Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Letter to the Editor "Changes to Neurosurgery Resident Education Since Onset of the COVID-19 Pandemic"

Letter:

With the onset of the coronavirus disease 2019 (COVID-19) pandemic and the resultant cancellation of elective surgical cases nationwide,[1] there have been significant changes to how neurosurgery is taught and practiced. The dramatic decrease in operative cases has significantly affected the training of neurosurgical residents, who depend on elective surgical volume to hone their clinical and operative skills.[2] Because residents must meet minimum case volumes to show proficiency on program completion,[3] there is concern among both residents and program directors (PDs) regarding the severity of the impact of COVID-19 on neurosurgical resident education.[4]

Recently, several centers have reported the significant changes that their departments have undergone as a result of the COVID-19 pandemic.[5-8] Included in these changes are alterations to the methods for educating residents[9] and the clinical care duties of residents. For example, Weber et al.[2] at the Medical University of South Carolina and Burke et al.[7] at the University of California San Francisco described reorganizing their services to reduce the number of residents in the hospital at any one time. Face-to-face patient handoffs have also been minimized and usual didactic programs have been shifted to videoconferencing platforms to reduce resident-to-resident contact.[2] Despite these single-institution experiences, there has yet to be a description of how residency programs on the whole are dealing with the pressures exerted by the COVID-19 pandemic. We sought to address this outstanding need by polling PDs, with the goal of using the information to help inform residency directors about how programs across the country are addressing resident education during the COVID-19 pandemic.

METHODS

Survey of PDs

After obtaining institutional review board approval, a survey was developed using Research Electronic Data Capture software (**Supplementary Figure 1**). Domains addressed by the survey included program details (residency size, location, and hospital size); COVID-19 burden in the catchment area of the associated hospital/health system; changes in case volume and resident duties (e.g., shift changes and responsibility for care of COVID-positive patients); and changes in resident wellness/support. We also included items about the exact interventions being used to continue resident education during the COVID-19 pandemic, including changes to regular meetings (e.g., grand rounds and morbidity and mortality [M&M] conferences), changes to didactic lectures, use of outside materials (e.g., materials published by the American Association of Neurological Surgeons [AANS] or Congress of Neurological Surgeons [CNS]), and use of tools to track resident participation/progress within the updated curriculum.

The survey was sent to PDs of all 116 Accreditation Council for Graduate Medical Education (ACGME)-accredited neurosurgery programs using Research Electronic Data Capture tools hosted at our institution.[10,11] PDs were invited to complete the survey within 2 weeks and reminded with e-mails after 1 week to improve the response rate.

Statistical Analysis

Survey responses were collated and summarized using Microsoft Excel (Microsoft, Redmond, Washington, USA). Descriptive data were summarized into tables showing the proportion of respondents giving each answer for the specific question. Comparisons between groups for categorical variables were performed using χ^2 analyses and comparisons between groups for binary variables were performed using Fisher exact tests. Statistical tests were performed using Statistica version 13.3.0 (TIBCO, Palo Alto, California, USA).

RESULTS

The survey elicited responses from 57 programs (49.1%) (**Table 1**). The median program size was 2 residents per class, and most programs were located in the Midwest (35.0%), Northeast (23.3%), or Southeast (16.7%). For responding programs, the median health system size was 890 beds (interquartile range, 600–1200 beds). The inpatient burden of COVID-positive patients at the time of response was that most programs had <50 COVID-positive patients (47.5%) or 51–100 COVID-positive patients (15.3%); few programs had >200 COVID-positive patients. Current case volume for most programs was <20% of pre-COVID volume (54.4%); only a few programs had >50% of their baseline case volume (11.9%). Although programs with higher COVID burdens tended to have greater reductions in their surgical volume, this difference was not statistically significant ($\chi^2 = 18.75$; $P = 0.09$). There was no significant interaction between case volume and either geographic region or residency program size.

