Virtual learning during the COVID-19 pandemic: a turning point in neurosurgical education

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OBJECTIVE The coronavirus disease 2019 (COVID-19) pandemic has caused dramatic changes in medical education. Social distancing policies have resulted in the rapid adoption of virtual learning (VL) by neurosurgeons as a method to exchange knowledge, but it has been met with variable acceptance. The authors surveyed neurosurgeons from around the world regarding their opinions about VL and how they see the future of neurosurgical conferences.

METHODS The authors conducted a global online survey assessing the experience of neurosurgeons and trainees with VL activities. They also questioned respondents about how they see the future of on-site conferences and scientific meetings. They analyzed responses against demographic data, regions in which the respondents practice, and socio-economic factors by using frequency histograms and multivariate logistic regression models.

RESULTS Eight hundred ninety-one responses from 96 countries were received. There has been an increase in VL activities since the start of the COVID-19 pandemic. Most respondents perceive this type of learning as positive. Respondents from lower-income nations and regions such as Europe and Central Asia were more receptive to these changes and wanted to see further movement of educational activities (conferences and scientific meetings) into a VL format. The latter desire may be driven by financial savings from not traveling. Most queried neurosurgeons indicated that virtual events are likely to partially replace on-site events.

CONCLUSIONS The pandemic has improved perceptions of VL, and despite its limitations, VL has been well received by the majority of neurosurgeons. Lower-income nations in particular are embracing this technology. VL is still evolving, but its integration with traditional in-person meetings seems inevitable.

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KEYWORDS virtual learning; e-learning; teleconference; education; COVID-19; knowledge exchange

ADVANCES in medicine are dependent on the effective exchange of knowledge. Traditionally, this has occurred through reading, testing, tutorials, problem-based teaching, didactic lectures and seminars, hands-on clinical experiences, and, most recently, online learning.¹ The coronavirus disease 2019 (COVID-19) pandemic has caused a seismic shift in the way we learn, and the impact is expected to be long-lasting.²

Most countries have suspended in-person medical education, conferences have been canceled or postponed, and teaching rounds and seminars have migrated from the classroom to the digital screen. The majority of medical

learning, such as teaching rounds or conferences, is occurring virtually.^{3–8} Although this trend may not be indefinite, it will without a doubt change the way we learn.

This shift to virtual learning (VL) poses new challenges. Is online learning as effective and efficient as in-person communication? What are the limits to video conferencing when demonstrating clinical skills? Are questions and responses equally engaging when delivered through a microphone versus face-to-face? Much of this remains to be seen. Regardless, the shift to online education has taken a tremendous step forward and is not likely to regress.

Neurosurgeons have been quick to adapt to the new

ABBREVIATIONS AANS = American Association of Neurological Surgeons; CNS = Congress of Neurological Surgeons; COVID-19 = coronavirus disease 2019; VL = virtual learning; WFNS = World Federation of Neurosurgical Societies.

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paradigm of virtual education. The Congress of Neurological Surgeons (CNS) has granted free access to many of its educational resources. The World Federation of Neurosurgical Societies (WFNS), American Association of Neurological Surgeons (AANS), CNS, and Brazilian Society of Neurosurgery are rapidly producing new material for continuing medical education.^{9–12} The AANS, for the first time, recently replaced their on-site conference with a virtual meeting.¹² The exceptional attendance inspired larger organizations to follow suit.^{8,13} The impact this will have on the future of the neurosurgical community is yet to be seen.

The majority of medical research has tended to occur in higher-income nations, and this has resulted in most conferences occurring in these nations as well.^{14,15} Unfortunately, attending meetings in these nations can be costly, which limits participation by attendees from lower-income nations and thus creates barriers to progress for these nations.¹⁴

To better understand the benefits of online neurosurgical learning, we set out to survey the opinions of neurosurgeons around the world regarding their experiences with this new platform. We also sought their opinions regarding future insight into the impact of this technology on the on-site conferences and meetings.

Methods

We designed a questionnaire assessing neurosurgeons' behaviors and opinions related to VL. We asked participants to provide basic information about their practice and experience in neurosurgery, their behaviors regarding neurosurgical VL before and after the COVID-19 pandemic, their perception of the value of VL, and their opinions on how future VL should be incorporated into on-site conferences and meetings.

