World Neurosurgery: X 23 (2024) 100326

Contents lists available at ScienceDirect

World Neurosurgery: X

journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Post-pandemic paradigm shift toward telemedicine and tele-education; an updated survey of the impact of Covid-19 pandemic on neurosurgery residents in United States

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ARTICLE INFO

Keywords:
Covid-19
Neurosurgery
Residency
Telemedicine
Tele-education

ABSTRACT

Background: Several strategies were implemented during the Covid-19 pandemic to enhance residency training and patient care.
Objective: This study aims to assess the post-pandemic landscape of neurosurgical training and practice.
Method: A survey consisting of 28 questions examining the challenges faced in neurosurgery and the adaptive measures was conducted among US neurosurgery residents from May 2022 to May 2023.
Results: This study encompassed 59 neurosurgical residents, predominantly male (72.9%) and in later years of training (66.1%) and were distributed across 25 states. Telemedicine and tele-education were pivotal during the pandemic, with virtual lecture series, standalone lectures, and virtual discussions highly favored. Remote didactic learning increased for nearly half of the residents, while 54.2% resumed in-person instruction. Telemedicine was deemed effective by 86.4% for evaluating neurosurgical patients. Access to teaching environments was restricted for 61.0% of residents, impacting their training. The pandemic significantly influenced elective surgeries, with complete cancellations reported by 42.4%. Reduced faculty engagement was noted by 35.6% of residents, while 47.5% reported a negative impact on the overall resident experience. The majority (76.3%) considered changes to their training reasonable given the global health situation.
Conclusions: Strategies implemented during the peak of the pandemic remain crucial in shaping neurosurgery training. Telemedicine has become indispensable, with widespread adoption. Tele-education has also expanded, providing additional learning opportunities. However, traditional didactic courses and hands-on experiences remain essential for comprehensive training. Balancing technology-driven methods with established approaches is crucial for optimizing neurosurgical education and maintaining high-quality patient care.

1. Introduction

The SARS-CoV-2 virus, first detected in Wuhan, China, is highly infectious, resulting in over 767 million infections and 6.9 million deaths worldwide.[1] In the United States alone, the toll has surpassed a million fatalities.[2] The Covid-19 pandemic has wrought an unprecedented crisis, profoundly affecting various spheres of life, encompassing social and economic dimensions. The healthcare sector, in particular, has borne the brunt, grappling with a surge of patients and the ensuing strain on resources, culminating in a significant mortality rate.[3] Consequently, a substantial segment of the population has experienced adverse economic consequences and witnessed a disruption in vital services. Moreover, the training milieu for medical residents has witnessed a paradigm shift, yielding far-reaching implications for resident readiness and long-term patient care.

In the domain of neurological surgery, the pandemic's impact has been profound. The apprehension surrounding heightened disease transmission and the imperative to alleviate strain on the healthcare system prompted the deferment or cancellation of numerous elective surgeries. Furthermore, a swift reduction in elective surgical procedures and Covid-related restrictions affected every facet of residency training, precipitating disruptions in routine hospital services, diminished

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https://doi.org/10.1016/j.wnsx.2024.100326
Received 20 July 2023; Accepted 21 February 2024
Available online 3 March 2024

exposure to clinical cases, and interruptions in hands-on training initiatives. Additionally, a preference for non-neurosurgical patient care was observed for non-urgent cases, primarily to safeguard the well-being of healthcare providers and reallocate resources, resulting in reduced case exposure for residents.[4] Many residency programs, including those in neurosurgery, swiftly adapted their training methodologies to ensure the safety of residents and patients, whilst upholding the continuity of training.[5] One such adaptation involved a transition towards virtual platforms, encompassing telemedicine technologies, e-conferencing, virtual didactic sessions, and online training modules, to accommodate clinical care and resident training.[6–8] With the recent announcement from the Centers for Disease Control and Prevention officially terminating the Public Health Emergency and a subsequent easing of restrictions,[9] these virtual platforms have demonstrated their efficacy and have become an integral facet of clinical care and training in neurosurgery.

Building on our initial surveys assessing neurosurgery training in the early phases of Covid-19, our prior investigations revealed a decrease in operative cases and work hours for residents.[10,11] To comprehensively understand how neurosurgery residency has evolved in response to the Covid-19 pandemic and to assess the enduring ramifications on neurosurgical training and patient care three years post-pandemic onset, we conducted a self-administered survey encompassing residents and clinicians across the United States. This study aims to scrutinize the challenges faced, the extent of disruption, and how the implemented changes persistently influence neurosurgery training in the post-pandemic landscape.