Changes in Resident Workload

Most programs have reduced resident COVID exposure risk by reducing the number of residents in the hospital at one time (94.7%) and by reducing the number of days per week that each resident works (35.1%) (**Table 2**). Some programs (47.4%) have reduced the number of residents scrubbing into surgical procedures (i.e., avoiding double scrubbing), and a similar proportion have not changed resident involvement in surgical care (43.9%). Two programs increased the number scrubbing into cases to make up for overall volume decrease. Of programs, 14% have redeployed residents to other services, most commonly to assist in caring for COVID-positive patients in intensive care unit settings. At responding institutions, residents in internal medicine (47.4%), anesthesia/critical care (43.9%), and general surgery (33.3%) were most commonly redeployed. Most PDs were not concerned that either their graduating chief residents (87.7%) or incoming chief residents (73.7%) would fail to meet ACGME case minimums. Of those who are concerned, the most common apprehension was that chiefs will not meet minimums for either vascular (15.8% for incoming chiefs and 7.0% for graduating chiefs) or functional cases (14.0% for incoming chiefs and 8.8% for graduating chiefs).

Table 1. Profile of Responding Programs

Attribute	Value
Number of invited programs	116
Number of responding programs	57 (49.1)
Program location	
Mid-Atlantic	6 (10.5)
Midwest	20 (35.0)
Northeast	12 (23.3)
Northwest	1 (1.7)
Southeast	10 (16.7)
Southwest	4 (8.3)
West coast	3 (5.0)
Residents per year, median (interquartile range)	2 (2—2)
Health system size, median (interquartile range)*	890 (600—1200)
COVID burden (cases in health system*)	
0—50	28 (47.5)
51—100	9 (15.3)
101—150	7 (11.9)
151—200	4 (6.8)
>200	11 (18.6)
Current case volume†	
<10%	11 (18.6)
10%—20%	20 (33.9)
20%—50%	21 (35.6)
>50%	7 (11.9)

Values are number (%) except where indicated otherwise.
*Health system defines as all hospitals in institutions health system that are staffed by the program's neurosurgery residents before onset of the COVID-19 pandemic.
†Case volume defined as proportion of pre-COVID case volume.

Table 2. Changes in Resident Roles and Deployment in Response to COVID Pandemic

Question	n (%)
Strategies to reduce resident exposure	
Reduction in resident shift length	20 (35.1)
Reduction in days worked per week	37 (64.9)
Reduction in number of residents in hospital at any one time	54 (94.7)
Other	7 (12.3)
Change in resident involvement in operative cases	
Minimize number of residents scrubbing	27 (47.4)
Increase the number of double-scrub cases	2 (3.5)
No change	25 (43.9)
Other	3 (5.3)
Redeployment of residents	
Residents have been redeployed to other services	8 (14.0)
If redeployed, populations covered	
ICU non-COVID	3 (5.3)
ICU COVID	6 (10.5)
Floor non-COVID	0 (0)
Floor COVID	0 (0)
Outpatient or emergency department screening	1 (1.8)
Transport teams	0 (0)
Proceduralist teams	1 (1.8)
Other	0 (0)
Other resident populations that have been redeployed	
General surgery	19 (33.3)
Internal medicine	27 (47.4)
Anesthesia/critical care	25 (43.9)
Other surgical subspecialties	9 (15.8)
Other	6 (10.5)

ICU, intensive care unit.

Changes in Resident Support

More than a third of programs (37%) reported that they have provided additional benefits to their residents since the onset of the COVID pandemic. The most common newly added benefits were providing counseling or wellness smartphone application resources (37%), hotel vouchers (32%), and childcare vouchers (19%). There was no significant association between burden of patients with COVID and the odds of a program offering any of these additional benefits. Many programs were already offering counseling or wellness smartphone applications to their residents before the onset of the COVID pandemic.

Changes in Resident Education

Nearly all programs were conducting grand rounds (100%) and M&M conferences (88%) using teleconferencing software (Table 3). The remaining programs either completely cancelled (12%) or had some small in-person meetings (4%). PDs reported that didactic lectures were primarily live-streamed lectures led by faculty (91%) or residents (65%). A substantial percentage endorsed also sourcing lectures (47%) or grand rounds from outside institutions (39%) or previously recorded sessions (33%). In general, lecture materials were being selected by the PD (65%) or by the residents (61%), rather than by the speaker or a previously formalized curriculum. Across all respondents, there was a relatively equal distribution regarding the change in the quantity of lectures delivered (39% increased and 30% decreased the number of lectures), with most programs (56%) delivering 3—6 hours of didactic material per week. There was no association between COVID-positive patient burden and either the absolute number of hours of didactic material delivered per week or the reported change in the quantity of didactic material delivered from pre-COVID onset to post-COVID onset. Resident participation was predominantly assessed via direct engagement of resident

