# Student Survey Results of a Virtual Medical Student Course Developed as a Platform for Neurosurgical Education During the Coronavirus Disease 2019 Pandemic

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■ BACKGROUND: **Before the coronavirus disease 2019 (COVID-19) pandemic, medical students training in neurosurgery relied on external subinternships at institutions nationwide for immersive educational experiences and to increase their odds of matching. However, external rotations for the 2020–2021 cycle were suspended given concerns of spreading COVID-19. Our objective was to provide foundational neurosurgical knowledge expected of interns, bootcamp-style instruction in basic procedures, and preinterview networking opportunities for students in an accessible, virtual format.**

■ METHODS: **The virtual neurosurgery course consisted of 16 biweekly 1-hour seminars over a 2-month period. Participants completed comprehensive precourse and postcourse surveys assessing their backgrounds, confidence in diverse neurosurgical concepts, and opinions of the qualities of the seminars. Responses from students completing both precourse and postcourse surveys were included.**

■ RESULTS: **An average of 82 students participated live in each weekly lecture (range, 41–150). Thirty-two participants completed both surveys. On a 1–10 scale self-assessing baseline confidence in neurosurgical concepts, participants were most confident in neuroendocrinology (6.79 $\pm$ 0.31) and least confident in spine oncology (4.24 $\pm$ 0.44), with an average of 5.05 $\pm$ 0.32 across all topics. Quality ratings for all seminars were favorable. The mean postcourse confidence was 7.79 $\pm$ 0.19, representing an improvement of 3.13 $\pm$ 0.38 ($P < 0.0001$).**

■ CONCLUSIONS: **Feedback on seminar quality and improvements in confidence in neurosurgical topics suggest that an interactive virtual course may be an effective means of improving students' foundational neurosurgical knowledge and providing networking opportunities before application cycles. Comparison with in-person rotations when these are reestablished may help define roles for these tools.**

## INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has caused large-scale disruptions in the daily operations of hospitals and medical schools worldwide. Medical schools have adapted to using remote virtual platforms to achieve student learning objectives and follow social distancing guidelines. Typically, medical students applying for residency positions in competitive surgical subspecialties in the United States have relied on visiting student externships at institutions of interest, as well as in-person interviews, to successfully match.[1] These external rotations also play a fundamental role in medical student education. They provide students with an immersive experience in the field that exposes them to a diverse sampling of cases, program idiosyncrasies, and training cultures that can influence how good a fit the applicant is for a program.

In April 2020, the Society of Neurological Surgeons recommended deferral of all medical student external rotations for the 2020–2021 academic year.[2] We recognized the need for a virtual neurosurgical educational resource for current and future residency applicants.[3-5] We designed a course that would provide 1) foundational knowledge that subinterns would be expected to learn, 2) bootcamp-style instruction in basic neurosurgical procedures with which subinterns frequently assist, 3) opportunities for interactions among students, faculty, and residents before interviews, and 4) tips for virtual interviews and navigating

**Key words**
- COVID-19
- Neurosurgery subinternships
- Neurosurgical education
- Virtual course

**Abbreviations and Acronyms**
**COVID-19**: Coronavirus disease 2019
**IMG**: International medical graduate
**SNS**: Society of Neurological Surgeons

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the interview season.[6] Precourse and postcourse surveys were administered to all course participants.

The primary purpose of this study was to assess the effectiveness of a virtual neurosurgery course in preparing medical students for residency applications and neurosurgery residency through self-assessed measures in student confidence across a wide range of neurosurgical topics.

## METHODS

The virtual neurosurgery course for medical students consisted of 16 one-hour seminars that were conducted biweekly over the course of a 2-month period. The course was sponsored entirely by the host institution's department of neurosurgery without any financial support from external organizations. It was advertised on social media platforms and interest was spread largely by word of mouth. The course was open to any interested student regardless of medical school status or country of origin. An overview of the curriculum is provided in Table 1. The virtual neurosurgery course for medical students was hosted remotely on the Zoom video conferencing platform (Figure 1A) in June and July 2020, divided into evening sessions lasting 1 hour. Students were encouraged to type questions into the online chat room for a quick response from the course director or they could hold their questions until the end to engage the speaker directly (Figure 1B). At the beginning of each session, participants were asked to raise their hands if they were final-year students applying into a neurosurgery course this cycle. Of these students, 15–20 were chosen for each session to serve as panelists, to whom the speaker could pose questions to assess core knowledge and reasoning. After each live webinar was completed, the recording of the session was posted online for on-demand viewing.

Three days before the start of the course, registered students were asked to complete a comprehensive survey collecting basic demographic and background information, as well as self-assessments of confidence and knowledge of specific topics within neurosurgery. On completion of the course, participants were asked to complete a follow-up survey (see Supplementary Content for the full precourse and postcourse surveys). All survey responses were kept confidential and anonymized for analysis, as communicated to students through e-mail and on the surveys.

Student survey responses were compared before and after the virtual course using paired analyses. In addition, subanalyses comparing responses between U.S. medical students and international medical graduates (IMGs) were performed. Prism 7 (GraphPad, La Jolla, California, USA) was used for statistical analysis. Continuous variables were compared using 2-sided paired t tests. $\chi^2$ tests were used to analyze categorical variables. Statistical significance was determined using $P < 0.05$. Students were also given an opportunity to provide anonymous free-response feedback on the course survey, including suggestions for future improvements.

## RESULTS

### Demographics

A total of 595 students originally registered for this course when the registration Web site went live. The online seminars were well attended, with an average of 82 students participating live in each weekly lecture (range, 41–150). Across all seminars, there was a group of approximately 40 students who attended almost every lecture. A total of 32 participants completed both the precourse and postcourse surveys (32/82 average participants each week; 39.0%), with most comprising the students who consistently watched each lecture live or on recording (average, 27/32 viewers per lecture; 84.4%). Among the respondents, the average age was 25.5 ± 0.56 years, 21 (65.6%) were male, and 15 (46.9%) identified as an underrepresented minority in medicine (Table 2). Nineteen respondents (59.4%) were IMGs, whereas the other 13 (40.6%) were U.S. medical students. Among the U.S. medical students, 12 (92.3%) had a home neurosurgery program. At the time of the lecture series, most respondents had completed either the third year of medical school (or equivalent) or a research year (34.4% and 28.1%, respectively) during 2019–2020. Most students were planning to complete their neurosurgical subinternships during 2020–2021 (11 students, 34.4%) or 2021–2022 (11 students, 34.4%) and were completely confident that they would apply into a neurosurgery course (25 students; 78.1%). Twelve students (37.5%) indicated that they would pursue an additional degree before applying. In comparing the demographic characteristics of the U.S. medical student and IMG cohorts, we found that both groups were remarkably similar, with the exception of a greater proportion of IMG students reporting that they would earn another degree during medical school ($P = 0.02$) and more U.S. medical students stating that they would be undertaking their neurosurgical subinternships during the 2020–2021 academic year ($P = 0.01$; Table 3).

