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Perceptions of the Virtual Neurosurgery Application Cycle During the Coronavirus Disease 2019 (COVID-19) Pandemic: A Program Director Survey

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■ OBJECTIVE: **The novel coronavirus disease 2019 (COVID-19) pandemic has led to a shift to virtual residency interviews for the 2020–2021 neurosurgery match, with unknown implications for stakeholders. This study seeks to analyze the perceptions of residency program directors (PDs) and associate program directors (APDs) regarding the current virtual format used for residency selection and interviews.**

■ METHODS: **An anonymous, 30-question survey was constructed and sent to 115 neurosurgery PDs and 26 APDs to assess respondent demographics, factors used to review applicants, perceptions of applicants and applicant engagement, perceptions of standardized letters and interview questions, the effect of the virtual interview format on various stakeholders, and the future outlook for the virtual residency interview format.**

■ RESULTS: **A total of 38 PDs and APDs completed this survey, constituting a response rate of 27.0%. Survey respondents received significantly more Electronic Residency Application Service applications in the 2020–2021 cycle compared with the 2019-2020 cycle ($P = 0.0029$). Subinternship performance by home-rotators, (26.3%), letters of recommendation (23.7%), and Step 1 score (18.4%) were ranked as the most important factors for evaluating candidates during the current virtual application cycle.**

■ CONCLUSIONS: **Our study highlights that applicants applied to a greater number of residency programs compared with years prior, that the criteria used by PDs/APDs to evaluate applicants remained largely consistent compared to previous years, and that the virtual residency interview format may disproportionately disadvantage Doctor of Osteopathic medicine and international medical graduate applicants. Further exploring attitudes toward signaling mechanisms and standardized letters may serve to inform changes to future neurosurgery match cycles.**

INTRODUCTION

The ongoing novel coronavirus disease 2019 (COVID-19) pandemic has caused significant disruptions to U.S. medical infrastructure, including pre- and postgraduate medical education.[1-3] Due to travel restrictions and equity measures that have been implemented across the country, the 2020–2021 neurosurgery residency application cycle was conducted using a virtual interview format rather than the traditional in-person format. This change had major implications for almost all facets of the residency match process. Recent commentary has noted that virtual interviews may allow for a more equitable and affordable application cycle compared with the traditional interview format, where applicants were expected to incur major travel

Key words
- COVID-19
- Education
- Match
- Neurosurgery
- Residency

Abbreviations and Acronyms
AANS: American Association of Neurological Surgeons
APD: Associate program director
COVID-19: Coronavirus disease 2019
DO: Doctor of Osteopathic Medicine
ERAS: Electronic Residency Application Service
IMG: International medical graduate
NRMP: National Resident Matching Program
PD: Program director

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expenses as they visited programs across the country.[4,5] However, virtual interviews are not amendable to direct or lengthy in-person communication that programs have traditionally used for properly gauging which applicants would be the best fit for their programs. Similarly, applicants may prefer in-person communication and on-site tours to properly evaluate a particular program's learning environment and culture.[6] Scant literature exists about the effectiveness of virtual interviews in resident selection before the COVID-19 pandemic.

While survey research has documented student and faculty perceptions of the virtual interview format across a number of medical specialties, the views of neurosurgery applicants and program directors (PDs) regarding virtual residency interviews have not yet been analyzed.[7-11] Therefore, the present study sought to survey the perceptions of residency PDs and associate program directors (APDs) regarding the 2020–2021 virtual application cycle. The findings of our work may serve to inform and guide further changes regarding the reincorporation of in-person interviews during the next residency application cycle, and to determine both the efficacy of virtual interviews and their possible role in future application cycles.

METHODS

Survey Construction

An anonymous, 30-question survey was constructed in Qualtrics (Provo, Utah, USA). Question formats included multiple choice, ranking, and free-response. The survey questions developed by the study authors were influenced by similar research investigating virtual residency interview cycles in other surgical subspecialties.[7-12] The survey contained 12 questions aimed at assessing respondent demographics and program characteristics, 3 questions focused on factors used to review applicants during the interview cycle, 5 questions gauging perceptions of applicants and applicant engagement, 6 questions regarding perceptions of standardized letters and interview questions, 1 question regarding the effect of the virtual interview format on various stakeholders, and 3 questions regarding the efficacy and future outlook for the virtual residency interview format (**Appendix 1**).

Survey Distribution

Neurosurgery PD and APD contact information was obtained using the American Association of Neurological Surgeons (AANS) directory, the American Medical Association's Fellowship and Residency Electronic Interactive Database (https://freida.ama-assn.org/Freida/#/), and manual review of residency program websites. Our final list contained 115 PDs and 26 APDs, who were contacted via an e-mail containing a survey link sent by a study team member (A.M.K.) on behalf of the senior authors (J.H. and D.M.). A follow up e-mail was sent to PDs and APDs 3 weeks later.

Statistical Analysis

Survey responses were captured using Qualtrics and exported into Microsoft Excel format (Microsoft Corp., Redmond, Washington, USA) for analysis using R statistical software (Version 3.3.2, r-project.org). Continuous variables such as Electronic Residency Application Service (ERAS) applications received, number of interview sessions held, number of applicants interviewed, and number of applicants from home institutions were compared using the Mann–Whitney U test due to violation of the normality assumption. Figures were created using both R and Microsoft Excel.

RESULTS

Respondent Characteristics and Differences Between Application Cycles

Table 1 displays the characteristics of the 38 residency program personnel who responded to our survey, which represented a survey response rate of 27.0% (the remaining responses to our survey are detailed in **Supplementary Table 1**). The majority of respondents consisted of residency PDs (84.2%), with the remaining respondents being APDs (15.8%). A majority of programs (57.9%) were currently training between 10 and 20 residents, and most (55.3%) were planning on accepting 2 new interns during the 2020–2021 application cycle.

While only 9 programs (23.7%) received >300 ERAS applications during the 2019–2020 application cycle, 19 programs (50.0%) received >300 applications during the 2020–2021 cycle. The mean number of interview sessions held by programs during both the 2019–2020 and 2020–2021 application cycles remained constant, with most programs holding 3 interview sessions (50.0%), followed by 4 sessions (21.1%), 2 sessions (18.4%), 5 sessions (7.9%), and 1 session (2.6%). During the 2019–2020 application cycle, only 6 (15.8%) programs interviewed >50 applicants, compared with 13 (34.2%) programs interviewing >50 applicants during the current cycle. Further, a smaller proportion of programs (18.4%) interviewed <40 applicants during the current application cycle compared with the previous 2019–2020 cycle (31.6%).

As displayed in **Table 2**, the 38 programs that responded to our survey received significantly more ERAS applications during the 2020–2021 cycle relative to the 2019–2020 cycle ($P = 0.0029$). There was no significant difference in the number of interview sessions held ($P = 1.00$), the number of applicants interviewed ($P = 0.13$), or the number of applicants from each program's home institution ($P = 0.51$) between the 2 application cycles.

Important Factors in Reviewing Applicants During Virtual and In-Person Application Cycles

Within our survey, respondents were asked to rank their 5 most important factors in reviewing applications during the 2020–2021 cycle. Subinternship performance (by home-rotators) was most often ranked as the most important factor (10 votes), followed by letters of recommendation (9 votes), Step 1 score (7 votes), third-year clinical rotation grades (4 votes), and virtual subinternship participation (2 votes). Virtual meet-and-greet attendance, publications, personal statement, medical school name, preclinical grades, and Alpha Omega Alpha status each received 1 vote as the most important factor in reviewing applications.