We obtained neurosurgeons' contact information from professional contact lists and social media forums (Facebook, Twitter, and WhatsApp) and through interpersonal contacts. We also utilized open-access social media-based surveys through neurosurgery groups (Facebook and Telegram).

We distributed questionnaires (in English and Spanish), which we had created using Google Forms (Google LLC), from May 21, 2020, to June 4, 2020. For potential Chinese participants, we emailed portable document format (PDF) questionnaires.

Respondents were asked to declare their subspecialty. We categorized the respondents' residence by income and region according to the World Bank classification.¹²

This study was conducted in accordance with STROBE guidelines.¹⁶

Statistical Methods

Statistical analysis was done using SPSS version 26 (IBM Corp.). Participant responses were tabulated using frequency histograms. To analyze relationships between independent variables and outcomes, we used multivariable logistic regression to calculate odds ratios and 95% confidence intervals and p values. Significance was considered at $p < 0.05$.

Results

We received 266 responses from social media-based neurosurgery groups through Facebook, Twitter, and Telegram and 625 responses from 1029 Facebook Messenger, Twitter, WhatsApp, and email direct invitations (response rate, 60.7%) for a total of 891 responses from 96 countries. Characteristics of the surveyed neurosurgeons are summarized in Fig. 1.

The vast majority of our respondents (90.3%) had attended VL activities during the COVID-19 pandemic, and these activities were primarily organized by international societies (63.2%; Fig. 2).

Experience With VL Activities Since the Start of the COVID-19 Pandemic

The majority of respondents told us that because of their VL experiences they would change aspects of their practice (55.7%). They believed that VL activities improved their knowledge of the best evidence-based practice (65.7%) and the level of care they provided to their patients (62.1%). Most respondents told us that they would also consider alternative management plans for their patients based on the knowledge they had acquired from VL sessions (63.4%) and that VL had helped them improve patient outcomes (56.7%) and communicate better with professional colleagues (63.6%). Furthermore, the majority of the respondents found that VL activities provided them with networking opportunities (58.4%) and indicated that their participation in future learning activities would likely increase (69.7%).

Virtual and On-Site Meetings and Conferences

Figures 3 and 4 show the opinions of respondents regarding future participation in VL. Respondents were more likely to increase their participation in the future if they were from Sub-Saharan Africa (OR 2.3, 95% CI 0.6–8.8) as compared to North America. We also found that those who had participated in VL during the pandemic were more likely to be willing to do so in the future (OR 5.3, 95% CI 2.7–10.5). However, academic versus nonacademic neurosurgeons (OR 0.7, 95% CI 0.4–1.2) and primarily cranial versus general neurosurgeons (OR 0.6, 95% CI 0.4–1) were less likely to be willing to participate in future VL activities. When we asked which subspecialty would not benefit from VL activities, 58.8% of respondents chose “none.”

Those who recommended that VL replace all on-site neurosurgical meetings were from lower-income nations: low (OR 4.6, 95% CI 2–10.6), lower-middle (OR 2.6, 95% CI 1.4–4.7), and upper-middle (OR 1.9, 95% CI 1.1–3.3) compared to high-income countries. European and Central Asian neurosurgeons (OR 2.5, 95% CI 1.1–5.8) were also more likely to propose such recommendations than North American neurosurgeons.

Respondents who had paid a fee for VL activities during the COVID-19 pandemic (OR 3.4, 95% CI 2.1–5.5), as compared to those who had not paid a fee, were significantly more likely to recommend that VL replace all on-site neurosurgical meetings.

When respondents were asked to what extent should

FIG. 1. A: Geographic distribution of respondents by current country of practice. Map generated using the GeoNames geographic database. CC BY 4.0 (<https://creativecommons.org/licenses/by/4.0/>). **B:** Categorization of respondents' current country of practice according to the World Bank country classification by income. **C:** Categorization of respondents' current country of practice according to the World Bank country classification by region. **D:** Respondent distribution by specialty. **E:** Respondent distribution by experience. **F:** Respondent distribution by practice setting.

neurosurgical VL activities replace on-site meetings on a scale from 1 to 5 (1 indicating completely and 5 indicating not at all), our regression model showed that neurosurgeons from regions other than North America were more likely to indicate that virtual activities should completely replace on-site meetings. Similarly, neurosurgeons from low-income versus higher-income nations (OR 5.2, 95% CI 0.6–43.7) and neurosurgeons who had paid a fee for VL activities during the COVID-19 pandemic versus those who had not paid a fee (OR 3.8, 95% CI 1.6–9.3) were also more likely to support replacing on-site meetings.