Table 3. Changes in Resident Educational Sessions in Response to COVID Pandemic

Question	N (%)
Which of the following formats are being used for grand rounds?	
Teleconferencing	57 (100)
In person	1 (2)
Completely cancelled	9 (16)
Other	
Which of the following formats are being used for M&M sessions?	
Teleconferencing	50 (88)
In person	2 (4)
Completely cancelled	7 (12)
Other	0 (0)
Which of the following formats are being used to deliver didactic lectures?	
Live-streamed faculty-led lectures	52 (91)
Live-streamed resident-led lectures	37 (65)
Recorded lectures	19 (33)
Lectures from other institutions	27 (47)
Grand rounds from other institutions	22 (39)
Other	6 (11)
How are didactic sessions selected?	
Speaker-selected	15 (26)
Program director-selected	37 (65)
Resident suggestion	35 (61)
Previously formalized curriculum	25 (44)
Other	1 (2)
Change in number of didactic sessions since onset of COVID	
Increased	22 (39)
Decreased	17 (30)
No change	18 (32)
Which of the following outside resources are being included into the curriculum?	
CNS Online Complimentary Education	42 (74)
SANS Residency Program	15 (26)
AANS/NREF Resident Education Courses	10 (18)
ThiemeMedOne Neurosurgery	8 (14)
Board preparation question banks	14 (25)
Smartphone/mobile educational applications	4 (7)
Other	3 (5)
How many hours per week are residents engaged in didactic lectures?	
0 hours	0 (0)
1–2 hours	6 (11)
3–6 hours	32 (56)
7–10 hours	12 (21)
>10 hours	1 (2)
Tools used to assess resident participation in online education sessions	
Mock oral boards	14 (25)
Online quizzes	9 (16)
Virtual polling	12 (21)
Interactive questions during lectures	33 (58)
Other	4 (7)
Participants in online educational sessions other than neurosurgical residents	
Advanced practice providers	33 (58)
Medical students	29 (51)
Residents	8 (14)
All members of institution	9 (16)
Neurosurgery residents only	13 (23)
Other	7 (12)

Continues

M&M, morbidity and mortality; CNS, Congress of Neurological Surgeons; SANS, Self-Assessment in Neurosurgery; AANS, American Association of Neurological Surgeons; NREF, Neurosurgery Research & Education Foundation.

attendees by the lecturer (58%). Some institutions also indicated that they were using mock oral boards (25%) and virtual polling (21%) features to further ensure resident engagement. Most programs were incorporating outside resources to supplement the education of their residents, most commonly in the form of the freely available Complimentary Online Education offered by the CNS (74%). Program size was not significantly associated with odds of using any of the outside resources listed (all $P > 0.05$). Approximately half of programs were including advanced practice providers (58%) and medical students (51%) in their resident didactic sessions.

PD Concerns

PDs overwhelmingly reported that increased use of teleconferencing solutions is the biggest change to the methods used to educate residents. Most state that their biggest concerns regarding the current crisis are maintaining resident education in the face of decreased case volume;, attempting to maintain resident morale; and reducing resident risk of developing the COVID-19 infection. PDs note that 1 positive effect of the COVID pandemic is increased use of teleconferencing solutions, which many report has increased attendance by both residents and faculty. Consequently, some see these teleconferencing sessions as team-building exercises and most (76%) indicate that they will likely increase their use of teleconferencing systems to either improve attendance or increase the number of potential lecturers. In addition, although the COVID pandemic has decreased operative volumes, several PDs find that the increased off-service time has led to increased resident productivity in terms of clinical research activities.