A total of 8 (21.1%) respondents indicated that the factors they listed as their top 5 most important were different compared with last year's interview cycle. These respondents indicated that third-year clinical rotation grades (4 votes), subinternship performance (3 votes), and Step 1 score (2 votes) were the most important factors in reviewing applications during the 2019–2020 cycle. Further, direct preinterview communication with an applicant,

Table 1. Survey Respondent and Residency Program Characteristics ($n = 38$)

Characteristic	*n* (%)
Respondent position	
Program director	32 (84.2)
Associate program director	6 (15.8)
Total number of residents training at program	
<10	6 (15.8)
10–20	22 (57.9)
>20	10 (26.3)
Number of new interns in 2021	
1	6 (15.8)
2	21 (55.3)
3	9 (23.7)
4	2 (5.3)

	2019–2020 cycle, n (%)	2020–2021 cycle, *n* (%)
Number of ERAS applications received		
<200	3 (7.9)	0 (0.0)
200–300	26 (68.4)	19 (50.0)
>300	9 (23.7)	19 (50.0)
Number of interview sessions held		
1	1 (2.6)	1 (2.6)
2	7 (18.4)	7 (18.4)
3	19 (50.0)	19 (50.0)
4	8 (21.1)	8 (21.1)
5	3 (7.9)	3 (7.9)
Number of applicants interviewed		
<40	12 (31.6)	7 (18.4)
40–50	20 (52.6)	18 (47.4)
>50	6 (15.8)	13 (34.2)
Number of applicants from home institution interviewed		
0	9 (23.7)	4 (10.5)
1–3	19 (50.0)	25 (65.8)
>3	10 (26.3)	9 (23.7)

ERAS, Electronic Residency Application Service.

publications, and letters of recommendation each received 1 vote as the most important factor in reviewing applications during the previous application cycle among this respondent cohort. However, it is important to note that the majority of survey respondents (78.9%) overall felt as if the factors they used to evaluate applicants were consistent between the current application cycle and the 2019–2020 cycle.

Table 2. Differential Survey Respondent Characteristics Between the 2019–2020 and 2020–2021 Application Cycles ($n = 38$)

Characteristic	2019–2020, *n* (%)	2020–2021, *n* (%)	*P* Value
Mean number of ERAS applications received ± SD	273.24 ± 50.59	312.32 ± 51.67	**0.0029**
Mean number of interview sessions held ± SD			
1	1 (2.6)	1 (2.6)	1.00
2	7 (18.4)	7 (18.4)	
3	19 (50.0)	19 (50.0)	
4	8 (21.1)	8 (21.1)	
5	3 (7.9)	3 (7.9)	
Mean number of applicants interviewed ± SD	42.82 ± 11.61	47.18 ± 11.59	0.13
Mean number of applicants from home institution ± SD	2.18 ± 1.80	2.53 ± 1.93	0.51

Bold value is statistically significant ($P < 0.05$).
ERAS, Electronic Residency Application Service; SD, standard deviation.

Applicant Engagement During Virtual Interview Cycle

Figure 1 displays responses to questions focused on the perception of applicants and methods used to engage with applicants during the 2020–2021 cycle. Overall, most programs (60.5%) perceived that the overall quality of applicants during the virtual interview cycle was the same relative to last year, with 11 programs (28.9%) perceiving this year's applicants as stronger and 4 programs (10.5%) perceiving applicants as weaker. A total of 17 respondents (44.7%) indicated they communicated the same amount with applicants during the present application cycle relative to last year, with 12 (31.6%) and 9 (23.7%) respondents indicating they had more and less time to communicate with applicants, respectively. A majority of respondents (78.9%) felt they communicated with outside faculty regarding applicants the same amount relative to the 2019–2020 application cycle, with 6 respondents (15.8%) indicating they communicated more with outside faculty and 2 respondents (5.3%) indicating that such communication occurred less. Overall, survey respondents held an average of 2.61 virtual events before the ERAS deadline (with a standard deviation of ± 2.43). The platforms used by survey respondents for engaging with applicants during the 2020–2021 cycle were as follows: Zoom sessions (81.6%), revamped residency program website (65.8%), revamped residency program video (60.5%), Instagram (47.4%), Facebook (36.8%), Twitter (34.2%), YouTube (21.1%), and Neurosurgery Hub/Uncle Harvey (2.6%).

Standardized Letters, Standardized Interview Questions, and Preference Signaling

Figure 2 displays responses to survey questions regarding the use of standardized letters, standardized interview questions, and preference signaling during the residency application process.

Regarding how the use of standardized letters during the 2020–2021 application cycle affected respondents' perceptions of applicants, 14 respondents (36.8%) indicated they had a neutral impact, 12 respondents (31.6%) indicated they had a positive impact, and 10 respondents (26.3%) indicated they had a negative impact; 2 respondents (5.3%) indicated they had a significantly positive impact. Importantly, no respondents indicated that the use of standardized letters had a significantly negative impact. A total of 15 respondents (39.5%) agreed that the use of standardized letters enhanced the selection process, whereas 14 respondents (36.8%) disagreed. There were 9 respondents (23.7%) who neither agreed nor disagreed with the statement that standardized letters enhanced the selection process. There were 17 responses to the optional free-text question asking survey respondents to provide their thoughts on the standardized letter format, including suggestions for improvement. Only 4 free-text responses (23.5%) had a positive view of standardized letters or had minor suggestions for improvement, with the remaining free-text responses (76.5%) describing the letters as being of limited utility, unhelpful, or confusing.

Most (63.2%) survey respondents' institutions did not use standardized interview questions, although a majority (76.3%) indicated they would be open to using standardized questions in future application cycles.

Regarding the prospect of incorporating a preference signaling system into future match cycles, many (39.5%) respondents expressed some interest, with 4 (10.5%) expressing strong interest, and 4 (10.5%) remaining neutral. Further, a total of 3 (7.9%) respondents expressed some disinterest, with 4 (10.5%) respondents expressing strong disinterest.

Effect of Virtual Interview Format on Stakeholders

Respondent perceptions regarding how virtual relative to in-person residency interviews would affect various stakeholders were assessed, with the results summarized in **Figure 3**. A majority of respondents (73.7%) believed that students from more prestigious schools were likely to benefit from the virtual interview format. Many respondents felt that DO (Doctor of Osteopathic Medicine) students (71.1%) and IMGs (international medical graduates) (68.4%) would suffer as a result of the virtual interview process. Survey respondents also indicated that current residents (57.9%), less-prestigious programs (60.5%), and students from less-prestigious schools (60.5%) would likely suffer due to the virtual interview format.

Efficacy of Virtual Interview Format and Future Outlook

Figure 4 displays survey responses to questions aimed at gauging perceptions of the efficacy of the virtual interview format. Overall, many respondents (39.5%) felt confident in matching a "good fit" resident to their program, with 7 respondents (18.4%) indicating that they felt very confident in matching a "good fit" resident. Importantly, 10 respondents (26.3%) did not feel confident in matching "good fit" residents, with 6 respondents (15.8%) indicating that they felt neutral about this question.

A vast majority of respondents (97.4%) believed that virtual interviews led students to apply to more residency programs, and most (65.8%) also believed that virtual interviews should remain an option for cost-constrained applicants in future application cycles.

Post-Match Results

Supplementary Table 2 summarizes the official match data from the 2019–2020 and 2020–2021 application cycles released by the Association of American Medical Colleges ERAS and the National Resident Matching Program (NRMP).[12,13] In 2020–2021, the average number of applications submitted per applicant increased from 2019–2020 by 7.9 (12%), from 65.7 to 73.5 applications, respectively. Specifically, MD, DO, and IMG applicants on average submitted 8.5 (11.9%), 30.8 (61.7%), and 4.6 (8.5%) more applications in the 2020–2021 cycle, compared with the previous cycle, to an average of 79.7, 80.6, and 58.8 average applications per applicant, respectively.

PDs received an average of 41.9 (15%) additional applications in the 2020–2021 cycle compared with the previous cycle, bringing the average applications per program to 321.7, compared with 279.8 in 2019–2020, with the largest relative increase observed in the number of DO applications. DO applications per program increased 47.5% to 16.1 in 2021–2020, compared with 10.9% in the previous cycle.