Respondents were significantly more likely to attend an on-site conference virtually if they were in academic practice (OR 5.3, 95% CI 1.9–14.8) or combined academic/nonacademic practice (OR 2.6, 95% CI 1–6.7) than in nonacademic practice. However, faculty/attending/consultant respondents, as compared to in-training respondents, were less likely to attend such virtual conferences (OR 0.4, 95% CI 0.2–1). This was also true for cranial (OR 0.3, 95% CI 0.1–0.9) and spine and peripheral nerve (OR 0.2, 95% CI 0.1–0.7) surgeons compared to general neurosurgeons.

Predictors of those who would be willing to pay a fee for VL activities were being from Sub-Saharan Africa (OR 6.6, CI 1.8–24.3) versus North America and being a neurosurgeon who had not participated in VL activities before the current pandemic (OR 1.7, 95% CI 1.2–2.4). On the contrary, neurosurgeons from low-income nations were significantly less likely to pay a fee for future VL activities than were those from high-income nations (OR 0.4, 95% CI 0.2–0.9).

Virtual Education and Training

Most respondents believed that VL would change neurosurgical education but only partially replace on-site learning activities (Fig. 4). However, respondents from Europe and Central Asia (OR 0.5, 95% CI 0.3–1) compared to North American respondents and respondents in academic practice (OR 0.6, CI 0.4–0.9) compared to those in nonacademic practice were less likely to believe that VL activities will alter neurosurgical training and education strategies in their country.

Many respondents believed that VL activities will alter neurosurgical training and education strategies in their region. This belief was far more likely among spine and peripheral nerve surgeons than general neurosurgeons (OR 2.7, 95% CI 1.2–5.7) and among Sub-Saharan Africa neurosurgeons than North American neurosurgeons (OR 3, 95% CI 1–8.8). Similar feelings were reported by faculty/attendant/consultant respondents versus in-training respondents (OR 1.3, 95% CI 1–1.8). Finally, neurosurgeons who had not participated in VL activities pre-COVID-19 (OR 1.4, 95% CI 1–1.9) and those who had paid fees for VL activities since the start of the pandemic (OR 2.8, 95% CI 1.6–5) also were more likely to believe that VL activities will alter neurosurgical training and education strategies in their country.

Discussion

Physicians acquire clinical knowledge primarily in practice but also by reading and interacting with others.

Workshops, symposia, and conferences have historically been the primary method by which this exchange has occurred.¹⁷ Even prior to the COVID-19 pandemic, staying abreast of the latest developments in practice has been challenging given time restrictions and difficulty accessing high-quality information. Conference attendance, for example, is very much driven by personal schedules, geography, and available finances.

Once the COVID-19 pandemic was officially declared, medical conferences were canceled or postponed worldwide, resulting in an almost complete cessation of in-person medical information exchange. This included the cancellation of the annual meetings of the AANS, CNS, WFNS, and The Society of Neurological Surgeons.^{6–8,18} Almost immediately, a seismic shift to VL as a method of continued interaction accelerated forward. Associations that already had prior experience with VL, such as the AANS and CNS, were able to move forward more quickly.^{19,20}

The elimination of geographical distance as a barrier to attendance combined with the generally reduced costs of such activities attracted new audiences to VL activities and dismantled misperceptions of reluctant participants. Although there have been challenges to this transition, attendance at VL activities has been steadily rising. The paradigm shift has also created new venues for participation, such as the Virtual Visiting Professor by the CNS and the open-access online lecture series by the AANS.^{9,12} Also, there has been a significant increase in online subscriptions to free resources such as *The Neurosurgical Atlas* during this pandemic.²¹

