Analysis of the 1990–2007 neurosurgery residency match: does applicant gender affect neurosurgery match outcome?

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OBJECTIVE With nearly half of graduating US medical students being female, it is imperative to understand why females typically make up less than 20% of the neurosurgery applicant pool, a number that has changed very slowly over the past several decades. Organized neurosurgery has strongly indicated the desire to overcome the underrepresentation of women, and it is critical to explore whether females are at a disadvantage during the residency application process, one of the first steps in a neurosurgical career. To date, there are no published studies on specific applicant characteristics, including gender, that are associated with match outcome among neurosurgery resident applicants. The purpose of this study is to determine which characteristics of neurosurgery residency applicants, including gender, are associated with a successful match outcome.

METHODS De-identified neurosurgical resident applicant data obtained from the San Francisco Fellowship and Residency Matching Service for the years 1990–2007 were analyzed. Applicant characteristics including gender, medical school attended, year of application, United States Medical Licensing Exam (USMLE) Step 1 score, Alpha Omega Alpha (AOA) status, and match outcome were available for study.

RESULTS Of the total 3426 applicants studied, 473 (13.8%) applicants were female and 2953 (86.2%) were male. Two thousand four hundred forty-eight (71.5%) applicants successfully matched. USMLE Step 1 score was the strongest predictor of match outcome with scores > 245 having an OR of 20.84 (95% CI 10.31–42.12) compared with those scoring < 215. The mean USMLE Step 1 score for applicants who successfully matched was 233.2 and was 210.8 for those applicants who did not match ($p < 0.001$). Medical school rank was also associated with match outcome ($p < 0.001$). AOA status was not significantly associated with match outcome. Female gender was associated with significantly lower odds of matching in both simple (OR 0.59, 95% CI 0.48–0.72) and multivariate analyses (OR 0.57, 95% CI 0.34–0.94 CI). USMLE Step 1 scores were significantly lower for females compared to males with a mean score of 230.1 for males and 221.5 for females ($p < 0.001$). There was no significant difference in medical school ranking or AOA status when stratified by applicant gender.

CONCLUSIONS The limited historical applicant data from 1990–2007 suggests that USMLE Step 1 score is the best predictor of match outcome, although applicant gender may also play a role.

<https://thejns.org/doi/abs/10.3171/2017.11.JNS171831>

KEYWORDS neurosurgery residency match; gender; applicant characteristics; United States Medical Licensing Exam

FOR decades, neurosurgery has been among the most competitive of residencies to obtain despite the length and duress of the process. Although women currently comprise nearly one-half of all graduating medical students, neurosurgery, along with orthopedic surgery,

thoracic surgery, and urology, continues to have extremely low representation of actively practicing female physicians among the surgical subspecialties. According to the most recent data from the Association of American Medical Colleges, only 7.8% of all practicing neurosur-

ABBREVIATIONS ABNS = American Board of Neurological Surgery; ACGME = American College of Graduate Medical Education; AOA = Alpha Omega Alpha; CI = confidence interval; ERAS = Electronic Resident Application Service; NRMP = National Residency Matching Program; OR = odds ratio; ROC = receiver operating characteristic; USMLE = United States Medical Licensing Exam.

SUBMITTED July 27, 2017. **ACCEPTED** November 14, 2017.

INCLUDE WHEN CITING Published online June 8, 2018; DOI: 10.3171/2017.11.JNS171831.