Match results between the 2019–2020 and 2020–2021 application cycles were similar, with the exception of DO applicants. The number of DO applicants matched into neurosurgery more than doubled from 3 to 8 applicants between the 2019–2020 and 2020–2021 application cycles, respectively. Meanwhile the total DO applicants remained relatively unchanged, resulting in a 164.4% increase in the proportion of total DO applicants successfully matching; 34.8% of DO applicants matched in 2020–2021, whereas only 12.0% matched in the previous cycle. The proportion of total MD applicants who matched remained stable at roughly 74% during the 2019–2020 and 2020–2021 application cycles. The proportion of total IMG applicants who matched decreased in the 2020–2021 from the previous cycle by 18.9%; 14.1% of IMG applicants matched in 2019–2020, whereas 11.4% matched in 2020–2021.

Despite these observed trends between the 2019–2020 and 2020–2021 application cycles, the proportion of total filled positions in the neurosurgery match remained largely unchanged among MD and IMG applicants at roughly 90% and 7%–8%, respectively, whereas the proportion of filled positions by DO applicants more than doubled from 1.3% in 2019–2020 to 3.4% in 2020–2021.

DISCUSSION

The COVID-19 pandemic has significantly disrupted the traditional residency application process, with major implications for both programs and applicants. The present study aimed to characterize PD and APD perceptions regarding the efficacy of the new virtual interview format as well as its implications on stakeholders prior to Match results. Importantly, our findings highlight a perceived increase in applications during the current cycle that were substantiated by match data, concerns regarding the effect of the virtual interview format on the evaluation of DO and IMG students who matched similarly well or better in the 2020–2021 cycle relative to the previous cycle, and mixed sentiments regarding the utility of standardized letters in evaluating applicants.

Among our study results, a notable finding was that survey respondents received a significantly greater number of ERAS applications during the current 2020–2021 application cycle compared

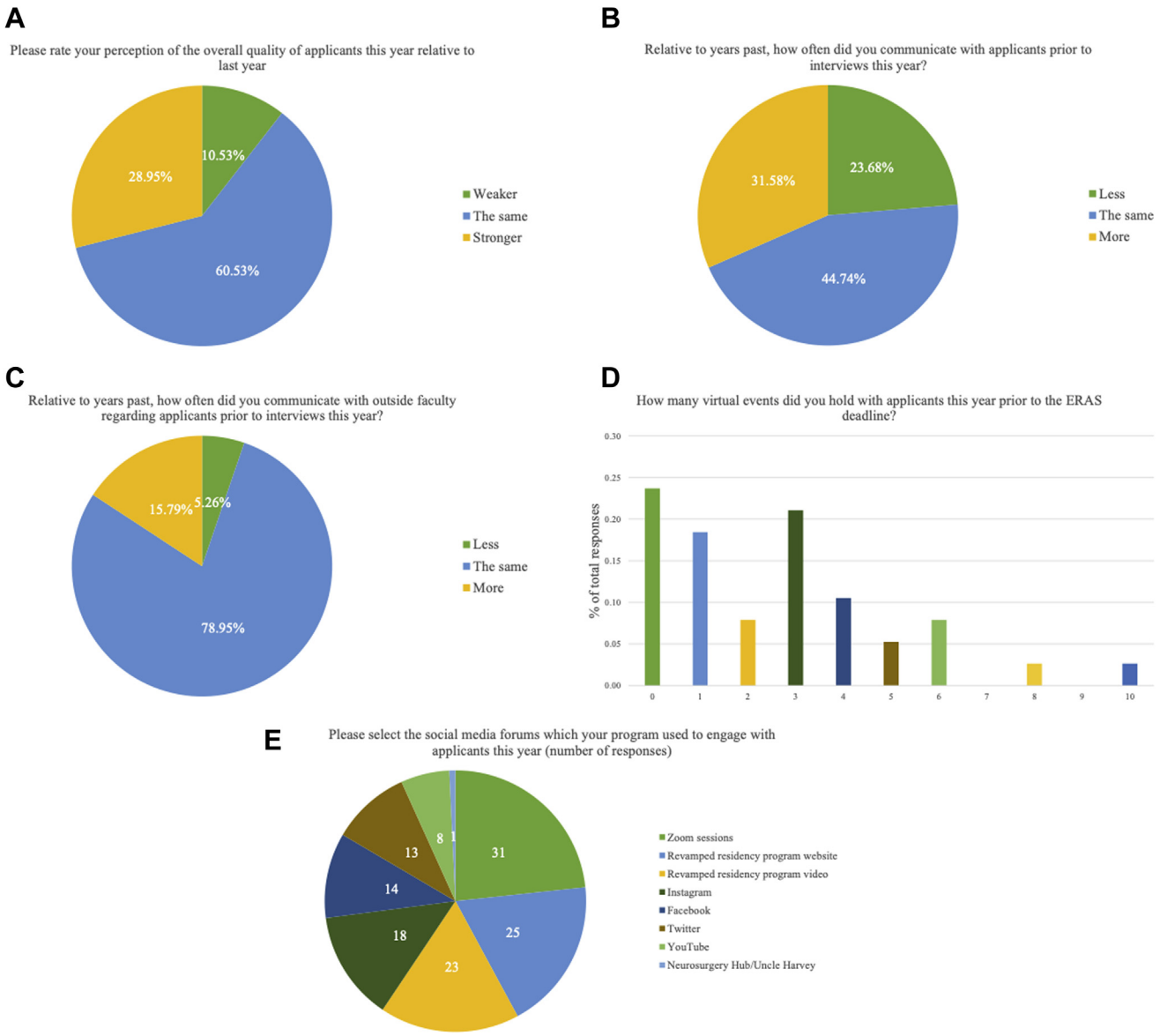

Figure 1. Perceptions of applicants and engagement during virtual interview cycle. (**A**) Perceptions of overall quality of applicants. (**B**) Perceptions of communication with applications relative to prior years. (**C**) Perceptions of communication with outside faculty relative to prior years. (**D**) Number of virtual events held. (**E**) Social media forums used to engage applicants.

with the 2019–2020 match. Our data also demonstrated that the vast majority of survey respondents believed that the virtual interview format led students to apply to more programs, a perception that also has been noted in survey research examining applicant perceptions of virtual residency interviews in otolaryngology.[9] This result is in line with Association of American Medical Colleges and NRMP match data (**Supplementary Table 2**), which showed that the number of applications per applicant in neurosurgery increased from 65.7 in 2019–2020 to 73.5 in 2020–2021.[14] Notably, DO applicants, who may share survey respondents' concerns that DO students may be negatively affected by virtual interviews, applied on average to 31 more programs per applicant in 2020–2021 relative to the 2019–2020 application cycle. This marked increase in applications among DO applicants from the previous cycle is more than 5 and 7 times greater than the relative increase in MD and IMG applications per applicant, respectively, between the 2019–2020 and 2020–2021 application cycles. Overall, our survey, substantiated by match data, supports recent commentary