**Table 1.** Lectures Comprising the Virtual Medical Student Course in Neurosurgery

| Lecture Number | Lecture Title |
|---|---|
| 1 | Introduction |
| 2 | Malignant brain tumors |
| 3 | Brain trauma |
| 4 | Spine trauma |
| 5 | Pituitary pathology and neuroendocrinology |
| 6 | Cerebrovascular 1 |
| 7 | Pediatric neurosurgery |
| 8 | Neurocritical care |
| 9 | Minor neurosurgical procedures |
| 10 | Cerebrovascular 2 |
| 11 | Degenerative spine |
| 12 | Spine tumors |
| 13 | Skull base |
| 14 | Functional neurosurgery |
| 15 | Life in neurosurgery |
| 16 | Navigating a virtual interview season |

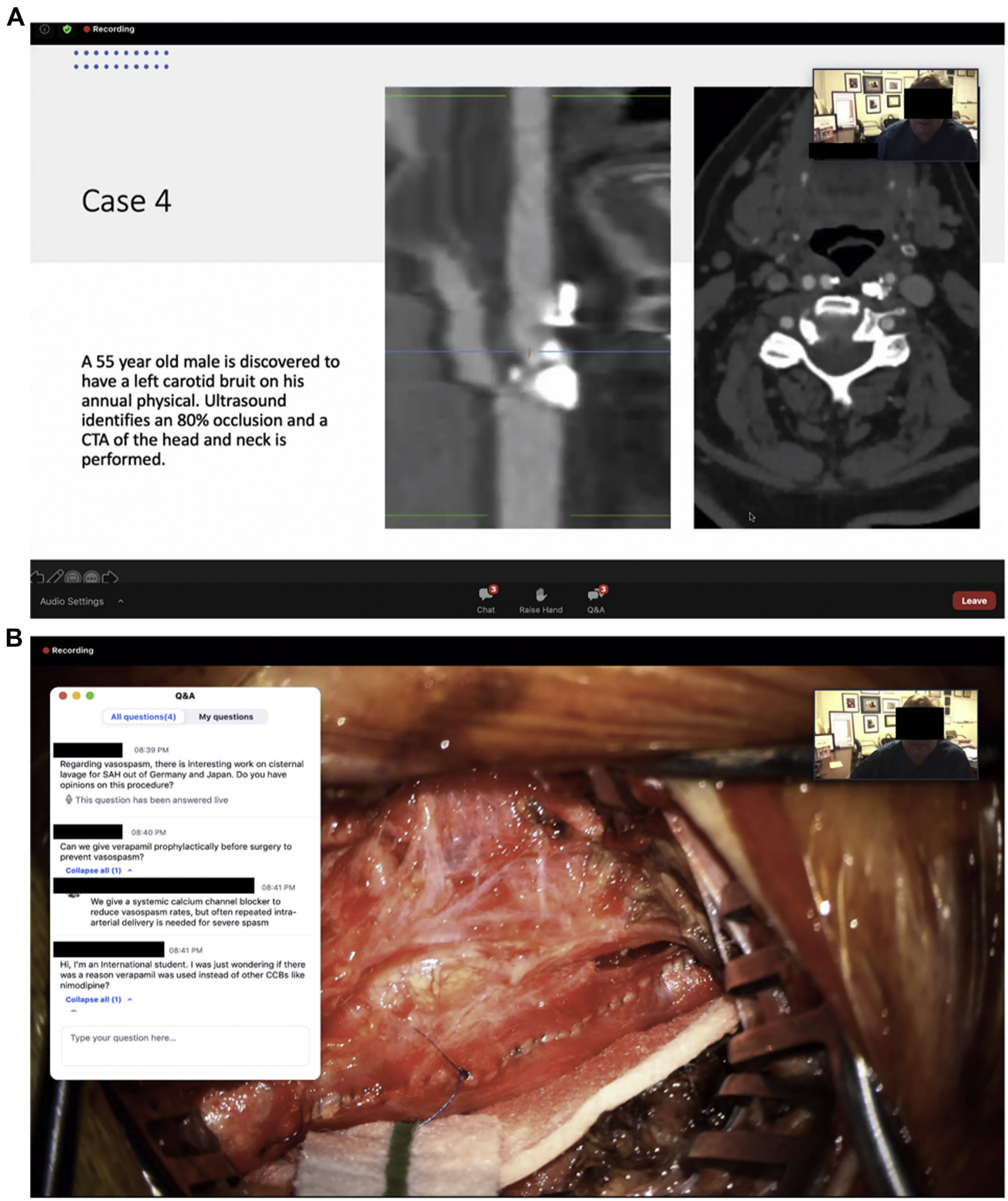


**Figure 1.** Example of a case-based seminar on topics in cerebrovascular neurosurgery led by faculty on the Zoom video conferencing platform. Participants were able to ask questions at any time using the "Raise Hand" functionality or by typing the question in a live question-and-answer chat box that would be fielded either by the presenters at appropriate stopping points or by other faculty viewing the lecture. All seminars were recorded and made publicly available for other participants to watch at a later time.

**Table 2.** Baseline Demographic, Neurosurgical Experience, and Other Information Collected from Virtual Course Participants on the Precourse Survey

| | N = 32 |
|---|---|
| Age (years), mean ± standard error of the mean | 25.5 ± 0.6 |
| Gender | |
| Male | 21 (65.6) |
| Female | 11 (34.4) |
| Underrepresented group in medicine | |
| Yes | 15 (46.9) |
| No | 17 (53.1) |
| Medical student in the United States | |
| Yes | 13 (40.6) |
| No | 19 (59.4) |
| Earning another degree during medical education | |
| Yes | 12 (37.5) |
| No | 11 (34.4) |
| Maybe | 9 (28.1) |
| Medical school year completed in 2019—2020 | |
| M1 | 1 (3.1) |
| M2 | 3 (9.4) |
| M3 | 11 (34.4) |
| M4 | 6 (18.8) |
| Research year | 9 (28.1) |
| Postgraduate | 2 (6.2) |
| Medical school year to be completed in 2020—2021 | |
| M1 | 0 (0.0) |
| M2 | 1 (3.1) |
| M3 | 5 (15.6) |
| M4 | 14 (43.8) |
| Research year | 7 (21.9) |
| Postgraduate | 5 (15.6) |
| Year first interested in neurosurgery | |
| Before medical school | 14 (43.8) |
| M1 | 5 (15.6) |
| M2 | 6 (18.8) |
| M3 | 3 (9.4) |
| M4 | 4 (12.5) |
| Year of neurosurgical subinternship | |
| 2020—2021 | 11 (34.4) |
| 2021—2022 | 11 (34.4) |
| 2022—2023 | 1 (3.1) |
| 2023—2024 | 4 (12.5) |
| Already completed one | 5 (15.6) |
| Applying to neurosurgery residency in 2020—2021 cycle | |
| Yes | 13 (40.6) |
| No | 16 (50.0) |
| Undecided | 3 (9.4) |
| Challenges for medical students in acquiring neurosurgical knowledge before subinternships | |
| Lack of formal surgical exposure during medical school | 25 (78.1) |
| Lack of concise learning resources geared toward medical students | 18 (56.3) |
| Lack of formal instruction on neurosurgical decision making in courses/electives | 29 (90.6) |
| Resources used to learn about neurosurgical concepts to date | |
| Neurosurgical Atlas | 22 (68.8) |
| Essential Neurosurgery for Medical Students Supplement in *Operative Neurosurgery* | 14 (43.8) |
| *Fundamentals of Neurosurgery* by Nitin Agarwal | 12 (37.5) |
| *Handbook of Neurosurgery* by Mark Greenberg | 17 (53.1) |
| Lectures at home institution | 23 (71.9) |
| Grand rounds at home institution | 17 (53.1) |
| Items hoping to gain from seminar series | |
| Exposure to fundamental topics in neurosurgery | 27 (84.3) |
| Networking opportunities with students and faculty outside home institution | 28 (87.5) |
| Learn skills and concepts useful for subinternships | 28 (87.5) |
| Learn more about host institution's neurosurgery residency program | 29 (90.6) |
| Learn more about virtual interview season and application cycle | 23 (71.9) |
| Neurosurgical subspecialties believed to have the greatest exposure to (clinical or research) | |
| Cerebrovascular | 15 (46.9) |
| Neuro-oncology | 13 (40.6) |
| Pediatrics | 6 (18.8) |
| Spine | 22 (68.8) |
| Skull base | 10 (31.3) |
| Functional | 7 (21.9) |
| Estimated hours of neurosurgery exposure | |
| <50 | 8 (25.0) |
| 51—100 | 6 (18.8) |
| 101—250 | 13 (40.6) |
| 251—500 | 2 (6.2) |
| >500 | 3 (9.4) |

Values are number (%) except where indicated otherwise.