geons are female (<https://www.aamc.org/data/workforce/reports/458712/1-3-chart.html>). Females currently constitute 17% of the neurosurgery resident workforce, second only to orthopedic surgery for the lowest percentage of female residents among surgical subspecialties (<https://www.aamc.org/data/workforce/reports/458766/2-2-chart.html>). At the end of the 20th century, at least 30% of US neurosurgical training programs had yet to graduate a female resident.⁶ Presently, among the 105 American College of Graduate Medical Education (ACGME)-accredited US neurosurgical training programs, 24 programs (23%) do not have female neurosurgical faculty, and 13 programs (12%) lack any female residents (<https://apps.acgme.org/ads/Public/Programs/Search?stateId=&specialtyId=35&specialtyCategoryTypeId=&numCode=&city=>). Of the 4616 practicing neurosurgeons currently certified by the American Board of Neurological Surgery (ABNS), only 272 (5.9%) are female, with the first woman receiving ABNS certification in 1962 (personal communication, ABNS). Underrepresentation of women throughout medicine, and particularly within neurosurgery, includes professorships, chairs, and all levels of leadership. To date, there have been only 7 female program directors and 3 female chairs of an ACGME-accredited neurosurgery training program.

With nearly half of graduating US medical students being female, it is imperative to eliminate any factors identified that contribute to the fact that females typically still represent less than 20% of the neurosurgery applicant pool, a number that has changed very slowly over the past several decades (<https://www.aamc.org/download/321560/data/factstablec2.pdf>). The lifestyle of a neurosurgeon, with long unpredictable work hours throughout training and in practice, residency training coinciding with a woman's peak childbearing years, lack of female role models and mentors, and limited exposure to neurosurgery during medical school, have all been offered as possible explanations for why female medical students do not apply to neurosurgery programs.^{6,23,25}

Organized neurosurgery has strongly indicated the desire to overcome the underrepresentation of women. Exploring whether females are at a disadvantage during the residency application process, one of the first steps in a neurosurgical career, is important. Studies addressing gender bias during residency application in other medical subspecialties have found no clear evidence of gender bias in resident selection.^{5,11,15} To date, there are no published studies on specific applicant characteristics, including gender, that are associated with match outcome among neurosurgery resident applicants.

The purpose of this study is to determine which characteristics of neurosurgery residency applicants, including gender, are associated with a successful match outcome.

Methods

Study Population

This study was approved by the University of Vermont Committee on Human Subjects Research Protection. De-identified neurosurgical resident applicant data obtained

from the San Francisco Fellowship and Residency Matching Service for the years 1990 through 2007 was included in the current study. Data on neurosurgical resident applicants and match outcome from 2008 to the present was collected by the National Residency Matching Program (NRMP) and the Electronic Resident Application Service (ERAS) and was unable to be obtained for inclusion in the current study.

During the 18-year period from 1990–2007, 3426 US medical school graduates participated in the neurosurgery resident match process and are included in the current study. Applicant characteristics including gender, medical school attended, year of application, and match outcome were available in all applicants for all years of the study. From 1997–2007, United States Medical Licensing Exam (USMLE) Step 1 scores were available for inclusion in the analysis ($n = 1858$). From 2002–2007, Alpha Omega Alpha (AOA) status was also available ($n = 836$). Neurosurgical resident applicants from medical schools outside of the US, applicants from chiropractic or osteopathic schools, applicants who did not submit a match list, and applicants who withdrew from the match were excluded from analysis.

Data Analysis

Data analyzed included gender, medical school rank, USMLE Step 1 scores, AOA status, year of application, and match outcome. Gender, AOA status, and match outcome were treated as categorical variables. The medical school attended was assigned a numerical rank according to the NIH funding for medical schools specific for each year of the study (<https://report.nih.gov/award/index.cfm>). Due to the variability in the number of medical schools that were ranked on a given year, we chose to use a categorical variable (1 to 40 vs > 40/unranked). USMLE Step 1 scores were analyzed both as a continuous variable and categorized into quartiles for regression analysis. Year of application was treated as a continuous variable.

