Similar to other surgical subspecialties, the neurological surgery residency started as an extension of the American College of Surgeons and was then formalized in 1953 with the initiation of the Residency Review Committee.¹ With governance through the American Board of Neurological Surgeons and the Accreditation Council for Graduate Medical Education (ACGME), neurological surgery remains highly regulated and competitive, with a low match rate relative to that of other specialties.²

Over the decades, the neurological surgery residency educational paradigms and training philosophies have shifted substantially to include nationwide ACGME regulations, including working hour limits, assessment of

Abbreviations
ACGME = Accreditation Council for Graduate Medical Education; AΩA = Alpha Omega Alpha; NRMP = National Residency Matching Program; USMLE = US Medical Licensing Examination.


Include When Citing Published online May 28, 2021; DOI: 10.3171/2020.11.JNS203637.
proficiency, and physician well-being. In 2003, the ACGME mandated an 80-hour work week restriction for all US residents. The Milestones, introduced 10 years later, focused on standardizing proficiency assessment and described the learning trajectory within 6 core competencies. Each is subdivided into sets of subcompetencies that allow for further specification of key ability areas, taking the trainee from a novice to ideally a proficient practitioner at the time of graduation. More recently, to address how clinical sites engage residents and fellow physicians in learning to provide safe, high-quality patient care, the Clinical Learning Environment Review (CLER) program was introduced. The CLER program focuses on 6 main areas: patient safety, healthcare quality, care transitions, supervision, well-being, and professionalism. These changes might have an impact on the resident workforce in many fields, including neurosurgery. It has been shown that perceived poor lifestyle or work-life balance was the most important factor deterring medical students from a career in neurosurgery and may be disproportionally affecting women and underrepresented minorities.

While neurological surgery residency programs are regulated with a high degree of scrutiny, each individual program has unique characteristics, highlights, and drawbacks, all of which are important to neurosurgery residency applicants. The aims of this study were to assess recent trends in neurosurgery match results and further analyze the factors contributing to decision-making during the match process for both applicants and program directors. A data-driven understanding of these characteristics may improve applicant and program match fit, thereby improving neurological surgery resident well-being, reducing the attrition rate, and overall enhancing the diversity of the neurosurgery resident workforce.

**Methods**

**Data Sources and Data Mining**


NRMP Applicant Surveys, released biennially since 2011, were analyzed for the following variables: factors associated with either applying to or ranking residency programs, type of ranking strategy used, number of applications submitted, number of interviews offered, number of interviews attended, and number of programs ranked. Criteria used by applicants to rank programs were divided into two categories: academic and well-being. The former included a program’s academic reputation, quality of faculty, quality of curriculum, and size of caseload, whereas the latter included applicant perceived fit, interview day experience, and quality of residents. To the best of our knowledge, the questions on the surveys remained unchanged over the study period.

The NRMP Program Director Surveys, released biennially since 2012, were analyzed for the following variables: factors associated with either granting an interview or ranking applicants, the use of US Medical Licensing Examination (USMLE) scores in granting an interview, number of applications received, number of interview invitations sent, number of applicants interviewed, number of applicants ranked, and residency positions available. They were also reviewed for program director preferences in interviewing or ranking applicants by cohort background, as defined below.

Data regarding match outcomes were obtained from two sources: NRMP Main Residency Match Results and data reports and Charting Outcomes report. The NRMP Main Residency Match Results, released annually since 2011, were analyzed to obtain data on match rates overall and broken down by cohort as defined below. The Charting Outcomes, released annually since 2016, contains academic and demographic information on applicants.

**Study Cohorts**

Applicants were divided into two cohorts: US senior medical students and independent applicants. The former cohort included applicants from US allopathic medical schools who applied during their senior year. The latter included US graduates that applied after their senior year of medical school and osteopathic, Canadian, US international, and non-US international graduates. Data were dichotomized between matched and unmatched within each cohort.