**Table 3.** Baseline Demographic, Neurosurgical Experience, and Other Information Collected from U.S. Medical School and International Medical Graduate Participants on the Precourse Survey

| | U.S. Medical Students (N = 13) | International Medical Graduate (N = 19) | *P* Value |
|---|---|---|---|
| Age (years), mean ± standard error of the mean | 25.6 ± 0.5 | 25.5 ± 0.9 | 0.93 |
| Gender | | | 0.07 |
| Male | 6 (46.2) | 15 (78.9) | |
| Female | 7 (53.8) | 4 (21.1) | |
| Underrepresented group in medicine | | | >0.99 |
| Yes | 6 (46.2) | 9 (47.4) | |
| No | 7 (53.8) | 10 (52.6) | |
| Earning another degree during medical education | | | 0.02 |
| Yes | 4 (30.8) | 8 (42.1) | |
| No | 8 (61.5) | 3 (15.8) | |
| Maybe | 1 (7.7) | 8 (42.1) | |
| Medical school year completed in 2019–2020 | | | 0.35 |
| M1 | 0 (0.0) | 1 (5.3) | |
| M2 | 1 (7.7) | 1 (5.3) | |
| M3 | 8 (61.5) | 5 (26.3) | |
| M4 | 1 (7.7) | 4 (21.0) | |
| Research year | 3 (23.1) | 6 (31.6) | |
| Postgraduate | 0 (0) | 2 (10.5) | |
| Medical school year to be completed in 2020–2021 | | | 0.55 |
| M1 | 0 (0.0) | 0 (0.0) | |
| M2 | 0 (0.0) | 1 (5.3) | |
| M3 | 3 (23.1) | 2 (10.5) | |
| M4 | 8 (61.5) | 8 (42.0) | |
| Research year | 2 (15.4) | 4 (21.1) | |
| Postgraduate | 0 (0.0) | 4 (21.1) | |
| Year first interested in neurosurgery (%) | | | 0.34 |
| Before medical school | 6 (46.1) | 8 (42.0) | |
| M1 | 3 (23.1) | 2 (10.5) | |
| M2 | 2 (15.4) | 4 (21.1) | |
| M3 | 2 (15.4) | 1 (5.3) | |
| M4 | 0 (0.0) | 4 (21.1) | |
| Year of neurosurgical subinternship | | | 0.01 |
| 2020–2021 | 9 (69.2) | 2 (10.6) | |
| 2021–2022 | 3 (23.1) | 8 (42.0) | |
| 2022–2023 | 0 (0.0) | 1 (5.3) | |
| 2023–2024 | 1 (7.7) | 3 (15.8) | |
| Already completed one | 0 (0.0) | 5 (26.3) | |
| Applying to neurosurgery residency in 2020–2021 cycle | | | 0.08 |
| Yes | 8 (61.5) | 5 (26.3) | |
| No | 5 (38.5) | 11 (57.9) | |
| Undecided | 0 (0.0) | 3 (15.8) | |
| Challenges for medical students in acquiring neurosurgical knowledge before subinternships | | | |
| Lack of formal surgical exposure during medical school | 6 (46.2) | 16 (84.2) | |
| Lack of concise learning resources geared toward medical students | 7 (53.8) | 11 (57.9) | |
| Lack of formal instruction on neurosurgical decision making in courses/electives | 11 (84.6) | 16 (84.2) | |
| Resources used to learn about neurosurgical concepts to date | | | |
| Neurosurgical Atlas | 7 (53.8) | 15 (78.9) | |
| Essential Neurosurgery for Medical Students Supplement in *Operative Neurosurgery* | 8 (61.5) | 6 (31.6) | |
| *Fundamentals of Neurosurgery* by Nitin Agarwal | 4 (30.8) | 8 (42.1) | |
| *Handbook of Neurosurgery* by Mark Greenberg | 8 (61.5) | 10 (52.6) | |
| Lectures at home institution | 9 (69.2) | 13 (68.4) | |
| Grand rounds at home institution | 10 (76.9) | 7 (36.8) | |
| Items hoping to gain from seminar series | | | |
| Exposure to fundamental topics in neurosurgery | 9 (69.2) | 18 (94.7) | |
| Networking opportunities with students and faculty outside home institution | 12 (92.3) | 16 (84.2) | |
| Learn skills and concepts useful for subinternships | 13 (100.0) | 15 (78.9) | |
| Learn more about host institution's neurosurgery residency program | 13 (100.0) | 17 (89.5) | |
| Learn more about virtual interview season and application cycle | 11 (84.6) | 12 (63.2) | |
| Neurosurgical subspecialties believed to have the greatest exposure to (clinical or research) | | | |

Continues

**Table 3.** Continued

| | U.S. Medical Students (N = 13) | International Medical Graduate (N = 19) | *P* Value |
|---|---|---|---|
| Cerebrovascular | 8 (61.5) | 7 (36.8) | |
| Neuro-oncology | 4 (30.8) | 3 (15.8) | |
| Pediatrics | 5 (38.5) | 10 (52.6) | |
| Spine | 11 (84.6) | 11 (57.9) | |
| Skull base | 3 (23.1) | 8 (42.1) | |
| Functional | 5 (38.5) | 1 (5.3) | |
| Estimated hours of neurosurgery exposure | | | 0.07 |
| <50 | 1 (7.7) | 7 (36.8) | |
| 51—100 | 3 (23.1) | 3 (15.8) | |
| 101—250 | 7 (53.8) | 6 (31.6) | |
| 251—500 | 2 (15.4) | 0 (0.0) | |
| >500 | 0 (0.0) | 3 (15.8) | |

Values are number (%) except where indicated otherwise.

When asked to identify perceived challenges or obstacles for medical students in acquiring neurosurgical knowledge before subinternships (Table 2), lack of formal instruction on neurosurgical decision making in courses/electives was the most commonly identified factor (29 respondents; 90.6%). Regarding resources used to learn about neurosurgical concepts, home institution lectures and the Neurosurgical Atlas (https://www.neurosurgicalatlas.com/) were the most commonly cited resources (71.9% and 68.8%, respectively). When asked what they hoped to gain from the virtual course, respondents identified a desire to learn more about the host institution's neurosurgical residency program (29 students; 90.6%) as well as learning skills and concepts that would be useful during subinternships (87.5%), and gaining networking opportunities (87.5%).

### Baseline Confidence in Neurosurgical Domains

The baseline experiences and confidence levels of participants were assessed in the prelecture survey. Most respondents had approximately 101—250 hours of clinical exposure to neurosurgery before the start of the course (13 respondents, 40.6%). Spine (22 respondents, 68.8%) and cerebrovascular neurosurgery (15 respondents, 46.9%) were the most cited neurosurgical subdisciplines to which participants believed they had the most exposure, whereas pediatric (6 respondents, 18.8%) and functional neurosurgery (7 respondents, 21.9%) were the least cited.

Participants were also asked to rate their confidence level on a scale of 1—10 (1, not confident at all; 10, very confident) with material pertaining to core concepts across various neurosurgical subdisciplines. Participants were most confident in neuroendocrinology (6.79 ± 0.31) and least confident in spine oncology (4.24 ± 0.44), with an average of 5.05 ± 0.32 across all topics. All of the other baseline confidences are summarized in Figure 2A and Table 4.

### Lecture Quality Ratings

Quality ratings on a scale of 1—5 were generally very favorable across all seminars in the series, with most scoring 4 or 5 in each domain. Students generally found the lectures to be interesting and engaging, at an appropriate level for medical students, and with minimal commercial bias. Furthermore, most participants indicated that they would strongly recommend the lectures to their friends and colleagues (Table 5).