A primary univariate analysis was then performed to determine statistically significant relationships between these selected applicant characteristics and match outcome. Because of the difficulty with missing USMLE and AOA data, three separate analyses were completed (all applicants [$n = 3426$], only those with USMLE data [$n = 1858$], and only those with AOA data [$n = 836$]). All conclusions were similar in each of these analyses, and thus the data presented is for all applicants ($n = 3426$). Chi-square tests were used for categorical variables and 2-sample *t*-tests were used for continuous variables. Simple and adjusted logistic regression models were also used and odds ratios (ORs) and 95% confidence intervals (CIs) were reported when appropriate. The Hosmer-Lemeshow goodness-of-fit test was used for logistic regression modeling. Area under the receiver operating characteristic (ROC) curve was also calculated for the logistic regression models. Statistical significance was defined as $p < 0.05$.

Results

Of the total 3426 residents applicants studied, 473

TABLE 1. Characteristics of neurosurgery applicants stratified by match outcome (US medical school graduates, 1990–2007)

Characteristic	No Match (n = 978)	Match (n = 2448)	p Value
Gender, n (%)			<0.001
Male, n = 2953	796 (27)	2157 (73)	
Female, n = 473	182 (38)	291 (62)	
Medical school rank, n (%)			<0.001
1–40, n = 1153	214 (19)	939 (81)	
>40, n = 2273	764 (34)	1509 (66)	
Mean USMLE Step 1 score $\pm$ SD*	211 $\pm$ 20	233 $\pm$ 18	<0.001
AOA membership, n (%)†			0.058
Yes, n = 109	29 (27)	80 (73)	
No, n = 727	137 (19)	590 (81)	

* USMLE Step 1 scores from 1997–2007.

† AOA membership from 2002–2007.

(13.8%) applicants were female and 2953 (86.2%) were male. In this cohort, 2448 (71.5%) neurosurgical resident applicants successfully matched into a neurosurgery training program over the study period.

Applicant Characteristics Stratified by Match Outcome

Medical School Ranking

Medical school rank was available for all applicants. Medical school rank was found to be significantly associated with match outcome with 939 (81%) of the 1153 applicants from top-40 medical schools matching as compared to 1509 (66%) of the 2273 applicants from a medical school not ranked in the top 40 ($p < 0.001$; Table 1). The OR for matching when the applicant was from a top-40 medical school was 2.2 (95% CI 1.87–2.64, $p < 0.001$) in a simple logistic regression model and 1.91 (95% CI 1.43–2.55) in an adjusted logistic regression model ($p < 0.001$; Table 2). There were no significant changes in medical school ranking over the course of the study.

USMLE Step 1 Score

USMLE Step 1 score was available for 1858 applicants. The mean USMLE Step 1 score for applicants that successfully matched was 233.2 and 210.8 for those applicants who did not match ($p < 0.001$; Table 1). In a simple logistic regression model, the ORs for quartiles of USMLE Step 1 score were large and statistically significant. Using the lowest quartile as the referent group (< 215), the ORs were 5.65 (95% CI 4.12–7.74), 10.12 (95% CI 7.02–14.63), and 15.33 (95% CI 9.92–23.68) for 215–231, 232–244, and ≥ 245 score quartiles, respectively. After adjusting for covariates in the adjusted logistic regression model, the ORs retained statistical significance. Again, using the lowest quartile as the referent group (< 215), the ORs were 5.02 (95% CI 3.06–8.22), 9.23 (95% CI 5.39–15.80), and 20.84 (95% CI 10.31–42.12) for 215–231, 232–244, and ≥ 245 score quartiles, respectively (Table 2).

Over the course of the study, the mean USMLE score increased significantly for all applicants ($p < 0.001$). The increase in USMLE score over time was essentially the same for female and male applicants (Fig. 1).

AOA Status

There was no significant association between AOA status and match outcome. Of the 109 applicants who were AOA members, 80 (73%) matched. Of the 727 applicants who were not AOA members, 590 (81%) matched ($p = 0.06$; Table 1). There was no change in AOA status over the course of the study.

Year of Application

The percentage of applicants who matched increased significantly during the study period, with 124 (59.1%) matching in 1990 compared with 159 (84.1%) matching in 2007 ($p < 0.001$).