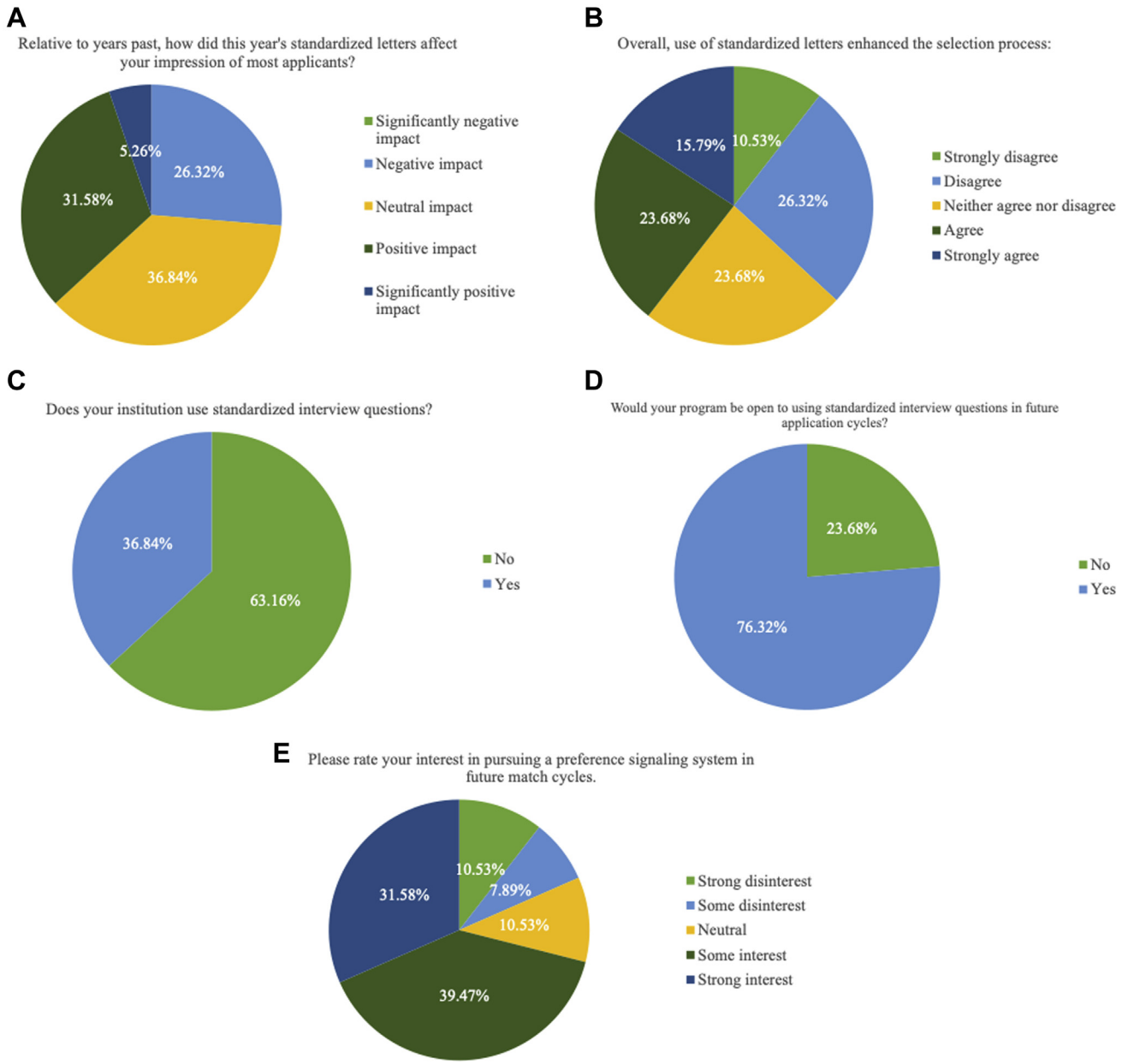

Figure 2. Perceptions of standardized letters and interview questions. (**A**) Perceptions of how standardized letters affected impressions of applicants. (**B**) Effect of standardized letters on enhancing the selection process. (**C**) Use of standardized interview questions. (**D**) Willingness to use standardized questions in future application cycles. (**E**) Interest in pursuing a preference signaling system in future match cycles.

positing that virtual residency interviews lead to an increase in the number of applications received by residency programs due to less travel-related cost constraints on the part of applicants and more scheduling flexibility on the part of programs.[15,16]

Studies within the otolaryngology literature have demonstrated that, against this background of increased residency applications, a small subset of competitive candidates may be receiving a disproportionately large number of interview offers.[16-18] While this phenomenon has not been well-characterized among neurosurgery applicants specifically, our results do support the possibility that virtual interviews may be driving the observed increase in the number of ERAS applications received by the programs who responded to our survey. It is also possible that the reduction in cost and time constraints afforded by the virtual interview process

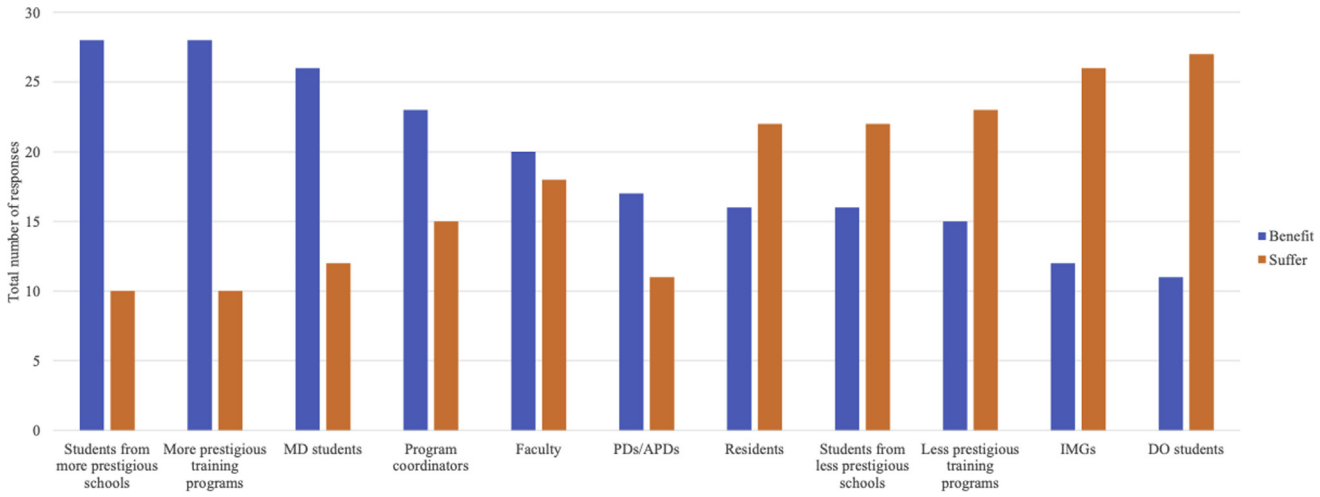

Figure 3. Perceptions regarding effect of virtual interview format on stakeholders. PDs/APDS, program directors/associate program directors; IMG, international medical graduates; DO, Doctor of Osteopathic Medicine.

may lead top candidates to participate in more interviews, filling slots that might otherwise go to a wider range of applicants. For example, applicants may use the monetary savings accrued from avoiding travel to apply to more programs than they would have during a normal, in-person interview cycle. This phenomenon may explain our survey result indicating that PDs feel that the virtual interview process disadvantages DO students, IMGs, and in some opinions students from "less prestigious" medical schools. However, despite PD and APD perceptions, the 2020–2021 match data (**Supplementary Table 2**) demonstrate a more successful match season for DO applicants overall, relative to the previous application cycle, evidenced by a 166% increase in successfully matched DO applicants from a 12% match rate among all DO applicants in 2019–2020 to a 35% match rate in 2021–2020. Meanwhile IMG applicants saw a small decrease in overall match rate from 14.1% in 2019–2020 to 11.4% in 2020–2021. However, it is important to note that during the 2015–2016 match, DO applicants had a 0% match rate while non-U.S. IMGs had a 16.7% match rate, highlighting the fact that match rates among these two groups has a large amount of variation from year to year.[13,19,20] Future surveys of applicants in the current cycle may help further clarify which, if any, candidates were truly disadvantaged in the virtual interview match cycle.