DISCUSSION

We present the results of a survey of PDs for ACGME-accredited neurosurgery residency programs regarding their responses to the COVID-19 pandemic. In general, we found that most programs made similar changes to resident duties in response to the COVID pandemic: most reduced the number of days per week worked by each resident and the number of residents in the hospital at any one time. In addition, redeployment of neurosurgery residents to care for either COVID-positive or non-COVID patients did occur. A percentage of programs introduced access to wellness/counseling apps in response to the COVID pandemic, although most (72%) had already offered these benefits before the COVID pandemic. PDs are optimistic that the COVID pandemic will not prevent either current or incoming chief residents from reaching ACGME case minimums. For education, most programs have moved both grand rounds and M&M sessions to teleconferencing platforms. Most are delivering 3–6 hours per week of didactic materials via live-streamed lectures led by either faculty or residents based on topics selected by either the PD or residents. Nearly three fourths of programs have begun to incorporate outside materials in their curriculum, most commonly in the form of the Online Complimentary Education offered by the CNS. A few programs have also used additional resources (e.g., board preparation question banks), suggesting that there are additional opportunities to supplement resident education. Materials cited by respondents that seem to be only minimally included in the curriculum are the *Neurosurgical Atlas*, the Neurosurgery Research & Education Foundation online resident education courses, the Rhoton Collection offered by the AANS, and the Virtual Global Spine Conference. However, It is certainly possible that individuals are using these resources on their own as part of self-directed learning.

The Johns Hopkins Experience

After the declaration of a national state of emergency on March 13, 2020,[12] our hospitals began cancelling all elective cases. This cancellation took effect on March 18, with a commensurate decrease in case volume. In addition to reducing operative cases, we implemented changes to reduce potential resident exposure to COVID-positive patients similar to those seen at other institutions starting shortly thereafter.[5-7] Changes included altering the resident coverage schedule to reduce the number of residents in the hospital at any one time, decreasing shift duration, transitioning patient handoffs to the virtual space, and eliminating the double scrubbing of cases to conserve personal protective equipment for the care of COVID-positive patients. In addition, several neurosurgery residents volunteered to assist with the care of patients with COVID in NCCU and throughout the hospital. Residents showing signs consistent with COVID infection underwent rapid testing using our institutional COVID protocol and were quarantined. No residents acquired COVID via occupational exposure to COVID-positive patients.

From an educational standpoint, we cancelled grand rounds and in-person meetings beginning in early March in response to the state of emergency declared in our state.[13] At that point, we immediately transitioned our weekly grand rounds and M&M conferences to Zoom videoconferencing software (Zoom Inc., San Jose, California, USA). In addition, all resident didactic lectures were transitioned to the electronic platform. Daily conferences consisted of morning case-based sessions led by a senior staff surgeon, as well as new 90-minute to 120-minute afternoon lecture periods consisting of 1 resident-led lecture and 1 faculty-led lecture. Lectures included both didactic material and operative video-based learning, with materials being selected based on input from the speaker, PD, and residents. In addition, the annual mock oral boards session for residents' self-assessment and faculty evaluations of their current progress was conducted with Zoom.[9] Based on the result of the present survey, we find that these changes are similar to those that have been enacted by programs nationwide.

Previous Descriptions of the Impact of COVID on Neurosurgical Residents

Burke et al.[7] reported on the impact of COVID-19 on American neurosurgery on April 3, 2020, just 3 weeks after the declaration of a national state of emergency in response to the COVID-19 pandemic.[12] In their work, these investigators described an algorithm for the triage of emergent surgical patients at an academic medical center as well as changes to hospital staffing and resident education in response to the COVID-19 crisis. Their paired coverage model divided residents into 2 nonoverlapping teams and eliminated cross-coverage across multiple hospitals so as to prevent disease spread. In addition, patient handoffs were shifted to the virtual setting and residents were prohibited from contacting residents who were not on their coverage team. However, although the investigators addressed how resident coverage would change, they did not address what changes would be implemented to maintain resident education during this period.