### Changes in Self-Assessed Confidence in Neurosurgical Domains

Postcourse survey responses indicated improved confidence levels across all surveyed topics across neurosurgical subdisciplines. The mean postcourse confidence level across all surveyed topics was 7.79 ± 0.19 out of 10, representing a mean increase of 3.13 ± 0.38 ($P < 0.0001$). Changes in self-assessed participant confidence levels for each surveyed subdiscipline may be found in Figure 2B. When these trends were re-examined separately in U.S. medical student and IMG cohorts, we found that there were no significant differences in the changes between precourse and postcourse confidence levels reported by participants across nearly all neurosurgical topics surveyed (Table 6). For example, the change in overall confidence across all surveyed topics was 2.99 ± 0.23 for U.S. medical students and 3.23 ± 0.38 for IMGs ($P = 0.63$).

Other follow-up questions in the postcourse survey asked participants to evaluate the personal impact of the course and what they had gained from it (Table 7). On a scale of 1—10 (1, no influence; 10, very influential), the mean course influence on participants' decisions to pursue neurosurgery was 7.41 ± 0.48. Among the respondents, 16 (50.0%) indicated that they were more likely or much more likely to pursue neurosurgery since completing the virtual course, whereas the other 50% of respondents indicated that their decision had not changed. The postcourse survey also showed that the course was well received by participants, because most stated that the course met or exceeded precourse expectations and learning goals (mean score, 4.69 ± 0.10; scale of 1—5) and that the course was valuable to the participants' learning and career development (mean, 4.63 ± 0.13; scale of 1—5). All participants stated that they would recommend the course to other students interested in neurosurgery (32 respondents; 100.0%) and most believed that the course would still be useful after the pandemic (31 respondents; 96.9%).

## DISCUSSION

To our knowledge, this virtual seminar series was among the first offered to medical students during the height of the COVID-19 pandemic. Because of the significant impact that the pandemic has had on neurosurgical practice,[7] education,[6,8-18] residency interviewing,[19] and subinternships,[2,20] we recognized the need for a virtual alternative for medical students to gain exposure to neurosurgery.[6] Accordingly, this course included faculty-led

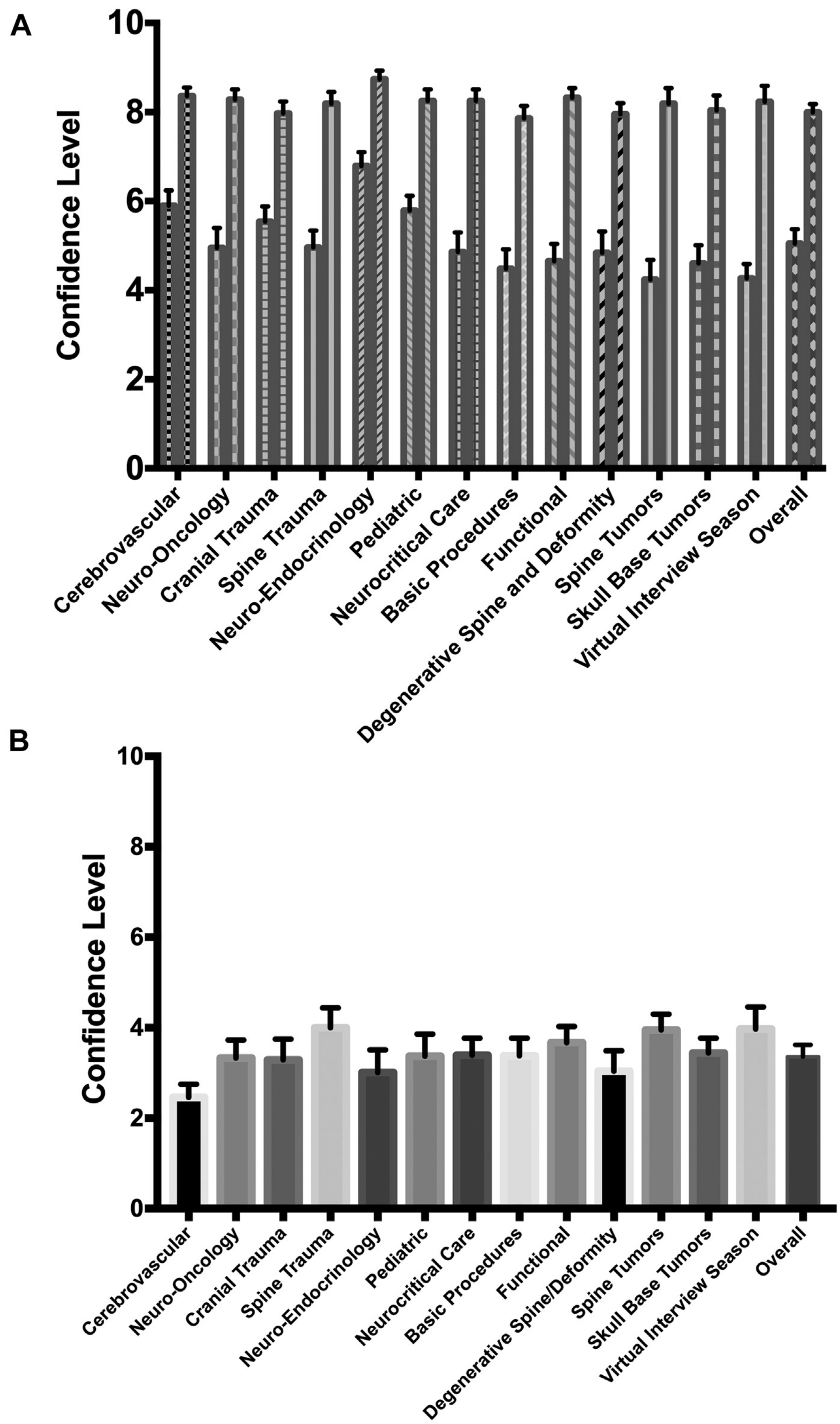


**Figure 2.** Self-assessed confidence levels of course participants in topics spanning diverse neurosurgical subdisciplines. Participants were asked to rate their confidence before the course and immediately after the course (**A**) in a variety of core neurosurgical concepts on a scale from 1 to 10, with 1 being no confidence at all and 10 being very confident. Comparing the precourse and postcourse differences across all participants for each neurosurgical concept surveyed showed significant improvements in confidence across all domains, with a mean increase of approximately 3–4 points in most areas (**B**).

**Table 4.** Precourse and Postcourse Confidence Levels Reported by Participants in Core Topics Across Various Neurosurgical Subdisciplines. Participants Also Assessed Their Own Confidence Levels in Topics Related to Virtual Interviews as Well as in Applying to Neurosurgical Residency. All Confidence Levels Were Assessed on a Scale from 1 (Low) to 10 (High)