Our study shed light on neurosurgery PD and APD perceptions regarding virtual interviews before the 2020–2021 neurosurgery match and present 2019–2020 and 2020–2021 match data to compare these perceptions with published match outcomes. We sought to identify important factors that may guide future decisions regarding whether virtual interviews should remain an option for neurosurgery applicants alongside traditional in-person interviews. Arguments in favor of incorporating virtual interviews into the residency match process beyond the pandemic contend that the travel and lodging requirements for traditional interviews make the process cost-prohibitive for certain applicants.[4,5,10,21] This sentiment was echoed by the majority of respondents to our survey, who agreed that virtual interviews should remain an option for cost-constrained applicants beyond the current COVID-19 pandemic. However, it is important to note that the financial burden associated with a virtual residency application cycle is not negligible, given that applicants will likely still incur significant expenses due to having to apply to a greater number of programs than would have been expected for a traditional, in-person interview cycle.[9,14] Further, research also has suggested that an increase in submitted applications does not necessarily lead to a more equitable distribution of interviews, and that strategies such as preference signaling may be necessary to ensure that programs extend interviews to applicants who are likely to matriculate.[15,17,18] Preference signaling may be an effective mechanism by which the perceived issue of stronger candidates receiving a disproportionately large share of interview invites may be remedied, specifically by ensuring that PDs and APDs are aware of which applicants have a genuine interest in training at their programs. Importantly, our survey also demonstrated that most respondents expressed at least some interest in using a preference signaling system in future match cycles. However, creation of such a system would require collaboration with the NRMP and may have legal constraints. Although the exact mechanism that would be used for preference signaling within neurosurgery is currently unclear, inspiration could be drawn from efforts such as the Star System proposed within otolaryngology, which allows applicants to "star" a predetermined number of residency programs who would then receive a list of all applicants who starred their program.[22] Similar preference signaling mechanisms also have been proposed within orthopedic surgery.[23] Investigating the perspectives of PDs and APDs regarding the perceived unequal distribution of interview invitations during the virtual residency application cycle may yield better insight into the feasibility of a

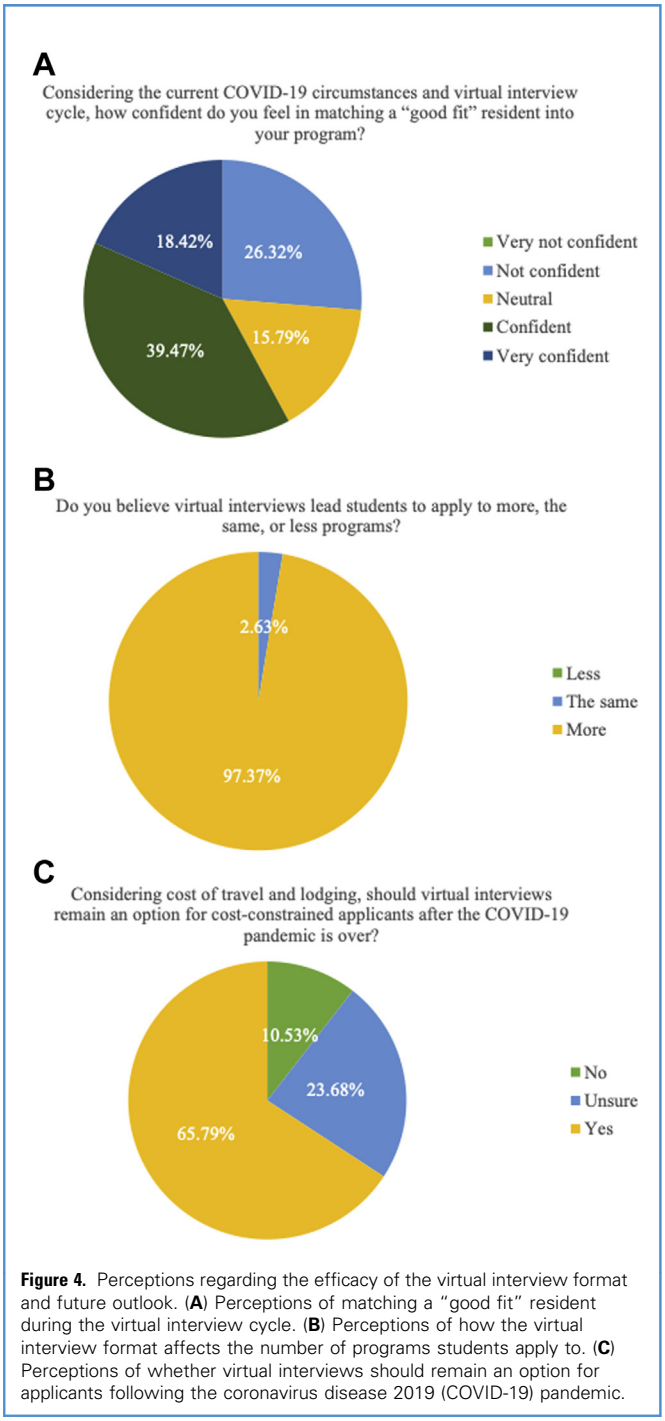

Figure 4. Perceptions regarding the efficacy of the virtual interview format and future outlook. (**A**) Perceptions of matching a "good fit" resident during the virtual interview cycle. (**B**) Perceptions of how the virtual interview format affects the number of programs students apply to. (**C**) Perceptions of whether virtual interviews should remain an option for applicants following the coronavirus disease 2019 (COVID-19) pandemic.

neurosurgery preference signaling system and will likely also be an important avenue for future research efforts.

Regarding the evaluation of candidates during both the 2019–2020 and 2020–2021 application cycles, survey respondents indicated that subinternship performance (for home rotators), letters of recommendation, and Step 1 score were among the most important factors used for evaluating candidates. These same factors were also highly cited in both the 2020 NRMP Program Director Survey and in the broader literature on the topic as important criteria for extending interview invitations and for ranking applicants.[24-27] Given that subinternships were cancelled during height of the COVID-19 pandemic, our interpretation of the survey results was that word of mouth between programs/faculty regarding the in-person subinternship experience and clinical performance of applicants was highly valued when making candidate selections. Of note, participation in virtual subinternships and virtual meetings did not significantly impact candidate selection. Interestingly, virtual meet-and-greet participation, Society of Neurological Surgeons virtual presentations, and virtual sub-I participation were much less often selected compared with the aforementioned factors, suggesting that the most important criteria for reviewing applicants remained rather consistent between in-person and virtual interview cycles and did not overtly shift heavily towards weighing virtual interactions.

Interesting, most survey respondents felt that overall quality of applicants during this year's cycle was similar compared with the 2019–2020 cycle, with the majority of respondents also indicating that communication with outside faculty before interviews was similar to last year. Opinion regarding communication with applicants before interviews was more split, with many respondents indicating they communicated more with applicants this year, whereas a sizeable portion indicated communication with applicants was decreased this year. Preinterview applicant engagement was further explored by asking respondents how many virtual events they held before the ERAS deadline and by asking what platforms they used to engage with applicants. Though standard guidelines for virtual interviews have not been established, Zoom has been widely regarded as a reliable method for engaging with prospective trainees, as evidenced by both our survey results and by similar research in other medical specialties.[12,16,28,29] In addition, our survey results demonstrated that 12 respondents (31.6%) did not use any form of social media (including Instagram, Facebook, Twitter, or YouTube) to engage prospective trainees, highlighting that while social media has become more common among neurosurgery residency programs, its use is likely not yet ubiquitous. Given that the effects of social media platforms on residency education, recruitment, and professionalism is not well established within the medical literature, further research regarding the use of such platforms within neurosurgery will be of crucial importance in optimizing future residency application cycles.[30]

Regarding the effect of virtual interviews on various stakeholders, opinion seemed fairly split between survey respondents on whether applicants from more or less prestigious schools and training programs stood to significantly benefit from the new interview format compared with in-person interviews. While our survey responses demonstrate a small number of respondents indicating that medical school name is one of the most important factors used in evaluating candidates, medical school name was not as often selected as an important factor relative to, for instance, Step 1 score or letters of recommendation. There appears to be considerable uncertainty in whether applicants from top schools have significantly benefitted from the current virtual interview format, and further research will be needed to confirm

the generalizability of our findings. In contrast, survey responses clearly indicate that PDs and APDs viewed DO students and IMGs as either somewhat suffering or significantly suffering as a result of the virtual interview format. The disparities and challenges faced by both these groups in navigating the neurosurgery match have been well characterized.[31-34] In considering whether to incorporate virtual interviews alongside in-person interviews for future application cycles, it may be important to note that the same groups who are perceived to be disadvantaged by virtual interviews (i.e., IMGs and DO students) are also perceived as likely suffering from the planned Step 1 pass/fail scoring change.[31-34] Careful planning and extensive discussion is warranted to ensure that these applicants continue to receive a fair evaluation in upcoming application cycles.