Applicant Gender

Female gender was associated with significantly lower odds of matching in both simple (OR 0.59, 95% CI 0.48–0.72, $p < 0.001$) and multivariate analyses (OR 0.57,

TABLE 2. Simple and adjusted ORs for match outcome

Characteristic	Simple Model			Adjusted Model*		
	OR	95% CI	p Value	OR	95% CI	p Value
Gender						
Male (ref)	1.00	—	—	1.00	—	—
Female	0.59	0.48–0.72	<0.001	0.57	0.34–0.94	0.030
USMLE Step 1 score†						
<215 (ref)	1.00	—	—	1.00	—	—
215–231	5.65	4.12–7.74	<0.001	5.02	3.06–8.22	<0.001
232–244	10.12	7.02–14.63	<0.001	9.23	5.39–15.80	<0.001
≥ 245	15.33	9.92–23.68	<0.001	20.84	10.31–42.12	<0.001
Medical school rank						
>40 (ref)	1.00	—	—	1.00	—	—
1–40	2.22	1.87–2.64	<0.001	1.91	1.43–2.55	<0.001

* Adjusted model was adjusted for all covariates except AOA. The Hosmer-Lemeshow goodness-of-fit test for the logistic regression model was $p = 0.44$. The area under the ROC curve was 0.826.

† USMLE Step 1 scores from 1997–2007.

FIG. 1. Graph of mean USMLE Step 1 scores of neurosurgery resident applicants, both by total and according to applicant gender (US medical school graduates, 1990–2007).

95% CI 0.34–0.94 CI, $p = 0.03$; Table 2). There was a significant increase in the number of female applicants over the course of the study period with 10% of the applicants being female in 1990 and 17.4% of the applicants being female in 2007 ($p = 0.002$). The percentage of female applicants ranged from a low of 5.3% in 2000 to a high of 21.9% in 2006. The percentage of female applicants who did not match ranged from 8.4% in 1992 to 51.4% in 2006. In 15 of the 18 match cycles studied, the percentage of unmatched female applicants (unmatched female applicants/total unmatched applicants) was greater than the percentage of females applicants (female applicants/total applicants; Fig. 2 upper), whereas the converse was true of male applicants (Fig. 2 lower).

Applicant Characteristics Stratified by Gender

USMLE Step 1 scores were significantly lower for females compared to males with a mean score of 230 ± 20 for males and 222 ± 18 for females ($p < 0.001$; Table 3). There was no significant difference in medical school ranking or AOA status when stratified by applicant gender (Table 3).

Changes Over Time

Over the course of the study, mean USMLE Step 1 score for both genders increased significantly ($p < 0.001$ and $p < 0.001$, respectively; Fig. 1). The number of female applicants also increased over time ($p = 0.002$). The OR for female applicants matching relative to male applicants dropped over the course of the study but this was not statistically significant ($p = 0.07$; Fig. 3). There was no change in medical school rank or AOA status of the applicants over time.

Discussion

There is very little information currently available on which neurosurgery residency applicant characteristics are important in the resident selection process. A recent

study surveyed neurosurgery residency programs and concluded that the interview process, USMLE Step 1 score, and letters of recommendation were the most important factors affecting resident selection.¹ Of these criteria, only the USMLE score is objective data; the interview process and letters of recommendation are both pointedly subjective. Few training programs have standardized protocols for the initial application, the applicant interview selection, or the interview process itself. The selection criteria used likely vary widely both by the individual interviewing the applicant and the training program itself. Consequently, significant attention has been focused on whether to consider alternatives to the current process. For example, the Cleveland Clinic employed and evaluated personality testing to address this issue.¹⁷ The significance of this challenge can be seen in the market growth of companies such as J3Personica, which provides assessment tools for resident selection. This challenge extends beyond medicine and neurosurgery as evidenced by a recent session of the Society of Neurological Surgeons Annual Meeting during which representatives across a wide spectrum, including business and music schools, related similar struggles during their own student selection (Society of Neurological Surgeons Annual Meeting 2016, Indianapolis, Indiana).