Weber et al.[2] more directly addressed the impact of COVID-19 on resident education. Like Burke et al.,[7] they reorganized resident shifts and patient handoffs to reduce resident-to-resident spread. However, they also reported that residents would be transitioned from an in-person didactic program to a videoconferencing-based system, with a minimum of 90 minutes of lecture led by senior residents using material assembled by staff neurosurgeons or sourced from online material. Carter and Chiocca described the implementation of similar curriculum changes at the Harvard-affiliated programs.[8] These investigators described the implementation of daily lunchtime lectures using videoconferencing software. During these lectures, department staff and medical students are instructed using a combination of operative video, journal club, and didactics. In a separate report,[5] the investigators in addition reported the continuation of normal resident lectures and M&M sessions using videoconferencing software. Although less specific, similar changes were endorsed by Eichberg et al. at the University of Miami.[6] Bray et al.[4] described the impact of COVID-19 on resident education at Emory. As with the centers described earlier, these investigators reported transition of grand rounds and didactic lectures to videoconferencing software. In addition, they reported using this platform to stream daily case conferences for residents, fellows, and medical students and to stream third-party materials provided by the CNS. The interventions reported by these programs seem to be similar to those reported by most of the survey respondents in the present study and show a strategy that could likely be implemented in all neurosurgical residencies.

There has been a reported uptick in the number of electronic resources made available to neurosurgical residents.[9] These include resources offered by professional societies, for example the *Grand Round* webinars and *Virtual Visiting Professor* series offered by the CNS[14] and the free resident courses offered through the Neurosurgery Research & Education Foundation of the AANS.[15] In addition, there has been increased use of third-party resources, including the *Neurosurgical Atlas*, which has reported more than a 20% increase in users/viewers since the onset of the pandemic.[9] We found that most programs are embracing lecture delivery via teleconferencing materials. In addition, nearly three quarters of programs incorporate the CNS Complimentary Online Education into their educational programs. This finding that programs are increasingly relying on video and other online materials is expected and reassuring given the limitations imposed by the COVID crisis. Although such education will never replace operative experience, video instruction has substantial precedent in U.S. academic centers as well as in limited-resource settings.[16-21] A previous survey of neurosurgical residents and attending neurosurgeons in India[17] showed that most respondents found that videos improved their surgical skills. One resource cited by nearly three quarters of the respondents surveyed by Kumar et al.[17] was the Rhoton video collection made freely available by the AANS. It therefore seems probable that incorporation of this collection along with other operative videos may help to enhance the curriculum of neurosurgical residents during this unusual time. Mobile telephone applications represent an additional resource that can be incorporated into the curricula of residents working remotely. A recent review by Bergeron et al.[22] found >100 mobile applications related to neurosurgery, including 65 applications dedicated to the delivery of didactic material (e.g. the *Neurosurgery Survival Guide* published by the CNS). The investigators reviewed the most popular applications and found them to be high-quality overall, with few instances of incompleteness and no instances of false statements. However, they did caution that care must be taken with widespread use of mobile applications, because they are not subject to the same rigorous peer review used for the primary literature. In the present survey, we found that mobile applications seem to be only minimally used, with only 7% of programs reporting using them as part of their didactic curriculum. Although it is possible that individuals use them on their own, formalizing and raising awareness about such applications may represent an additional means of educating residents at a distance.

An additional strategy that was not considered by the survey involves using mobile devices to aid residents in practicing operative skills. Huotarinen et al.[23] described using a smartphone camera in conjunction with suture and several household supplies to allow residents to individually improve their microsurgical skills. The investigators found this training method to significantly improve resident skill using the conventional microscope. Although the tested sample was small, this strategy represents a potential option for residents and programs who have been forced to reduce resident participation in surgical cases because of the COVID-19 pandemic.

Resident Wellness

One aspect of the COVID crisis that has been largely overlooked in the neurosurgery literature is work to maintain resident wellness. In this time of crisis, it is widely acknowledged that extreme physical and emotional stresses are being placed on medical trainees at all levels. Trainees report stress regarding the physical risks posed by having to care for COVID-positive patients[24,25] as well as the potential impact that COVID restrictions may have on future career prospects.[26] Neurosurgical residency is demanding,[27,28] and although overall attrition rates are below average (11% between 2005 and 2010 vs. 18% for general surgery residents),[29,30] it has been noted that low operative volume and outside social stressors are associated with higher rates of burnout.[31] This situation raises concern for increased resident burnout rates during the COVID crisis. To address resident burnout, multiple programs have previously implemented resident wellness initiatives (Table 4).[27,28,32,33] In the setting of this COVID pandemic, it seems that these wellness initiatives are increasingly important. Previous initiatives outside the COVID pandemic have included implementation of gym