Overall, our survey results conveyed that opinions regarding the utility of standardized letters in evaluating neurosurgery residency applicants were mixed. While previous research has characterized perceptions regarding the potential implementation of standardized letters, our survey represents the first effort of quantifying attitudes toward the actual use of standardized letters during the application cycle.[35] In the free-text portion of the survey, respondents commented that the standardized letter format was not being used consistently and noted some letters were not helpful in further differentiating candidates. However, respondents also noted that with formatting improvements during future application cycles, standardized letters have the potential to aid in the evaluation of applicants. Ongoing exchanges between organized neurosurgery, faculty, and applicants in the coming years may help ensure a successful incorporation of the standardized letter format into the neurosurgery match process. Further, while standardized interview questions were not used by a majority of survey respondents, most respondents did indicate an interest in using such questions in future application cycles. Therefore, standardized interview questions may be another promising avenue through which to optimize the residency interview format and should remain an important part of conversations regarding further potential changes to the match process.

Limitations

There are a number of limitations to the present study. Data were collected by means of a voluntary survey, which had an incomplete response rate (27%), thereby potentially limiting the generalizability of our results. Some degree of selection bias may have been introduced into our study, given that PDs and APDs who have a greater familiarity with Qualtrics or other online survey platforms may have been more likely to respond to our survey. Our survey was also sent to PDs and APDs during a global pandemic that has significantly strained the U.S. healthcare system, which have influenced both our incomplete response rate and the nature of survey responses. The results obtained using our sample of respondents (38) would ideally be validated in future studies incorporating a larger sample size of neurosurgery PDs and APDs, which is planned after the results of the Match are available. Further, we were only able to capture perceptions specifically from PDs and APDs, and we hope future research efforts will be able to study the perceptions of other stakeholders such as applicants and residents. In addition, our methodology did not allow us to determine whether survey responses were received from PDs and APDs from the same program, and therefore some respondent overlap may be possible. It is also important to note that the present study only analyzed responses from PDs and APDs regarding the neurosurgery residency application process within the United States, and therefore certain findings may not be directly applicable to the residency application process in other countries. However, our specific findings regarding how IMGs may be affected by virtual residency interviews may be of interest to the broader, global neurosurgical community. Acknowledging these limitations, we believe our survey provides important preliminary data regarding neurosurgery faculty perceptions of the virtual application cycle conducted during the ongoing COVID-19 pandemic. Our work may prove useful in both informing and guiding changes in residency interview formatting during the coming years.

CONCLUSIONS

The present study represents the first effort to analyze neurosurgery PD and APD perceptions of the virtual residency interview format implemented in response to the COVID-19 pandemic. A significantly greater number of ERAS applications submitted during the current application cycle compared to the 2019–2020 cycle supports perceptions that virtual interviews allow applicants to apply to a greater number of programs. This did not lead to a significant increase in the number of applicants interviewed, albeit a trend toward more applicants interviewed was observed. The incorporation of virtual interviews into application cycles after resolution of the pandemic warrants consideration of the benefits and drawbacks of allowing applicants to potentially apply to an even greater number of programs. Preference signaling mechanisms, standardized letters, and standardized interview questions will likely remain important topics of interest as our field's residency application process continues to evolve. Subsequent investigations aimed at understanding the number of interviews top applicants attended in the virtual format compared with previous years may shed light on the impact of the virtual match on neurosurgery applicants collectively. We hope that our study provides actionable information that can be used to guide changes to future neurosurgery match cycles.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Adrian E. Jimenez: Conceptualization, Methodology, Software, Data curation, Formal analysis, Investigation, Writing – original draft. **Adham M. Khalafallah:** Conceptualization, Methodology, Software, Data curation, Formal analysis, Investigation, Writing – original draft. **Robert M. Romano:** Writing – original draft, Investigation, Formal analysis, Data curation. **Lola B. Chambless:** Conceptualization, Methodology, Software, Formal analysis, Investigation. **Stacey Quintero Wolfe:** Conceptualization, Methodology, Supervision, Project administration. **Timothy F. Witham:** Conceptualization, Supervision, Project administration. **Judy Huang:** Conceptualization, Methodology, Supervision, Project administration. **Debraj Mukherjee:** Conceptualization, Methodology, Supervision, Project administration.