| Concept or Skill | Before Course (Mean ± SEM) | After Course (Mean ± SEM) | *P* Value |
|---|---|---|---|
| Cerebrovascular neurosurgery (overall) | 5.90 ± 0.34 | 8.36 ± 0.19 | <0.0001 |
| Pathophysiology and management of arteriovenous malformations | 4.31 ± 0.42 | 7.97 ± 0.24 | <0.0001 |
| Pathophysiology and management of aneurysms | 5.81 ± 0.43 | 8.34 ± 0.21 | <0.0001 |
| Pathophysiology and management of intracranial hemorrhages | 6.47 ± 0.37 | 8.56 ± 0.21 | <0.0001 |
| Pathophysiology and management of strokes | 7.00 ± 0.34 | 8.56 ± 0.22 | 0.0003 |
| Malignant brain tumors (overall) | 4.95 ± 0.45 | 8.28 ± 0.23 | <0.0001 |
| Pathophysiology and management of gliomas | 5.06 ± 0.47 | 8.19 ± 0.26 | <0.0001 |
| Pathophysiology and management of malignant metastatic disease in the central nervous system | 4.84 ± 0.46 | 8.38 ± 0.24 | <0.0001 |
| Head trauma (overall) | 5.54 ± 0.34 | 7.97 ± 0.27 | <0.0001 |
| Pathophysiology and management of skull fractures | 5.63 ± 0.36 | 7.97 ± 0.28 | <0.0001 |
| Pathophysiology and management of traumatic hemorrhages | 6.07 ± 0.35 | 8.13 ± 0.26 | <0.0001 |
| Practices in evidence-based acute intracranial trauma care | 4.93 ± 0.39 | 7.81 ± 0.29 | <0.0001 |
| Spine trauma (overall) | 4.96 ± 0.38 | 8.19 ± 0.26 | <0.0001 |
| Pathophysiology and management of spinal fractures | 5.33 ± 0.38 | 8.31 ± 0.26 | <0.0001 |
| Surgical decision making in spine trauma | 4.59 ± 0.41 | 8.06 ± 0.27 | <0.0001 |
| Neuroendocrinology/pituitary pathology (overall) | 6.79 ± 0.31 | 8.74 ± 0.19 | <0.0001 |
| Pituitary anatomy | 7.19 ± 0.33 | 8.88 ± 0.19 | <0.0001 |
| Diseases of the pituitary gland | 7.48 ± 0.35 | 8.91 ± 0.18 | 0.001 |
| Surgical management of pituitary disorders | 5.70 ± 0.34 | 8.44 ± 0.23 | <0.0001 |
| Pediatric neurosurgery (overall) | 5.79 ± 0.33 | 8.25 ± 0.26 | <0.0001 |
| Pathophysiology and management of hydrocephalus | 6.96 ± 0.37 | 8.78 ± 0.20 | <0.0001 |
| Pathophysiology and management of pediatric brain tumors | 5.70 ± 0.42 | 8.47 ± 0.23 | <0.0001 |
| Neuroembryology | 5.78 ± 0.41 | 7.78 ± 0.35 | 0.001 |
| Spinal dysraphism | 4.70 ± 0.43 | 7.97 ± 0.36 | <0.0001 |
| Neurocritical care (overall) | 4.86 ± 0.44 | 8.25 ± 0.26 | <0.0001 |
| Monitoring modalities in the intensive care unit | 4.72 ± 0.44 | 8.19 ± 0.28 | <0.0001 |
| Evidence-based management of intracranial pressure crises and other emergencies | 5.00 ± 0.47 | 8.31 ± 0.25 | <0.0001 |
| Minor neurosurgical procedures (overall) | 4.48 ± 0.44 | 7.86 ± 0.28 | <0.0001 |
| Indications and protocols for external ventricular drain placement | 5.00 ± 0.53 | 8.22 ± 0.26 | <0.0001 |
| Subdural evacuating port system for subdural hematoma | 4.09 ± 0.50 | 7.69 ± 0.32 | <0.0001 |
| Bolt placement | 3.09 ± 0.51 | 7.41 ± 0.38 | <0.0001 |
| Protocols and indications for lumbar punctures and lumbar drain placement | 5.72 ± 0.46 | 8.13 ± 0.35 | <0.0001 |
| Functional neurosurgery (overall) | 4.65 ± 0.39 | 8.32 ± 0.22 | <0.0001 |
| Pathophysiology and management of epilepsy | 5.53 ± 0.48 | 8.56 ± 0.22 | <0.0001 |
| Neuromodulation for epilepsy | 4.59 ± 0.41 | 8.34 ± 0.23 | <0.0001 |
| Stereo electroencephalography and responsive neurostimulation | 3.50 ± 0.40 | 7.91 ± 0.30 | <0.0001 |
| Deep brain stimulation and movement disorders | 4.97 ± 0.48 | 8.47 ± 0.22 | <0.0001 |

SEM, standard error of the mean.

Continues

**Table 4.** Continued

| Concept or Skill | Before Course (Mean ± SEM) | After Course (Mean ± SEM) | *P* Value |
|---|---|---|---|
| Degenerative spine conditions (overall) | 4.91 ± 0.46 | 7.95 ± 0.25 | <0.0001 |
| Understanding and measuring spinal parameters | 4.47 ± 0.50 | 7.84 ± 0.28 | <0.0001 |
| Clinical approaches to degenerative disease | 5.59 ± 0.47 | 8.00 ± 0.25 | <0.0001 |
| Surgical decision making in the cervical/thoracic/lumbar regions | 4.75 ± 0.49 | 7.88 ± 0.28 | <0.0001 |
| Understanding the basics of open and minimally invasive surgical approaches in the spine | 4.84 ± 0.48 | 8.09 ± 0.28 | <0.0001 |
| Spine tumors (overall) | 4.24 ± 0.44 | 8.19 ± 0.22 | <0.0001 |
| Pathophysiology and management of spinal metastases | 4.44 ± 0.44 | 8.19 ± 0.24 | <0.0001 |
| Pathophysiology and management of primary bone tumors in the spine | 4.25 ± 0.47 | 8.19 ± 0.23 | <0.0001 |
| Pathophysiology and management of other intradural spinal diseases, including primary tumors and vascular malformations | 4.03 ± 0.47 | 8.19 ± 0.23 | <0.0001 |
| Skull base (overall) | 4.60 ± 0.41 | 8.04 ± 0.26 | <0.0001 |
| Endoscopic approaches to the skull base | 3.78 ± 0.48 | 8.06 ± 0.27 | <0.0001 |
| Open approaches to the skull base | 4.09 ± 0.47 | 7.84 ± 0.31 | <0.0001 |
| Pathophysiology and management of vestibular schwannomas | 4.66 ± 0.44 | 7.94 ± 0.29 | <0.0001 |
| Pathophysiology and management of meningiomas | 5.56 ± 0.46 | 8.38 ± 0.24 | <0.0001 |
| Differential diagnosis of skull base tumors | 4.91 ± 0.50 | 8.00 ± 0.28 | <0.0001 |
| Virtual interviews (overall) | 4.27 ± 0.42 | 8.23 ± 0.36 | <0.0001 |
| Strategies for success during a virtual interview | 4.25 ± 0.42 | 8.34 ± 0.36 | <0.0001 |
| Exploring a program without a physical visit | 4.28 ± 0.46 | 8.13 ± 0.38 | <0.0001 |
| Overall confidence level in all topics | 5.05 ± 0.32 | 8.19 ± 0.20 | <0.0001 |
| Confidence in applying into neurosurgical residency | 9.34 ± 0.30 | 9.41 ± 0.29 | 0.882 |

SEM, standard error of the mean.

didactic sessions in each neurosurgical subdiscipline, virtual bootcamp-style sessions introducing students to basic neurosurgical procedures, and special sessions focused on practical advice for virtual interviews and navigating a neurosurgical career. It is likely for these reasons that this course received significant interest from students (595 registrants) worldwide within a matter of weeks of being announced, also highlighting a key advantage of the online format of the course.

We asked registrants to fill out comprehensive precourse and postcourse surveys that would allow us to evaluate the efficacy of this medium for student learning and identify areas for improvement. The virtual neurosurgery course was well received by participants. The discrepancy between total registrants and survey respondents is partially explained by recorded lecture availability. Some students chose to watch the lectures in recorded format after they were released online. Only students participating in the live webinars were asked to complete both precourse and postcourse surveys.

Most students stated that the seminar series met or exceeded their precourse expectations and believed that the course was valuable to their learning and career development (Table 7). Students most commonly believed that they gained knowledge of the host institution's neurosurgery residency program (93.8%), important skills and concepts useful for subinternships (90.6%), and exposure to fundamental topics in neurosurgery (87.5%) through the course. Although most students still believed that they gained networking opportunities (59.4%) and learned more about virtual interviews from the course (65.6%), these rates were below the precourse numbers for what students were hoping to gain from the course (87.5% and 71.9%, respectively), suggesting that a greater emphasis on these areas may lead to improved student satisfaction and benefit in future iterations of the course. This situation may also show challenges associated with a virtual environment, which could be addressed through software adaptations in the right setting.