Table 4. Previously Described Resident Wellness Initiatives

Institution	Previous Wellness Initiatives
Louisiana State University-New Orleans	Gym memberships Mind-body wellness sessions Team workout sessions
Medical University of South Carolina	Exercise lectures Mind-body wellness sessions Primary care appointments and bloodwork Spouse support programs Team workout sessions Team-building exercises
Tufts Medical Center	Financial wellness lecture series Holiday parties and social events Team bonding experiences
University of Florida	Exercise lectures Mind-body wellness sessions
University of Minnesota	Conflict resolution skill sessions Exercise lectures Personal development and career planning sessions Team-building exercises
University of Pittsburgh	Faculty mentorship program Gym memberships Team workout sessions Wellness and mindfulness lectures
Vanderbilt	Exercise lectures Gym memberships Leadership lectures Team-building exercises and trips
Wake Forest	Exercise lectures Gym memberships Mind-body wellness sessions Quarterly resident/faculty events Team workout sessions Team-building exercises

Sources: Quintero Wolfe et al.[28] and Ares et al.[32]

memberships, group exercise sessions, and regular lectures on wellness[28] (Table 4). Quintero-Wolfe et al.[28] recently summarized wellness initiatives at 7 residency programs. These investigators found that the most popular items included scheduled workout sessions, regular wellness lectures, and participation in scheduled group events, including the annual neurosurgery softball tournament. Several groups have directly reported the impact of physical fitness initiatives on resident mental health. The first description was by Spiotta et al.[27] In subsequent reports, this group reported that such interventions were seen by residents as "very important," with most reporting the interventions to have positive impacts on their physical and mental health.[34] These investigators also reported team-building efforts to increase team cohesiveness and to improve scores on previously validated measures of anxiety and sleepiness.[33] In response to this experience, Louisiana State University implemented a similar exercise program for residents at their New Orleans campus; two thirds of the residents reported the intervention to significantly improve their job satisfaction.[28] Implementation of a mindfulness-based initiative at the University of Florida was similarly reported to improve resident motivation and conflict-handling abilities.[28] Along these same lines, since the pandemic began, our institution has offered all students and trainees free mental telehealth counseling to deal with some of the new challenges and stressors.

In the setting of the current COVID pandemic, many of these initiatives may not be possible. However, similar interventions using videoconferencing software (e.g., group online fitness classes) can help foster the same level of camaraderie that has been found to boost resident performance and quality of life. In addition, PDs responding to our survey noted that virtual social gatherings, happy hours, and similar events via videoconferencing software can help bolster resident morale and sense of community. Ammar et al.[35] noted similar effects in their report on efforts to maintain wellness among neurosurgical residents at a New York City program. These investigators endorsed the increased use of check-ins between faculty and residents and between residents as a means of maintaining contact during these times of social distancing. The investigators also reported offering childcare resources and flexible work scheduling to help reduce resident anxiety about nonclinical concerns. In the present survey, we found that only a few programs provide these services.

Limitations

The present study has several limitations inherent to all survey-based research. First, we had only a 50% response rate to our survey. Although this rate is relatively high for such survey studies, it is possible that novel educational interventions being used at centers are not captured here. In addition, many questions were set up as multiple-choice questions to simplify responding. Because this strategy can miss some of the nuances of open-ended answers,[36] we intentionally included some areas for free text response to capture additional details of the response. As a result, some programs may use interventions that were missed.

CONCLUSIONS

The COVID-19 pandemic has led to drastic changes in neurosurgical training and overall resident experience. We provide the results of a survey of PDs describing both the interventions being pursued to continue resident education and the changes in resident involvement. We find that most programs have experienced large decreases in their case volume and are attempting to compensate by moving didactic lectures to teleconferencing software and increasingly incorporating educational resources from outside sources. In addition, most programs are reducing resident in-hospital time and reducing the number of residents in-house at any one time to reduce risk of COVID exposure. We hope that these results can help create transparency and consistency across neurosurgery residency programs for the benefit of all trainees, as well as generate consideration of how the common adaptations adopted rapidly by programs will affect how neurosurgical education occurs in the future.

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