REFERENCES

1. Rose S. Medical student education in the time of COVID-19. JAMA. 2020;323:2131-2132.
2. Emanuel EJ. The inevitable reimagining of medical education. JAMA. 2020;323:1127-1128.
3. Gabrielson AT, Kohn JR, Sparks HT, et al. Proposed changes to the 2021 residency application process in the wake of COVID-19. Acad Med. 2020; 95:1346-1349.
4. Zaki MM, Nahed BV. Letters to the editor: using virtual interviews in residency selection beyond covid-19. Acad Med. 2020;95:e7-e8.
5. Agarwal N, Choi PA, Okonkwo DO, et al. Financial burden associated with the residency match in neurological surgery. J Neurosurg. 2017;126:184-190.
6. Huppert LA, Hsiao EC, Cho KC, et al. Virtual interviews at graduate medical education training programs [e-pub ahead of print]. Acad Med. https://doi.org/10.1097/ACM.0000000000003868, accessed February 1, 2021.
7. Kenigsberg AP, Khouri RK, Kuprasertkul A, et al. Urology residency applications in the COVID-19 era. Urology. 2020;143:55-61.
8. Bamba R, Bhagat N, Tran PC, et al. Virtual interviews for the independent plastic surgery match: a modern convenience or a modern misrepresentation? J Surg Educ. 2021;78:612-621.
9. Izreig S, Torabi SJ, Kasle DA, et al. Otolaryngology Match 2020—21: survey of prospective applicants in the setting of COVID-19. Ann Otol Rhinol Laryngol. 2021;130:450-458.
10. Seifi A, Mirahmadizadeh A, Eslami V. Perception of medical students and residents about virtual interviews for residency applications in the United States. PLoS One. 2020;15:1-15.
11. Hill MV, Ross EA, Crawford D, et al. Program and candidate experience with virtual interviews for the 2020 Complex General Surgical Oncology interview season during the COVID pandemic. Am J Surg. 2021;222:99-103.
12. Majumder A, Eckhouse SR, Brunt LM, et al. Initial experience with a virtual platform for advanced gastrointestinal minimally invasive surgery fellowship interviews. J Am Coll Surg. 2020;231: 670-678.
13. National Resident Matching Program. National Resident Matching Program, Results and Data: 2016 Main Residency Match. Available at: https://www.nrmp.org/wp-content/uploads/2016/04/Main-Match-Results-and-Data-2016.pdf. Accessed February 1, 2021.
14. American Association of Medical Colleges. ERAS Statistics. Available at: https://www.aamc.org/data-reports/students-residents/report/eras-statistics. Accessed February 1, 2021.
15. Morgan HK, Winkel AF, Standiford T, et al. The case for capping residency interviews. J Surg Educ. 2021;78:755-762.
16. Asaad M, Rajesh A, Kambhampati PV, et al. Virtual interviews during COVID-19. Ann Plast Surg. 2021;86:367-370.
17. Whipple ME, Law AB, Bly RA. A computer simulation model to analyze the application process for competitive residency programs. J Grad Med Educ. 2019;11:30-35.
18. Lee AH, Young P, Liao R, et al. I dream of Gini: quantifying inequality in otolaryngology residency interviews. Laryngoscope. 2019;129:627-633.
19. National Resident Matching Program. National Resident Matching Program, Charting Outcomes in the Match for U.S. Osteopathic Medical Students and Graduates; 2016. Available at: https://www.nrmp.org/wp-content/uploads/2016/09/Charting-Outcomes-US-Osteopathic-2016.pdf. Accessed February 1, 2021.
20. National Resident Matching Program. National Resident Matching Program, Charting Outcomes in the Match for International Medical Graduates. Available at: https://www.nrmp.org/wp-content/uploads/2016/09/Charting-Outcomes-IMGs-2016.pdf. Accessed February 1, 2021.
21. Wright AS. Virtual interviews for fellowship and residency applications are effective replacements for in-person interviews and should continue post-COVID. J Am Coll Surg. 2020;231:678-680.
22. Salehi PP, Benito D, Michaelides E. A novel approach to the national resident matching program—the star system. JAMA Otolaryngol Head Neck Surg. 2018;144:397-398.
23. Bernstein J. Not the last word: want to match in an orthopaedic surgery residency? Send a rose to the program director. Clin Orthop Relat Res. 2017;475: 2845-2849.
24. National Resident Matching Program. Results of the 2020 NRMP Program Director Survey. Available at: https://mkonrmp3oyqui6wqfm.kinstacdn.com/wp-content/uploads/2020/08/2020-PD-Survey.pdf. Accessed February 1, 2021.
25. Green M, Jones P, Thomas JX. Selection criteria for residency: results of a national program directors survey. Acad Med. 2009;84:362-367.
26. Al Khalili K, Chalouhi N, Tjoumakaris S, et al. Programs selection criteria for neurological surgery applicants in the United States: a national survey for neurological surgery program directors. World Neurosurg. 2014;81:473-477.e2.
27. Lubelski D, Healy AT, Friedman A, et al. Correlation of personality assessments with standard selection criteria for neurosurgical residency applicants. J Neurosurg. 2016;125:986-994.
28. Wolff M, Burrows H. Planning for virtual interviews: residency recruitment during a pandemic. Acad Pediatr. 2020;21:24-31.
29. Hill MV, Bleicher RJ, Farma JM. A How-to guide: virtual interviews in the era of social distancing. J Surg Educ. 2021;78:321-323.
30. Sterling M, Leung P, Wright D, Bishop TF. The use of social media in graduate medical education: a systematic review. Acad Med. 2017;92: 1043-1056.
31. Beckman JJ, Speicher MR. Characteristics of ACGME residency programs that select osteopathic medical graduates. J Grad Med Educ. 2020;12: 435-440.
32. Chandra A, Brandel MG, Wadhwa H, et al. The path to U.S. neurosurgical residency for foreign medical graduates: trends from a decade 2007—2017. World Neurosurg. 2020;137:e584-e596.
33. Huq S, Khalafallah AM, Botros D, et al. Perceived impact of USMLE Step 1 pass/fail scoring change on neurosurgery: program director survey. J Neurosurg. 2020;133:928-935.
34. Goshtasbi K, Abouzari M, Tjoa T, et al. The effects of pass/fail USMLE step 1 scoring on the otolaryngology residency application process. Laryngoscope. 2021;131:E738-E743.
35. Field NC, Gullick MM, German JW. Selection of neurological surgery applicants and the value of standardized letters of evaluation: a survey of United States program directors. World Neurosurg. 2020;136:e342-e346.

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SUPPLEMENTARY DATA

Supplementary Table 1. Remaining Survey Responses ($n = 38$)

Characteristic	*n* (%)
Please rate the perception of the overall quality of applicants this year relative to last year.	
Weaker	4 (10.5)
The same	23 (60.5)
Stronger	11 (28.9)

Please rank the top 5 top elements most helpful in your review of applicants this year.	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Virtual meet-and-greet participation	1 (2.6)	2 (5.3)	0 (0.0)	1 (2.6)	2 (5.3)
SNS virtual presentation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)
Virtual sub-I participation	2 (5.3)	1 (2.6)	1 (2.6)	0 (0.0)	0 (0.0)
Whether an applicant applied for an away rotation at your program (before mandated cancellation)	0 (0.0)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)
Subinternship performance (home rotators)	10 (26.3)	3 (7.9)	1 (2.6)	2 (5.3)	4 (10.5)
Preinterview applicant direct communication	0 (0.0)	1 (2.6)	0 (0.0)	1 (2.6)	1 (2.6)
Preinterview outside faculty communication regarding an applicant	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.3)	1 (2.6)
Publication	1 (2.6)	8 (21.1)	11 (28.9)	5 (13.2)	4 (10.5)
Personal statement	1 (2.6)	1 (2.6)	3 (7.9)	4 (10.5)	1 (2.6)
Medical school name	1 (2.6)	0 (0.0)	0 (0.0)	4 (10.5)	3 (7.9)
Letters of recommendation	9 (23.7)	10 (26.3)	4 (10.5)	10 (26.3)	5 (13.2)
Preclinical grades	1 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.3)
Third-year clinical rotation grades	4 (10.5)	1 (2.6)	8 (21.1)	2 (5.3)	1 (2.6)
AOA status	1 (2.6)	4 (10.5)	1 (2.6)	0 (0.0)	0 (0.0)
Step 1 score	7 (18.4)	6 (15.8)	6 (15.8)	4 (10.5)	5 (13.2)
Step 2 CK score	0 (0.0)	1 (2.6)	2 (5.3)	0 (0.0)	0 (0.0)
Awards	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.6)	3 (7.9)
Extra-curricular activities	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (7.9)
Former student-athlete	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geographic location of applicant	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.3)	0 (0.0)
Were these top 5 elements the same during last year's interview cycle?					
Yes			30 (78.9)		
No			8 (21.1)		

If "yes" to the previous question, please rank the top 5 top elements most helpful in your review of applicants last year.	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Virtual meet-and-greet participation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
SNS virtual presentation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Virtual sub-I participation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Continues

Supplementary Table 1. Continued

If "yes" to the previous question, please rank the top 5 top elements most helpful in your review of applicants last year.	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Whether an applicant applied for an away rotation at your program (before mandated cancellation)	0 (0.0)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)
Subinternship performance (home rotators)	3 (7.9)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)
Preinterview applicant direct communication	1 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.6)
Preinterview outside faculty communication regarding an applicant	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Publication	1 (2.6)	1 (2.6)	1 (2.6)	3 (7.9)	1 (2.6)
Personal statement	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)	1 (2.6)
Medical school name	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)	1 (2.6)
Letters of recommendation	1 (2.6)	1 (2.6)	2 (5.3)	3 (7.9)	1 (2.6)
Preclinical grades	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Third-year clinical rotation grades	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.6)	1 (2.6)
AOA status	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)	1 (2.6)
Step 1 score	2 (5.3)	3 (7.9)	2 (5.3)	0 (0.0)	0 (0.0)
Step 2 CK score	0 (0.0)	0 (0.0)	1 (2.6)	0 (0.0)	0 (0.0)
Awards	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Extra-curricular activities	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Former student-athlete	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Geographic location of applicant	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Relative to years past, how often did you communicate with applicants before interviews this year.					
Less			9 (23.7)		
The same			17 (44.7)		
More			12 (31.5)		
Relative to years past, how often did you communicate with outside faculty regarding applicants before interviews this year?					
Less			2 (5.3)		
The same			30 (78.9)		
More			6 (15.8)		
Please select the social media forums which your program used to engage with applicants this year.*					
Twitter			13 (34.2)		
Instagram			18 (47.4)		
Facebook			14 (36.8)		
YouTube			8 (21.1)		
Zoom sessions			31 (81.6)		
NeurosurgeryHub/Uncle Harvey			1 (2.6)		
Revamped residency program website			25 (65.8)		
Revamped residency program video			23 (60.5)		

SNS, Society of Neurological Surgeons; AOA, Alpha and Omega; CK, clinical knowledge; ERAS, Electronic Residency Application Service; SD, standard deviation; COVID-19, coronavirus disease 2019; PDs, program directors; APDs, associate program directors; DO, Doctor of Osteopathic Medicine; IMG, International medical graduate.
*Respondents were permitted to select more than 1 option.