Neurosurgical education has the additional challenge of having to teach complex psychomotor skills. Traditionally, this has been performed in hands-on cadaver labs and at vendor exhibits where attendees are able to explore the latest innovations with expert supervision. VL at this time cannot provide such experiences and thus has limitations. But in the future, this aspect will likely change as new technologies such as virtual reality, augmented reality, and 3D printing become available.^{22–24}

Experience With VL Activities Since the Start of the COVID-19 Pandemic

In a recent Cochrane review, VL was found to provide little or no benefit over traditional learning with regard to knowledge acquisition, skills, and patient-related outcomes.²⁵ This finding was not in keeping with the opinion of the majority of our respondents, who were willing to change their clinical practice based on their VL activities. Our respondents also reported an improvement in their knowledge of the best evidence-based practices and in the level of care that they provided to their patients. They also reported that they were more aware of alternative management plans and believed that they had a greater likelihood of achieving better patient outcomes.

The majority of respondents (78.3%) indicated that their participation in VL activities had increased since the start of the COVID-19 pandemic in line with the increase in the availability of such activities.⁹ Additionally, 69.7% said they would increase their future participation in these events based on their experiences, indicating a general acceptance of VL among the neurosurgical community.

FIG. 2. **A:** Frequency of participation before the start of the COVID-19 pandemic. **B:** Proportion of respondents who attended a paid activity before the start of the COVID-19 pandemic. **C:** Frequency of participation since the start of the COVID-19 pandemic. **D:** Proportion of respondents who attended a paid activity since the start of the COVID-19 pandemic. **E:** Distribution of attended VL activities sponsored by different organizations.

Virtual and On-Site Meetings and Conferences

There was great interest in VL activities by respondents from low-income regions like Sub-Saharan Africa. The pandemic has provided new learning opportunities that were not previously available. Although many of these activities have been free or relatively inexpensive, the savings in travel expenses has made even events with fees attractive for individuals with fewer financial resources.

We found some reservations toward greater adoption of VL activities among academics, who seemed to have a

preference toward on-site learning. Since such individuals are more likely to be the presenters of scientific content at those events, VL may not offer the interaction and scientific engagement these presenters are aiming to get from the event. Furthermore, for some presenters at scientific conferences, meeting-related expenses may be paid for by their institutions, thus making on-site learning more attractive.

On-site conferences were also preferred by general neurosurgeons as a group. We wondered whether this response might be driven by the limited ability of VL to

FIG. 3. A: Proportion of respondents who would recommend replacing all on-site neurosurgical conferences and meetings with virtual conferences and meetings. **B:** Respondent opinions on the extent to which neurosurgical VL activities would replace on-site neurosurgical learning activities. **C:** Respondent opinions on the neurosurgical subspecialties that would not benefit from neurosurgical VL activities. **D:** Proportion of respondents interested in attending neurosurgical conferences and meetings virtually, if there were an option for virtual attendance.

provide hands-on training. This may change in the future as simulation technology and virtual reality advance in the neurosurgical field.²⁰

Perhaps of even greater concern regarding VL is credibility. As the corpus of knowledge online expands, less reliable and sometimes inaccurate sources are becoming prevalent. This can lead to misinformation.²⁶ Consequently, it is necessary for participants to be critical of their sources of VL. This is where established organizations have the advantage of being able to curate learning activities that can be trusted and being efficient in their ability to educate.

VL is also limited by internet access. Broadband reliability varies around the world and can even be a challenge in some higher-income nations. Poor connectivity in lower-income nations and Sub-Saharan Africa can result in poor sound or video quality, disconnection, question and answer overlap, and long lag times between questions and responses.²⁷ Also in Sub-Saharan African nations, the cost of internet connectivity can be as much as fifty times higher than similar internet speeds in Europe.^{27,28} Organized neurosurgery is trying to address some of these issues—the Global Neurosurgery Initiative, for example, is trying to introduce high-quality neurosurgical education to these nations.²⁹ This will make them less dependent on the upcoming fifth-generation (5G) wireless technology

that is expected to have a major impact on the future of the telecommunication of education and healthcare.³⁰