Before the virtual course, participants most frequently indicated that they had previous clinical or research exposure to spine (68.8%) and cerebrovascular (46.9%) neurosurgery (Table 2). These exposures generally mirrored the baseline confidence levels of participants by neurosurgical subdiscipline (Figure 2A). Although confidence in all neurosurgical concepts and subdisciplines increased significantly by the end of the course, comparatively smaller increases were noted for cerebrovascular and degenerative spine surgery, likely because precourse

**Table 5.** Quality Ratings for Each Course Seminar Collected from Participants on the Postcourse Survey Using a Scale of 1 (Poor) to 5 (Excellent)

| Seminar | Watched the Seminar Live or on Recording (N=32), n (%) | Overall Quality of Presenter (Mean ± SEM) | Presenter Was Engaging (Mean ± SEM) | Lecture Material Was Appropriate for my Level (Mean ± SEM) | Lecture Material Was Interesting (Mean ± SEM) | Seminar Enhanced my Understanding (Mean ± SEM) | Audio/Video Quality Was Adequate (Mean ± SEM) | I Would Recommend the Seminar to Others (Mean ± SEM) |
|---|---|---|---|---|---|---|---|---|
| Cerebrovascular neurosurgery | 29 (90.6) | 4.97 ± 0.03 | 4.94 ± 0.04 | 4.72 ± 0.10 | 4.97 ± 0.03 | 4.84 ± 0.07 | 4.75 ± 0.09 | 4.97 ± 0.03 |
| Brain tumors | 30 (93.8) | 4.91 ± 0.07 | 4.88 ± 0.07 | 4.75 ± 0.10 | 4.91 ± 0.07 | 4.75 ± 0.10 | 4.88 ± 0.07 | 4.91 ± 0.07 |
| Head trauma | 26 (81.3) | 4.75 ± 0.10 | 4.69 ± 0.11 | 4.75 ± 0.11 | 4.69 ± 0.11 | 4.63 ± 0.12 | 4.69 ± 0.11 | 4.81 ± 0.09 |
| Spine trauma | 28 (87.5) | 4.75 ± 0.15 | 4.69 ± 0.15 | 4.63 ± 0.17 | 4.69 ± 0.15 | 4.63 ± 0.16 | 4.75 ± 0.14 | 4.75 ± 0.14 |
| Neuroendocrinology | 29 (90.6) | 4.81 ± 0.13 | 4.72 ± 0.14 | 4.75 ± 0.14 | 4.75 ± 0.14 | 4.72 ± 0.14 | 4.78 ± 0.13 | 4.81 ± 0.19 |
| Pediatric neurosurgery | 29 (90.6) | 4.94 ± 0.06 | 4.91 ± 0.07 | 4.97 ± 0.03 | 4.94 ± 0.04 | 4.88 ± 0.06 | 4.97 ± 0.03 | 4.97 ± 0.03 |
| Neurocritical care | 27 (84.4) | 4.91 ± 0.05 | 4.88 ± 0.06 | 4.78 ± 0.10 | 4.94 ± 0.04 | 4.94 ± 0.06 | 4.97 ± 0.03 | 5.00 ± 0.00 |
| Minor neurosurgical procedures | 21 (65.6) | 4.66 ± 0.13 | 4.66 ± 0.13 | 4.66 ± 0.13 | 4.69 ± 0.12 | 4.66 ± 0.13 | 4.66 ± 0.13 | 4.75 ± 0.12 |
| Functional neurosurgery | 26 (81.3) | 4.75 ± 0.11 | 4.75 ± 0.11 | 4.72 ± 0.12 | 4.72 ± 0.11 | 4.69 ± 0.11 | 4.75 ± 0.11 | 4.75 ± 0.11 |
| Degenerative spine conditions | 24 (75.0) | 4.69 ± 0.11 | 4.66 ± 0.12 | 4.69 ± 0.11 | 4.63 ± 0.13 | 4.69 ± 0.11 | 4.78 ± 0.11 | 4.78 ± 0.11 |
| Spine tumors | 28 (87.5) | 4.78 ± 0.11 | 4.75 ± 0.10 | 4.78 ± 0.11 | 4.66 ± 0.12 | 4.81 ± 0.09 | 4.84 ± 0.09 | 4.84 ± 0.09 |
| Skull base | 26 (81.3) | 4.78 ± 0.11 | 4.72 ± 0.11 | 4.69 ± 0.12 | 4.72 ± 0.12 | 4.63 ± 0.13 | 4.75 ± 0.11 | 4.75 ± 0.11 |
| Virtual interviews | 21 (65.6) | 4.75 ± 0.15 | 4.72 ± 0.15 | 4.75 ± 0.15 | 4.72 ± 0.15 | 4.75 ± 0.15 | 4.75 ± 0.15 | 4.72 ± 0.15 |
| Average | 27 (84.4) | 4.80 ± 0.09 | 4.77 ± 0.10 | 4.74 ± 0.11 | 4.77 ± 0.08 | 4.74 ± 0.08 | 4.79 ± 0.10 | 4.83 ± 0.11 |

**Table 6.** Differences in Precourse and Postcourse Confidence Levels Reported by Participants at U.S. And International Medical Schools in Core Topics Across Various Neurosurgical Subdisciplines. Participants Also Assessed Their Own Confidence Levels in Topics Related to Virtual Interviews as Well as in Applying to Neurosurgical Residency

| Concept or Skill | U.S. Medical Students (N = 13) | International Medical Graduate (N = 19) | *P* Value |
|---|---|---|---|
| Cerebrovascular neurosurgery (overall) | 2.29 ± 0.26 | 2.58 ± 0.35 | 0.55 |
| Pathophysiology and management of arteriovenous malformations | 2.77 ± 0.29 | 4.26 ± 0.45 | 0.02 |
| Pathophysiology and management of aneurysms | 2.54 ± 0.32 | 2.53 ± 0.42 | 0.99 |
| Pathophysiology and management of intracranial hemorrhages | 2.08 ± 0.38 | 2.11 ± 0.36 | 0.96 |
| Pathophysiology and management of strokes | 1.77 ± 0.34 | 1.42 ± 0.35 | 0.50 |
| Malignant brain tumors (overall) | 2.69 ± 0.33 | 3.76 ± 0.50 | 0.12 |
| Pathophysiology and management of gliomas | 2.62 ± 0.37 | 3.47 ± 0.52 | 0.23 |
| Pathophysiology and management of malignant metastatic disease in the central nervous system | 2.77 ± 0.35 | 4.05 ± 0.50 | 0.07 |
| Head trauma (overall) | 2.40 ± 0.27 | 2.44 ± 0.43 | 0.94 |
| Pathophysiology and management of skull fractures | 2.32 ± 0.28 | 2.35 ± 0.45 | 0.96 |
| Pathophysiology and management of traumatic hemorrhages | 2.13 ± 0.34 | 1.99 ± 0.43 | 0.81 |
| Practices in evidence-based acute intracranial trauma care | 2.76 ± 0.30 | 2.97 ± 0.47 | 0.74 |
| Spine trauma (overall) | 2.98 ± 0.23 | 3.39 ± 0.51 | 0.53 |
| Pathophysiology and management of spinal fractures | 2.99 ± 0.25 | 2.97 ± 0.51 | 0.98 |
| Surgical decision making in spine trauma | 2.98 ± 0.23 | 3.81 ± 0.54 | 0.24 |
| Neuroendocrinology/pituitary pathology (overall) | 2.38 ± 0.32 | 1.65 ± 0.31 | 0.12 |
| Pituitary anatomy | 2.17 ± 0.36 | 1.36 ± 0.30 | 0.09 |
| Diseases of the pituitary gland | 1.98 ± 0.34 | 1.04 ± 0.33 | 0.06 |
| Surgical management of pituitary disorders | 2.99 ± 0.32 | 2.56 ± 0.39 | 0.43 |
| Pediatric neurosurgery (overall) | 2.65 ± 0.33 | 2.33 ± 0.39 | 0.56 |
| Pathophysiology and management of hydrocephalus | 2.11 ± 0.38 | 1.62 ± 0.35 | 0.36 |
| Pathophysiology and management of pediatric brain tumors | 3.03 ± 0.35 | 2.58 ± 0.43 | 0.46 |
| Neuroembryology | 2.18 ± 0.47 | 1.88 ± 0.47 | 0.67 |
| Spinal dysraphism | 3.29 ± 0.35 | 3.24 ± 0.59 | 0.95 |
| Neurocritical care (overall) | 3.54 ± 0.40 | 3.29 ± 0.48 | 0.71 |
| Monitoring modalities in the intensive care unit | 3.54 ± 0.41 | 3.42 ± 0.50 | 0.86 |
| Evidence-based management of intracranial pressure crises and other emergencies | 3.54 ± 0.41 | 3.16 ± 0.49 | 0.58 |
| Minor neurosurgical procedures (overall) | 4.02 ± 0.34 | 2.95 ± 0.52 | 0.13 |
| Indications and protocols for external ventricular drain placement | 4.23 ± 0.41 | 2.53 ± 0.55 | 0.03 |
| Subdural evacuating port system for subdural hematoma | 3.77 ± 0.44 | 3.47 ± 0.57 | 0.70 |
| Bolt placement | 4.46 ± 0.40 | 4.21 ± 0.67 | 0.78 |
| Protocols and indications for lumbar punctures and lumbar drain placement | 3.62 ± 0.40 | 1.58 ± 0.56 | 0.01 |
| Functional neurosurgery (overall) | 3.40 ± 0.33 | 3.86 ± 0.41 | 0.42 |
| Pathophysiology and management of epilepsy | 3.23 ± 0.40 | 2.89 ± 0.45 | 0.60 |
| Neuromodulation for epilepsy | 3.46 ± 0.36 | 3.95 ± 0.43 | 0.42 |
| Stereo electroencephalography and responsive neurostimulation | 4.00 ± 0.32 | 4.68 ± 0.49 | 0.30 |
| Deep brain stimulation and movement disorders | 2.92 ± 0.43 | 3.89 ± 0.46 | 0.15 |