Predictors of Match Outcome

USMLE Step 1 Score

USMLE Step 1 score is frequently cited as one of the most important factors for applicants applying to neurosurgery.¹⁹ In the current study, USMLE Step 1 score was noted to be the strongest predictor of successful match outcome. Those applicants with USMLE Step 1 scores above 245 had an OR for matching nearly 21 times as high as those scoring below 215. This data is concordant with other published studies of USMLE Step 1 scores in relation to resident selection.^{2,10,12,23,24,26} Historically, the USMLE was not created or designed to be used as a tool for residency selection and there is minimal evidence to

FIG. 2. Upper: Graph of the percentage of total female applicants and percentage of unmatched female applicants to neurosurgery residency programs (US medical school graduates, 1990–2007). **Lower:** Graph of the percentage of total male applicants and percentage of unmatched male applicants to neurosurgery residency programs (US medical school graduates, 1990–2007).

support the selection of resident applicants based on higher USMLE Step 1 scores.²¹ Multiple specialty-specific studies have found a positive correlation between USMLE Step 1 scores and scores on written board examinations during residency.^{13,14,16,18} Within neurosurgery specifically, the USMLE Step 1 score has been correlated with higher ABNS primary written examination board scores during residency.¹⁸ It is also unclear whether USMLE scores predict career accomplishment beyond residency in any specialty and no data are currently available on whether USMLE scores are associated with a successful career as a neurosurgeon.^{7,21}

Medical School Ranking

Applicants from medical schools ranked among the top 40 in NIH funding were more likely to match in neurosurgery. This finding is not unexpected as these medical schools are likely to have students who are highly competitive academically. In addition, medical schools ranked among the top 40 are likely to have strong neurosurgery training programs, giving applicants from these medical schools a perceived advantage over students applying from medical schools that may not have a neurosurgery training program. Letters of recommendation from leaders in neurosurgery at these institutions are sought after by

neurosurgery resident applicants and contribute to success in residency application.

Gender

In the current study, female applicants appeared to be

TABLE 3. Characteristics of neurosurgery applicants stratified by gender

Characteristic	Male (n = 2953)	Female (n = 473)	p Value
Match outcome, n (%)			<0.001
Yes, n = 2448	2157 (73)	291 (62)	
No, n = 978	796 (27)	182 (38)	
Medical school ranking, n (%)			0.360
1–40, n = 1153	985 (33)	168 (36)	
>40, n = 2273	1968 (67)	305 (64)	
Mean USMLE Step 1 score $\pm$ SD*	230 $\pm$ 20	222 $\pm$ 18	<0.001
AOA membership, n (%)†			0.367
Yes, n = 109	89 (13)	20 (16)	
No, n = 727	618 (87)	109 (84)	

* USMLE Step 1 scores from 1997–2007.

† AOA membership from 2002–2007.

FIG. 3. Natural log (nLog) of the ORs for matching to neurosurgery residency programs by year among female applicants compared with male applicants. *Diagonal line* = fitted values of the statistical model.

less likely to match into neurosurgery than male applicants in 15 of the 18 years studied, even after adjusting for important covariates such as USMLE Step 1 score and medical school ranking. It is important to note that USMLE Step 1 scores were consistently lower in female applicants for all years of the study. Published studies of gender-related differences in USMLE performance have not demonstrated any consistent gender effect on either the USMLE Step 1 or Step 2 scores, and this finding denotes further study.^{8,9}

A study of how applicant gender impacts match outcome on surgical subspecialties, including neurosurgery, in the Canadian Residency Matching Service demonstrated that applicant gender had no effect on match outcome.³ However, no other potentially confounding variables were included in the analysis. Despite this limitation, the conclusion was that gender bias during resident selection did not contribute to female underrepresentation in most surgical subspecialties and that other factors, including lack of interest in surgical subspecialties or lifestyle concerns by women, likely play a greater role in explaining gender disparity. Similar studies were also performed in radiology and ophthalmology using the Canadian Residency Matching Service, reaching similar conclusions.^{4,5}