Respondents from European and Central Asian regions were in favor of completely replacing on-site conferences and meetings with VL activities. This is probably financially motivated but may also be related to geographical distance from North America, where a large number of meetings tend to occur. Other authors have also found similar responses in low-income nations.³¹ Traditionally, participation by lower-income nations at major scientific meetings has been poor.¹⁴

Although organizers have reduced registration fees for these participants, the major barrier remains travel and accommodation costs. Schott et al. estimated that the cost of attending a conference in one's own country is \$1424, and this would be doubled if the attendee traveled to another continent.³² Support to attend conferences has been provided at the organizational level, such as through the WFNS Young Neurosurgeon grants, but overall participation is still limited.³³ Otherwise, participation in international meetings has largely been provided at the departmental level or through personal means.

Furthermore, recommendations that virtual conferences and meetings completely replace on-site conferences and meetings were more likely to be made by European and Central Asian neurosurgeons, increased participation

FIG. 4. **A:** Likelihood of future participation in neurosurgical VL activities based on respondent experience with the neurosurgical VL activities they attended during the COVID-19 pandemic. **B:** Likelihood of paying a fee in the future to attend any neurosurgical VL activities. **C:** Factors affecting the decision to participate in any type (virtual or on-site) of neurosurgical learning activity. **D:** Respondent opinions on whether neurosurgical VL could alter neurosurgical training and education strategies in their current country of practice.

in VL activities during the pandemic and paying a fee for VL activities, and were less likely by neurosurgeons from high-income nations. This might reflect the paucity of attendance at on-site meetings by neurosurgeons from low-income countries because of the traveling and registration expenses.

Moreover, a number of reputable on-site meetings are organized in high-income countries, where a neurosurgeon's income is higher. Both factors would make it easier for neurosurgeons in these countries to attend on-site meetings within their geographical region or to be able to afford travel expenses to attend events of interest in other countries.^{7,8,34} However, it was surprising that neurosurgeons who had increasingly participated in VL activities were less likely to recommend VL replacement of all on-site meetings. This may be due to the drawbacks of VL activities that they had found through participation, such as the difficulty of interacting with the different participants, the impossibility of networking in prerecorded events and the less efficient networking during live events, and even the challenge of occasional technical issues, especially with the use of the more advanced technology required for virtual reality or in countries in which access to a stable high-speed internet connection is inconsistent. It is expected that there will be a learning curve until the most efficient setup for virtual events is established.

It seems that as we move forward, the option to virtu-

ally attend conferences and meetings will likely become more common. We found that there was great interest in this option among neurosurgeons in academic practice or combined (academic and nonacademic) practice compared to those in nonacademic practice and among in-training respondents compared to faculty/attendant/consultant respondents.

Neurosurgeons from Sub-Saharan Africa were willing to pay a fee to attend VL conferences, but those from lower-income nations were not. This likely reflects limited financial resources, and neurosurgery organizations may have to consider further reducing fees for this group of nations.

Future Directions

VL is in a renaissance period as we meet the challenges of the COVID-19 pandemic. We anticipate many changes ahead as this new educational platform evolves to meet the needs of our global neurosurgical community. Innovation in VL activities such as virtual reality platforms,²⁴ virtual operating room live series,²¹ augmented reality,³⁵ and simulation labs³⁶ will contribute to the increased adoption of VL. Ultimately, VL will find its place in the way neurosurgeons transfer their experience to the next generation.

Conclusions

Our survey demonstrated a varied acceptance of VL as

a new method of knowledge transfer. Although the majority of our respondents are now willing to embrace this new medium, some have reservations about its overuse. The COVID-19 pandemic has forced neurosurgeons to reconsider the way in which we share knowledge, and the impact is likely to be long-lasting. Ultimately, a balance will be achieved between VL and hands-on or traditional on-site conferences. The cost savings of VL, combined with increased accessibility for distant geographical audiences and those with fewer resources, cannot be ignored. Integrating VL into the neurosurgical curricula will increase information dissemination and improve care overall.

Acknowledgments

Dedication

To our brothers and sisters who have fallen to this invisible enemy. As we write this article, hundreds of physicians throughout the world have died at the frontlines fighting the COVID-19 infection. In these unprecedented times, our thoughts, actions, and prayers are with them and their families.

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Disclosures

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