**Statistical Analysis**

Statistical analysis was completed using Stata MP version 14.1 (StataCorp LP) and R version 3.5.0 (The R Foundation). Cohort characteristics were compared using independent-samples t-tests, one-way ANOVA, or Wilcoxon rank-sum tests for continuous variables, and Pearson’s chi-square test for categorical variables. The mean ± SD is reported for continuous variables, and proportions are reported for categorical variables. Trends are graphically shown, according to the following formula: \( \text{TREND} = (\text{known}_y's, [\text{known}_x's], [\text{new}_x's], \text{[const]}). \) All tests were two-sided, with statistical significance defined as \( p \leq 0.05. \)

**Results**

**Neurosurgery Residency Positions, Match Rate, and Cohort Characteristics**

Figure 1 summarizes changes in the number of residency positions and neurosurgery residency applicants over the study period. The total number of residency positions increased from 195 to 232 (+16%). Over the same time frame, the annual number of US senior medical student applicants increased from 208 to 265 (+27%), whereas the number of independent applicants remained stable, from 75 to 76 (+1%), with a variation range of 73 to 115. Over the study period, a total of 2935 applicants applied to neurosurgery residency, including 2135 US senior medical students and 800 independent applicants, for a total of 1891 matched residency positions. The overall average match rate was 65%, ranging from 59% to 70% each year. The average match rate was significantly higher for the US
senior medical students than the independent applicants (58.4% and 6.2%, respectively; p < 0.05). On average, each program received 212 applications, offered 49 invitations, interviewed 37 applicants, and ranked 28 candidates to match, for an average of two positions per program. These numbers did not significantly change over the years during the study period.

Table 1 summarizes characteristics of the two cohorts dichotomized by match results. In both cohorts, matched applicants had a significantly higher number of publications (p < 0.05). In the independent applicant cohort, the publication rate was more than double for the matched applicants, relative to unmatched (34 vs 15). In the US senior medical student cohort, matched applicants were more likely to have a PhD, Alpha Omega Alpha (AΩA) membership, and a degree from a top 40 NIH-funded school, compared with unmatched applicants.

Trends Across and Within Cohorts

Overall, applicants in the independent applicant cohort submitted a significantly greater number of applications than those in the US senior medical student cohort (p < 0.05). Figure 2 shows changes in the number of applications, interview invitations, accepted interviews, and programs ranked per applicant in the US senior medical student (Fig. 2A) and independent applicant (Fig. 2B) cohorts. In both cohorts over time, there was a significantly increased number of submitted applications, while the number of interview invitations, accepted interviews, and programs ranked remained unchanged. In the US senior medical student cohort, the application/interview ratio more than doubled over the study period, from 1.7 in 2011 to 3.3 in 2019. In the independent applicant cohort, this ratio remained overall stable, from 18.6 in 2011 to 17.9 in 2019. The number of submitted applications, number of interview invitations, accepted interviews, and programs ranked did not significantly differ within each cohort comparing matched versus unmatched applicants.

The Applicants’ Perspective

The Applicant Survey response rate was stable over the years (Fig. 3), with an average of 48% (range 45%–53%). Figure 4 summarizes the top 3 ranked factors considered important by the applicants when ranking programs in each cohort. In both cohorts, applicant preference in rank shifted from being based on programs’ academic components toward more well-being criteria, as defined in Methods. Of note, interview experience and perceived fit have been noted to be among the top 3 factors in the US senior medical student cohort since 2017 and in the independent applicant cohort since 2015.

The Program Directors’ Perspective

Over the study period, the program director response rates decreased (Fig. 3) from 43% to 27% with an average of 39% (range 27%–54%). Table 2 summarizes the top factors considered by program directors to offer an interview. Letters of recommendation and USMLE Step 1 scores were consistently among the 3 top factors to select candidates for interview. Additionally, 81% of program directors set a USMLE Step 1 threshold score over which applicants had to mark to qualify for interview. Passing the USMLE Step 2 was required by 68% of program directors. Top criteria used by program directors during the ranking process included subjective criteria such as faculty interview, interaction with residents, and interpersonal skills, and remained constant over the years (Table 2).