Continues

**Table 6.** Continued

| Concept or Skill | U.S. Medical Students (N = 13) | International Medical Graduate (N = 19) | *P* Value |
|---|---|---|---|
| Degenerative spine conditions (overall) | 2.31 ± 0.39 | 3.54 ± 0.50 | 0.08 |
| Understanding and measuring spinal parameters | 2.54 ± 0.41 | 3.95 ± 0.54 | 0.07 |
| Clinical approaches to degenerative disease | 1.92 ± 0.41 | 2.74 ± 0.50 | 0.25 |
| Surgical decision making in the cervical/thoracic/lumbar regions | 2.54 ± 0.41 | 3.53 ± 0.54 | 0.19 |
| Understanding the basics of open and minimally invasive surgical approaches in the spine | 2.23 ± 0.46 | 3.95 ± 0.51 | 0.02 |
| Spine tumors (overall) | 3.69 ± 0.30 | 4.12 ± 0.48 | 0.50 |
| Pathophysiology and management of spinal metastases | 3.54 ± 0.28 | 3.89 ± 0.51 | 0.60 |
| Pathophysiology and management of primary bone tumors in the spine | 3.62 ± 0.34 | 4.16 ± 0.50 | 0.43 |
| Pathophysiology and management of other intradural spinal diseases, including primary tumors and vascular malformations | 3.92 ± 0.33 | 4.32 ± 0.48 | 0.54 |
| Skull base (overall) | 3.12 ± 0.31 | 3.66 ± 0.47 | 0.39 |
| Endoscopic approaches to the skull base | 3.92 ± 0.34 | 4.53 ± 0.52 | 0.38 |
| Open approaches to the skull base | 3.85 ± 0.37 | 3.68 ± 0.51 | 0.81 |
| Pathophysiology and management of vestibular schwannomas | 2.69 ± 0.35 | 3.68 ± 0.50 | 0.15 |
| Pathophysiology and management of meningiomas | 2.31 ± 0.36 | 3.16 ± 0.50 | 0.22 |
| Differential diagnosis of skull base tumors | 2.85 ± 0.43 | 3.26 ± 0.53 | 0.58 |
| Virtual interviews (overall) | 3.65 ± 0.52 | 4.18 ± 0.47 | 0.46 |
| Strategies for success during a virtual interview | 3.46 ± 0.55 | 4.53 ± 0.46 | 0.15 |
| Exploring a program without a physical visit | 3.85 ± 0.53 | 3.84 ± 0.50 | 0.99 |
| Overall confidence level in all topics | 2.99 ± 0.23 | 3.23 ± 0.38 | 0.63 |
| Confidence in applying into neurosurgical residency | 0.08 ± 0.10 | 0.05 ± 0.48 | 0.96 |

All confidence levels were assessed on a scale from 1 (low) to 10 (high) before and after the course. Changes in confidence were assessed by subtracting the postcourse confidence level from the corresponding precourse confidence level.

exposures to these areas were already greater among participants than for other subspecialties (Figure 2B). It is also possible that these areas also represent topics that are complicated enough such that a single hour-long seminar may not be enough to significantly increase medical student confidence in the topic. Conversely, the most improved domains pertained to virtual interviews, spine tumors, spine trauma, and functional neurosurgery, in which participants all identified as having minimal exposure and confidence at baseline (Figure 2A). In addition, despite resulting in significant improvements in student confidence in all surveyed neurosurgical topics, the course did not significantly alter participant confidence in applying into neurosurgical residency ($P = 0.882$), likely because baseline confidence in this area was already so high (precourse, 9.34 ± 0.30; postcourse, 9.41 ± 0.29). We found that changes in confidence levels in neurosurgical topics (Table 6) and the overall interest in neurosurgery and the value of the course to students' learning and career development (Table 8) were similar between U.S. and IMG participants, suggesting that the course experience for students interested in neurosurgery is likely a shared one.

Given the novelty of circumstances necessitating a virtual course format, participant feedback regarding the quality of the audio/video, the presenters, and the presentations was paramount. In previous years, efforts have been made to implement neurosurgery training camps to prepare students for subinternships.[21-26] These efforts similarly resulted in near-universal improvements in student preparedness and confidence in applicable neurosurgical skills. However, these training camps benefited from being held in person with hands-on components to facilitate student learning and skills acquisition. This virtual medical student course, although it adopted similar learning goals for students, required a different line of thinking to adapt the course to a Web-based format and

**Table 7.** Participant Response Data from the Postcourse Survey Indicating the Perceived Value and Benefits of the Virtual Course

| | N = 32 |
|---|---|
| Course influence on decision to pursue neurosurgery (1, no influence; 10, very influential) (mean ± SEM) | 7.41 ± 0.48 |
| Has your decision to pursue neurosurgery changed since completing the virtual seminar series? | |
| Yes, MUCH MORE likely to go into neurosurgery | 13 (40.6) |
| Yes, MORE likely to go into neurosurgery | 3 (9.4) |
| No, always knew I was going into neurosurgery | 16 (50.0) |
| Yes, LESS likely to go into neurosurgery | 0 (0.0) |
| Yes, MUCH LESS likely to go into neurosurgery | 0 (0.0) |
| Lecture series met precourse expectations and learning goals (1, did not meet expectations; 5, exceeded expectations), mean ± SEM | 4.69 ± 0.10 |
| Value of overall course to participant's learning and career development (1, not valuable at all; 5, very valuable), mean ± SEM | 4.63 ± 0.13 |
| Would you recommend this course to other students interested in neurosurgery? | |
| Yes | 32 (100.0) |
| No | 0 (0.0) |
| Maybe | 0 (0.0) |
| Would the virtual course still be useful for future students after the pandemic passes? | |
| Yes | 31 (96.9) |
| No | 0 (0.0) |
| Maybe | 1 (3.1) |
| Items gained from seminar series | |
| Exposure to fundamental topics in neurosurgery | 28 (87.5) |
| Networking opportunities with students and faculty outside home institution | 19 (59.4) |
| Learn skills and concepts useful for subinternships | 29 (90.6) |
| Learn more about host institution's neurosurgery residency program | 30 (93.8) |
| Learn more about virtual interview season and application cycle | 21 (65.6) |
| Course improved understanding of: (1, strongly disagree; 5, strongly agree), mean ± SEM | |
| Life as a neurosurgery resident | 4.78 ± 0.10 |
| The stages of a neurosurgical career | 4.84 ± 0.09 |
| Circumstances in which a fellowship is beneficial | 4.66 ± 0.12 |
| The landscape and considerations for finding a job in neurosurgery | 4.59 ± 0.13 |
| Perspectives from early, mid, and late career neurosurgeons | 4.72 ± 0.11 |

Values are number (%) except where indicated otherwise.
SEM, standard error of the mean.

retain the learning efficacy and skills acquisition that have been reported in previous neurosurgical training camps. Results from our analyses suggest that the functionality of the video conferencing platform was sufficient for facilitating live, interactive seminars and discussions among faculty and students. Participants reported widespread satisfaction with the qualities of the presentations, presenters, and audio/video components (Table 5). Furthermore, most students reported that each seminar enhanced their understanding of the topics discussed and that they would recommend the seminars to other interested students.

