Table 1. Continued

Residency Program	Associated Medical School
University of Cincinnati	University of Cincinnati College of Medicine
University of Colorado	University of Colorado School of Medicine
University of Florida/Gainesville	University of Florida College of Medicine
University of Illinois at Chicago	University of Illinois College of Medicine at Chicago
University of Illinois/Peoria	University of Illinois College of Medicine at Peoria
University of Iowa	University of Iowa Carver College of Medicine
University of Kansas	University of Kansas School of Medicine
University of Kentucky	University of Kentucky College of Medicine
University of Louisville	University of Louisville School of Medicine
University of Maryland	University of Maryland School of Medicine
University of Massachusetts	University of Massachusetts Chan Medical School
University of Michigan	University of Michigan Medical School
University of Minnesota	University of Minnesota Medical School
University of Mississippi	University of Mississippi School of Medicine
University of Missouri/Columbia	University of Missouri School of Medicine
University of Nebraska	University of Nebraska College of Medicine
University of North Carolina	University of North Carolina at Chapel Hill School of Medicine
University of Oklahoma	University of Oklahoma College of Medicine
University of Pennsylvania	Perelman School of Medicine at the University of Pennsylvania
University of Pittsburgh	University of Pittsburgh School of Medicine
University of Rochester	University of Rochester School of Medicine
University of South Florida	University of South Florida Morsani College of Medicine
University of Southern California	Keck School of Medicine at the University of Southern California
University of Tennessee/Memphis	University of Tennessee College of Medicine
University of Texas/Galveston	University of Texas Medical Branch at Galveston, School of Medicine
University of Texas/Houston	McGovern Medical School at the University of Texas Health Science Center at Houston
University of Texas/San Antonio	University of Texas Health Science Center at San Antonio
University of Texas/Southwestern	University of Texas Southwestern Medical School
University of Utah	University of Utah School of Medicine
University of Vermont	Larner College of Medicine at the University Vermont
University of Virginia	University of Virginia School of Medicine
University of Washington	University of Washington School of Medicine
University of Wisconsin/Madison	University of Wisconsin School of Medicine
Vanderbilt University Medical Center	Vanderbilt University School of Medicine
Virginia Commonwealth University	Virginia Commonwealth University School of Medicine
Wake Forest University	Wake Forest School of Medicine
Washington University	Washington University School of Medicine in St. Louis
West Virginia University	West Virginia University School of Medicine
Continues	

Supplementary Table 1. Continued

Residency Program	Associated Medical School
William Beaumont Hospital	Oakland University William Beaumont School of Medicine
	Michigan State University College of Osteopathic Medicine
	Michigan State University College of Human Medicine
	Wayne State University School of Medicine
Yale University	Yale School of Medicine