Continues

Supplementary Table 1. Continued

If "yes" to the previous question, please rank the top 5 top elements most helpful in your review of applicants last year.	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
How many virtual events did you hold with applicants this year before the ERAS deadline (mean ± SD)?			2.61 ± 2.43		
Relative to years past, how did this year's standardized letters affect your impression of most applicants?					
Significantly negative impact			0 (0.0)		
Negative impact			10 (26.3)		
Neutral impact			14 (36.8)		
Positive impact			12 (31.6)		
Significantly positive impact			2 (5.3)		
Overall, the use of standardized letters enhanced the selection process.					
Strongly disagree			4 (10.5)		
Disagree			10 (26.3)		
Neither agree nor disagree			9 (23.7)		
Agree			9 (23.7)		
Strongly agree			6 (15.8)		
Does your institution use standardized interview questions?					
Yes			14 (36.8)		
No			24 (63.2)		
Would your program be open to using standardized interview questions in future application cycles?					
Yes			29 (76.3)		
No			9 (23.7)		
Do you believe virtual interviews lead students to apply to more, the same, or fewer programs?					
Fewer			0 (0.0)		
The same			1 (2.6)		
More			37 (97.4)		
Considering the cost of travel and lodging, should virtual interviews remain an option for cost-constrained applicants after the COVID-19 pandemic is over?					
Yes			25 (65.8)		
No			4 (10.5)		
Unsure			9 (23.7)		

Who will benefit/suffer from virtual interviews this year?	Significantly benefit	Somewhat benefit	Somewhat suffer	Significantly suffer
Students from less prestigious schools	7 (18.4)	9 (23.7)	14 (36.8)	8 (21.1)
Students from more prestigious schools	10 (26.3)	18 (47.4)	9 (23.7)	1 (2.6)
Less prestigious training programs	5 (13.2)	10 (26.3)	16 (42.1)	7 (18.4)
More prestigious training programs	7 (18.4)	21 (55.3)	9 (23.7)	1 (2.6)
PDs/APDs	4 (10.5)	13 (34.2)	17 (44.7)	4 (10.5)
Faculty	3 (7.9)	17 (44.7)	16 (42.1)	2 (5.3)

Continues

Supplementary Table 1. Continued

Who will benefit/suffer from virtual interviews this year?	Significantly benefit	Somewhat benefit	Somewhat suffer	Significantly suffer
Residents	2 (5.3)	14 (36.8)	20 (52.6)	2 (5.3)
Program coordinators	4 (10.5)	19 (50.0)	12 (31.6)	3 (7.9)
DO students	3 (7.9)	8 (21.1)	13 (34.2)	14 (36.8)
MD students	6 (15.8)	20 (52.6)	10 (26.3)	2 (5.3)
IMGs	4 (10.5)	8 (21.1)	13 (34.2)	13 (34.2)
Considering the current COVID-19 circumstances and virtual interview cycle, how confident do you feel in matching a "good fit" resident into your program?				
Very confident	7 (18.4)			
Confident	15 (39.5)			
Neutral	6 (15.8)			
Not confident	10 (26.3)			
Very not confident	0 (0.0)			
"Preference signaling" has been suggested as a mechanism for programs to better elucidate who among their applicants harbor a strong desire to match at their specific program. In such a system applicants are asked to "signal" a small number of programs they are especially interested in prior to matching. Please rate your interest in pursuing a preference signaling system in future match cycles.				
Strong interest	12 (31.6)			
Some interest	15 (39.5)			
Neutral	4 (10.5)			
Some disinterest	3 (7.9)			
Strong disinterest	4 (10.5)			

SNS, Society of Neurological Surgeons; AOA, Alpha and Omega; CK, clinical knowledge; ERAS, Electronic Residency Application Service; SD, standard deviation; COVID-19, coronavirus disease 2019; PDs, program directors; APDs, associate program directors; DO, Doctor of Osteopathic Medicine; IMG, International medical graduate.
*Respondents were permitted to select more than 1 option.

Supplementary Table 2. ERAS/NRMP Neurosurgery Match Data Comparing the 2019–2020 and 2020–2021 Application Cycles*

Characteristic	2020	2021	Change from 2020	
Total positions	232	234	+2	+0.9%
Total positions filled	232	234	+2	+0.9%
Average applications submitted	65.7	73.5	+7.9	+12.0%
MD	71.2	79.7	+8.5	+11.9%
DO	49.8	80.6	+30.8	+61.7%
IMG	54.2	58.8	+4.6	+8.5%
Average applications per program	279.8	321.7	+41.9	+15.0%
MD	208.7	229.4	+20.7	+9.9%
DO	10.9	16.1	+5.2	+47.5%
IMG	60.3	76.2	+15.9	+26.3%
Total applicants	490	503	+13	+2.7%
MD	337	331	−6	−1.8%
MD, U.S. seniors	273	269	−4	−1.5%
MD, U.S. graduates	64	62	−2	−3.1%
DO	25	23	−2	−8.0%
DO, U.S. seniors	18	14	−4	−22.2%
DO, U.S. graduates	7	9	+2	+28.6%
IMG	128	149	+21	+16.4%
IMG, U.S.	n.d.	n.d.		
IMG, Non-U.S.	n.d.	n.d.		
Applicants matched	232	234	+2	+0.9%
MD	211	209	−2	−0.9%
MD, U.S. seniors	203	198	−5	−2.5%
MD, U.S. graduates	8	11	+3	+37.5%
DO	3	8	+5	+166.7%
DO, U.S. seniors	3	6	+3	+100.0%
DO, U.S. graduates	0	2	+2	
IMG	18	17	−1	−5.6%
IMG, U.S.	6	6	0	0.0%
IMG, Non-U.S.	12	11	−1	−8.3%
Percent of applicants matched	47.3%	46.5%		−1.7%
MD	62.6%	63.1%		+0.8%
MD, U.S. seniors	74.4%	73.6%		−1.0%
MD, U.S. graduates	12.5%	17.7%		+41.9%
DO	12.0%	34.8%		+189.9%
DO, U.S. seniors	16.7%	42.9%		+157.1%
DO, U.S. graduates	0.0%	22.2%		
IMG	14.1%	11.4%		−18.9%
IMG, U.S.	n.d.	n.d.		
IMG, Non-U.S.	n.d.	n.d.		
Percent of positions filled	100.0%	100.0%		0.0%
MD	90.9%	89.3%		−1.8%
MD, U.S. Seniors	87.5%	84.6%		−3.3%
MD, U.S. Graduates	3.4%	4.7%		+36.3%
DO	1.3%	3.4%		+164.4%
DO, U.S. Seniors	1.3%	2.6%		+98.3%
DO, U.S. Graduates	0.0%	0.9%		
IMG	7.8%	7.3%		−6.4%
IMG, U.S.	2.6%	2.6%		−0.9%
IMG, Non-U.S.	5.2%	4.7%		−9.1%

ERAS/NRMP, Electronic Residency Application Service/National Resident Matching Program; DO, Doctor of Osteopathic Medicine; IMG, International medical graduate; n.d., not determined.

*Adapted from ERAS (Association of American Medical Colleges) Preliminary Statistics for 2021 and NRMP Reports 2020 and 2021.