## Future Directions

On the postcourse survey, 96.9% of participants indicated they believed that the virtual course would still be useful for future students after the pandemic. These findings mirror those of previous survey studies that found that resident, fellow, and faculty respondents from numerous neurosurgical programs carried a certain preference for continued use of virtual neurosurgical educational conferences beyond the pandemic.[27] These findings seem to suggest that the current learners with varying levels of experience may even prefer a virtual format for certain aspects of neurosurgical education. These findings also suggest an ongoing need for accessible and high-quality neurosurgical resources geared toward medical students. This need was similarly echoed by participants on the precourse survey (Table 2), as well as in previous studies in medical student education in neurosurgery.[1,3,4] Accordingly, it is likely that future iterations of this course or others like it will be produced for students in subsequent application cycles. Identifying areas to target for improvement is critical to optimize the usefulness of the course.

Several areas for improvement can be identified. First, relatively fewer participants believed that they gained sufficient networking opportunities with students and faculty outside their home institutions (Table 7). Incorporation of a dedicated networking session or use of the smaller breakout group sessions may better accomplish this element during the virtual course. Another area of improvement is the use of more objective precourse and postcourse measures of participant evaluation to better gauge learning. Several participants suggested incorporating live procedures so that participants can better appreciate neurosurgical decision making in real time. We anticipate that incorporating some of these suggestions into future iterations of

**Table 8.** Participant Response Data from the Postcourse Survey Indicating the Perceived Value and Benefits of the Virtual Course

| | U.S. Medical Students (N = 13) | International Medical Graduate (N = 19) | *P* Value |
|---|---|---|---|
| Course influence on decision to pursue neurosurgery (1, no influence; 10, very influential), mean ± SEM | 5.31 ± 0.66 | 8.84 ± 0.33 | <0.0001 |
| Has your decision to pursue neurosurgery changed since completing the virtual seminar series? | | | 0.004 |
| Yes, MUCH MORE likely to go into neurosurgery | 1 (7.7) | 12 (63.2) | |
| Yes, MORE likely to go into neurosurgery | 1 (7.7) | 2 (10.5) | |
| No, always knew I was going into neurosurgery | 11 (84.6) | 5 (26.3) | |
| Yes, LESS likely to go into neurosurgery | 0 (0.0) | 0 (0.0) | |
| Yes, MUCH LESS likely to go into neurosurgery | 0 (0.0) | 0 (0.0) | |
| Lecture series met precourse expectations and learning goals (1, did not meet expectations; 5, exceeded expectations), mean ± SEM | 4.62 ± 0.18 | 4.74 ± 0.10 | 0.54 |
| Value of overall course to participant's learning and career development (1, not valuable at all; 5, very valuable), mean ± SEM | 4.46 ± 0.20 | 4.74 ± 0.13 | 0.23 |
| Would you recommend this course to other students interested in neurosurgery? | | | >0.99 |
| Yes | 19 (100.0) | 19 (100.0) | |
| No | 0 (0.0) | 0 (0.0) | |
| Maybe | 0 (0.0) | 0 (0.0) | |
| Would the virtual course still be useful for future students after the pandemic passes? | | | >0.99 |
| Yes | 19 (100.0) | 19 (100.0) | |
| No | 0 (0.0) | (0.0) | |
| Maybe | 0 (0.0) | (0.0) | |
| Items gained from seminar series | | | |
| Exposure to fundamental topics in neurosurgery | 9 (69.2) | 19 (100.0) | |
| Networking opportunities with students and faculty outside home institution | 9 (69.2) | 10 (52.6) | |
| Learn skills and concepts useful for subinternships | 12 (92.3) | 18 (94.7) | |
| Learn more about host institution's neurosurgery residency program | 13 (100.0) | 17 (89.5) | |
| Learn more about virtual interview season and application cycle | 10 (76.9) | 11 (57.9) | |
| Course improved understanding of: (1, strongly disagree; 5, strongly agree), mean ± SEM | | | |
| Life as a neurosurgery resident | 4.77 ± 0.14 | 4.79 ± 0.12 | 0.91 |
| The stages of a neurosurgical career | 4.92 ± 0.06 | 4.79 ± 0.14 | 0.47 |
| Circumstances in which a fellowship is beneficial | 4.69 ± 0.11 | 4.63 ± 0.17 | 0.79 |
| The landscape and considerations for finding a job in neurosurgery | 4.62 ± 0.15 | 4.58 ± 0.18 | 0.87 |
| Perspectives from early, mid, and late career neurosurgeons | 4.85 ± 0.13 | 4.63 ± 0.16 | 0.33 |

Values are number (%) except where indicated otherwise.
SEM, standard error of the mean.

this course will further increase its value and appeal to students, even after in-person subinternships are reinstated.

### Limitations

Several study limitations must be acknowledged. First, because this study relied on participant survey data, the results are subject to a response bias, particularly toward providing positive feedback given that the course was offered free of charge. Furthermore, applicants may be concerned that the host institution may use their responses in the process of applicant selection, thereby withholding negative comments. In addition, this study had a relatively low postcourse survey response rate, meaning that some of the opinions of course participants might not have reflected the data collected. Another limitation is that this study did not use an objective measure of participant improvement. Instead, a self-assessed confidence level was surveyed, which is an imperfect measure of improvement and may not directly correlate with knowledge and skill acquisition. In addition, because a 1–10 scale was used to assess confidence, whereas a 1–5 scale was used to assess lecture quality, it is possible that this could have introduced a potential bias into the results. Future use of objective knowledge assessments would address this issue. First-year and second-year medical students were underrepresented in this course. A possible reason for this situation is that the course was advertised within neurosurgical circles on social media that may have less visibility for younger medical students. Increasing outreach to other medical schools, possibly through partnerships or neurosurgical professional organizations, may better promote this course to a wider student audience in the future.

## CONCLUSIONS

Participant feedback on seminar quality and changes in self-assessed confidence in neurosurgical topics suggest that a virtual Web-based medical student seminar series may be an effective means of providing a high-quality interactive educational environment to improve students' foundational knowledge across neurosurgical subdisciplines for the level of subinternship. In addition, this format can be used to provide networking opportunities before residency interviews. Future studies incorporating cohort match data and more objective measures of concept mastery may further support the findings from this study.

## CRediT AUTHORSHIP CONTRIBUTION STATEMENT

**Michael L. Martini:** Conceptualization, Methodology, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Kurt A. Yaeger:** Data curation, Writing - review & editing. **Christopher P. Kellner:** Data curation, Writing - review & editing. **Constantinos Hadjipanayis:** Data curation, Writing - review & editing. **Raj Shrivastava:** Data curation, Writing - review & editing. **J Mocco:** Data curation, Writing - review & editing. **Peter F. Morgenstern:** Conceptualization, Methodology, Writing - review & editing.

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