Certainly, much in neurosurgery and medicine has changed in the decade since the data were collected in this study. During the final year of this study (2007), the first woman was appointed chair of a neurosurgical training program and the second in 2016. Women now hold leadership positions in organized neurosurgery including the American Association of Neurological Surgeons, Congress of Neurological Surgeons, Council of State Neurosurgical Societies, Neurosurgical Society of America, and all the Joint Sections. Training programs with multiple, simultaneous female residents are also more common. While the number of females in neurosurgery remains low in comparison to most other specialties, women are now entering training programs that have graduated female residents previously, and nearly one-quarter of neurosurgery training programs have female faculty. During the

study period of 1990 to 2007, most women may have been the first female residents in their programs, and only a very small number of training programs had female faculty. Over the course of this study, the percentage of female medical students graduating rose from 35% in 1990 to 49% in 2007 and the number of female resident applicants also rose from 10% to 17% (Fig. 4). These are all positive trends that speak to the successful efforts on the part of neurosurgery to address gender disparity.

In 2008, neurosurgery transitioned from the San Francisco Residency and Fellowship Matching Services to the ERAS/NRMP. De-identified individual data on the neurosurgical match from 2008 to the present was requested from both ERAS and NRMP for the present study but denied due to privacy concerns. From the limited publicly available ERAS data of the 2008 through 2016 neurosurgery match, there has been little increase in the number of female applicants applying to neurosurgery (<https://www.aamc.org/download/321560/data/factstablec2.pdf>). Unfortunately, the number of female applicants in the years following 2007 still remains below 20% (Fig. 4). There is no data currently available on whether the number of female applicants successfully matching into neurosurgery residency positions is increasing. Neurosurgery resident match outcome data are provided by the NRMP with “summary statistics” on the neurosurgery resident match including “measures” stratified by match outcome such as USMLE scores, research experience, abstracts/presentations/publications, work experiences, volunteer experiences, AOA status, and attendance at a top-40 NIH-funded medical school. Gender, however, is not a listed applicant “measure.”²⁰ No statistical analysis between the matched and unmatched applicants is provided, and it remains uncertain which applicant “measures” are currently associated with match outcome. In the future, acquisition of the individual applicant data from ERAS/NRMP from 2008 forward could provide a crucial update to the current study by determining whether these positive trends in reducing gender disparity in neurosurgery have continued to

FIG. 4. Graph of the percentage of female medical school graduates and percentage of females applying to neurosurgery residency training programs. The shaded area represents time elapsed since the study period (2007–2017). Data was not available for 2008–2009 during matching service transition.

evolve over time. In addition, it would also provide a new baseline for future studies addressing gender disparity in neurosurgery as well as provide information on how best to guide medical students interested in a career in neurosurgery, regardless of gender.

Conclusions

Utilizing limited data from the neurosurgical applicant pool from 1990 to 2007, the data from the current study suggests that USMLE Step 1 score is the best predictor of match outcome, although applicant gender may also play a role. This finding affords neurosurgery a great opportunity to address any areas of potential bias during the residency application process that may preclude neurosurgery from attracting the brightest medical students.

Acknowledgments

We would like to thank The Society of Neurological Surgeons for their support of this study and Nivedetta Ramkumar and Peter Callas for statistical support and analysis.

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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: Durham, Grady, Benzil. Acquisition of data: Durham, Donaldson. Analysis and interpretation of data: Durham, Benzil. Drafting the article: Durham, Benzil. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Durham. Statistical analysis: Durham.

Supplemental Information

Previous Presentations

Portions of this work were presented in abstract form and as a presentation at the Society of Neurological Surgeons Annual Meeting in Houston, Texas, May 21, 2017, and at the New England Neurosurgical Society Annual Meeting, in Chatham, Massachusetts, June 23, 2017.

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