Over time, a decreasing number of program directors offered interviews to all types of applicants, from 28% in 2012 to 4% in 2018. Whereas all program directors extended interviews to US senior applicants, a minority stated their intention to interview independent applicants, as follows: US and non-US international medical graduates (48% and 43%, respectively), osteopathic medical graduates (27%), and US postgraduate applicants (63%).

Discussion

Neurosurgery continues to be a highly sought-after residency, as corroborated by our data showing an over-
FIG. 2. Bar graph showing changes from 2011 to 2019 in the number of applications, interview invitations, accepted interviews, and programs ranked per applicant in the US student (A) and the independent applicant (B) cohorts. *p < 0.05.

FIG. 3. Applicant and program director (PD) response rates over time. Dotted lines represent response trends. Data are expressed as percentages.
all growing number of applicants from the US and abroad over the past decade. This is in contrast to trends reported in the past. However, neurosurgery residency remains highly competitive, with an average match rate of 67% in 2019, positioning it among the most difficult to match specialties after dermatology, interventional radiology, radiation oncology, and thoracic surgery. Our study confirms that similar to other highly competitive fields, the neurological surgery match rate for US senior medical student applicants is significantly higher than that for independent applicants. Many factors can contribute to the lower match rate for independent applicants. Our results suggest that one can be attributed to the program director’s reluctance to offer interviews to non-US senior medical students. During the study period, the percentage of program directors offering interviews to all types of applicants (including independent applicants) dropped from 28% in 2012 to 4% in 2018. Additional obstacles, like the need to request a visa for some independent applicants, might also play an important factor.

Factors contributing to a successful match are important to identify. Whereas USMLE scores posed a “barrier to entry” during the program director selection process (see below), our study showed that they did not significantly differ when comparing matched versus unmatched applicants in each cohort. On the other hand, other factors predicted a successful match. In both cohorts, the matched applicants had a significantly higher number of publications than unmatched applicants in the same cohort. Additionally, US senior matched applicants had a higher number of PhD degrees (12.8% vs 6.4%), AΩA memberships (28.3% vs 8.5%), and medical degrees from a top 40 NIH-funded US medical school (41% vs 32%). Similar trends were observed in the overall US senior medical student match in 2018. These findings are corroborated by an earlier study by Leschke and Hunt in 2018, using similar methodology to analyze the NRMP Charting Outcomes reports, finding that number of contiguous ranks, USMLE Steps 1 and 2, research AΩA status, and top 40 NIH-funded medical schools are significant factors in a successful neurosurgery residency match. An older study reviewing the San Francisco Matching Service between 1990 and 2007 confirmed that Step 1 score was the greatest predictor of match success. In the same analysis, female gender was found to be associated with lower odds of matching. Our results indicate that while the Step 1 score is still an

### TABLE 2: Top 3 factors used by program directors to offer interviews and during the ranking process

<table>
<thead>
<tr>
<th>Match Year</th>
<th>Interview Offer</th>
<th>Ranking Process*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>LOR</td>
<td>Faculty interview 92%</td>
</tr>
<tr>
<td></td>
<td>Interest in research</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>USMLE Step 1 score</td>
<td>81%</td>
</tr>
<tr>
<td>2014</td>
<td>LOR</td>
<td>Faculty interview 98%</td>
</tr>
<tr>
<td></td>
<td>USMLE Step 1 score</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>AΩA</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td>Dean’s letter</td>
<td>81%</td>
</tr>
<tr>
<td>2016</td>
<td>LOR</td>
<td>Faculty interview 97%</td>
</tr>
<tr>
<td></td>
<td>USMLE Step 1 score</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>Interest in research</td>
<td>83%</td>
</tr>
<tr>
<td></td>
<td>Personal statement</td>
<td>82%</td>
</tr>
<tr>
<td>2018</td>
<td>LOR</td>
<td>Faculty interview 100%</td>
</tr>
<tr>
<td></td>
<td>USMLE Step 1 score</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>AΩA</td>
<td>88%</td>
</tr>
<tr>
<td></td>
<td>Rotation w/in department</td>
<td>88%</td>
</tr>
</tbody>
</table>

LOR = letters of recommendation.

* In 2012, ranking factors were reported as the mean among survey participants scored according to a 5-point scale: 1 = not at all important to 5 = very important.
important factor in offering a residency interview, less-objective factors such as interpersonal factors are more influential in the ranking process. It remains to be seen how the conversion of the USMLE to pass/fail grading will affect the overall residency match process. It is our hypothesis that this de-objectification of applicants will enhance the diversity of the resident cohort.

The shift in importance for criteria used to rank programs by the applicants is an important observation in this study. In both cohorts, the applicants’ focus shifted from being highly based on programs’ academic components toward well-being factors in later years. As the decade progressed, the applicants’ perceived fit, the interview day experience, and subjective assessment of the residents became more important factors. This trend suggests that applicants shift their values to include factors that enhance their day-to-day interactions and well-being as opposed to factors that are only associated with surgical training. This is consistent with the broader trend in medical education toward improving trainee mental health and wellness.

Compared with other specialties, neurosurgery has had one of the highest USMLE scores, with a mean Step 1 score of 245 and mean Step 2 score of 249 in 2018, only below dermatology, interventional radiology, orthopedic surgery, otolaryngology, plastic surgery, and radiation oncology. Our data show that program directors use objective data such as USMLE scores to screen candidates for interviews. Moving forward, the impact of the USMLE Step 1 transition from a numeric score to simply a pass/fail in January 2022 on the applicant selection process needs to be examined.

Over the years, letters of recommendation were consistently listed as one of the top criteria used by program directors for interview invitation and ranking selection. The potential bias for these has been described in the literature, with suggestion to create a Standardized Letter of Evaluation (SLOE) to mitigate these effects. The current COVID-19 pandemic has changed subinternships and social interactions in general, most likely influencing medical students’ evaluations. How these changes will play a role moving forward needs to be further examined. The subjective criteria such as faculty interviews, interactions with residents, and interpersonal skills used by program directors are in parallel with those used by the applicants. These data underscore the importance of the interview process and interpersonal interactions with residents and faculty. On the other hand, since the ranking is mostly based on subjective criteria, it is important to introduce a culture that fosters education on and recognition of unconscious bias in the ranking process.

Limitations

The data on neurological surgery residency applicant and program director perspectives reported in our study are based on survey data analysis compiled by each party. The accuracy of factors chosen by either party cannot be ascertained. Given this, the results may be influenced by reporting bias. However, by aggregating data from multiple survey-based studies, we intend to illustrate general trends in the residency match process. A further weakness of our study is the decreased program director response rate over the study period. Hopefully, our results will inspire a greater compliance moving forward. Furthermore, the data collection was restricted to NRMP-published documents, which are only released every 2 years. The response rates for both program directors and applicants were significantly less than complete, which may cause our results to only partially represent each group.

Conclusions

Despite its demanding and competitive nature, neurosurgery continues to attract an increased number of medical students from the US and abroad. Over the past decade, when applying to neurosurgery residency, applicants placed a greater value on residency programs that focus on residents’ well-being. Program director criteria used to offer interviews and rank applicants remained constant over time, valuing USMLE scores and letters of recommendation. It is possible that the changes in board score reporting and format of medical student rotations due to the COVID-19 pandemic will have an impact on this process.

References


13. National Resident Matching Program. Results of the 2017

Disclosures
Dr. Germano: consultant for Brainlab and Integra and direct stock ownership in Integra, Elminda, and Surgical Theater.

Author Contributions
Conception and design: Germano, Yaeger. Acquisition of data: Germano, Yaeger. Analysis and interpretation of data: Germano, Yaeger. Drafting the article: Yaeger, Schupper, Gilligan. Critically revising the article: all authors. Reviewed submitted version of manuscript: Yaeger, Schupper, Gilligan. Statistical analysis: Germano, Yaeger. Study supervision: Germano.

Correspondence
Isabelle M. Germano: Icahn School of Medicine at Mount Sinai Health System, New York, NY. isabelle.germano@mountsinai.org.