2. Methods

2.1. Study design and participants

The primary aim of this survey was to collect perspectives from residents regarding the impact of the Covid-19 pandemic on their training and the ensuing modifications implemented in their education. Eligibility for participation extended to residents specializing in neurological surgery across all years of their training. Suitable study participants were discovered though an extensive search of each residency program's official website. This investigation specifically targeted neurosurgical residents from 40 states within the United States, encompassing those affiliated with Accreditation Council for Graduate Medical Education (ACGME) accredited neurosurgery programs, as well as the District of Colombia. In total, 1572 neurosurgery residents in 7 years of training were under enrollment during the survey period.[12] Completed Checklist for Reporting of Survey Studies (CROSS) could be found in Supplementary Materials S1.

2.2. Survey

A cross-sectional survey was sent as web-link questionnaires to neurosurgical residents in the United States. It included closed- or open-ended questions focusing on resident training experience in the last year of the pandemic (i.e., May 2022 to May 2023) (Table 1). The survey questions, comprising a total of 28 questions for residents, were designed and vetted by us based on our previous surveys conducted at the onset of the pandemic but modified to capture the enduring impacts.[10,11] The questions pertained to demographics, residency, personal safety, restrictions on electives, effects and challenges in practice, learning, adoption of technologies, quality of care to patients, vaccination, and effect on lifestyle. These questions were designed to capture residents' experience with the pandemic and how it may have impacted their training.

2.3. Survey dissemination

The survey questions with related sub-questions were implemented

Table 1
List of survey questions to neurosurgery residents and their responses.

Question	Response
Q0 – How do you identify?	Man Woman I prefer not to say
Q1 – What is your year in residency?	PGY-1 to PGY-7
Q2 – In what state is your program located?	List of states plus District of Columbia
Q3 – Did the pandemic impact your residency application process? Select all that apply.	Virtual interviews Did not do an away rotation Was limited to one away rotation Did not get to visit the current residency program Applied to more residency programs Applied to fewer residency programs The pandemic did not impact my residency application process
Q4 – Do you feel that your personal safety, health, and well-being were appropriately prioritized during the pandemic?	Yes No
SubQ4 – Do you feel as though your safety, health, and well-being were compromised as a result of decisions that prioritized business/financial outcomes for your institution during the pandemic?	Yes No Unsure
Q5 – In the past two years, has resident access to the teaching environment been limited by your program or the hospital since the pandemic?	Yes, and they are still present Yes, but they have been removed No
Q6 – In the past two years, how many times have elective surgeries been restricted at your institution?	Never Once 2–5 >5
Q7 – In the past two years, how many times have elective surgeries been canceled at your institution?	Never Once 2–5 >5
Q8 – In the past two years, how has the volume at the three listed locations changed at your institution? - Outpatient Clinic	Percentage values for: Outpatient Clinic Inpatient Consults ER Admissions
Q9 – Prior to the pandemic, how many hours per week, on average, did you work in your residency program?	This does not apply to me 70 or more 60–69 50–59 40–49
Q10 – How many hours per week, on average, do you work now in your residency program?	70 or more 60–69 50–59 40–49 Less than 40
Q11 – Prior to the pandemic, how many hours per week did your program spend on didactic learning?	This does not apply to me >10 7–9 5–6 3–4 1–2 None
Q12 – How many hours per week does your program currently spend on didactic learning	>10 7–9 5–6 3–4 1–2 None
Q13 – Since the pandemic, I have spent increased time __ (select all that apply)	Conducting non-neurosurgical medical care (ER triage, ICU shifts, etc.) In remote didactic lectures with my program or national organizations (e.g., AANS, CNS, etc.) Reading/board preparation In the cadaver/anatomy lab In the basic science research lab Working on clinical research studies, case reports, etc.

(continued on next page)

Table 1 (*continued*)

Question	Response
	None of the above
Q14 – Do you believe that the pandemic has affected the amount of time you have had to study for written boards?	I have had more time to study I have had less time to study My board preparation has not been affected
Q15 – Have you noticed more or less faculty engagement with resident education since the pandemic?	More engagement Less engagement The teaching engagement of our faculty has not changed
Q16 – Has your program leadership or other faculty checked in regularly with your cohort to assess whether your educational needs were being met during the pandemic?	Yes No
Q17 – In the past two years, has your program incorporated remote platforms such as Zoom, GoToMeeting, Skype, etc., for academic conferences/formal didactics?	Yes, but we have resumed in-person conferences and lectures Yes, and we have continued to utilize remote platforms No
Q18 – In the past two years, how has the amount of organized didactic lectures your program provides to residents changed?	0–25% DECREASE 26–50% DECREASE 51–75% DECREASE 76–100% DECREASE 0–25% INCREASE 26–50% INCREASE 51–75% INCREASE 76–100% INCREASE No Change
Q19 – What is your general disposition regarding the use of remote platforms for didactic conferences?	Generally favorable Indifferent Generally negative We are not using remote learning platforms
Q20 – In the past two years, has exposure required you to take time off training?	Yes No
Q21 – At the time of this survey, how many dosages of any vaccination have you received?	0 1 2 3 or more
Q22 – If applicable, when did you receive your first vaccination?	Monthly answers
Q23 – If applicable, when did you receive your most recent vaccination at the time of this survey?	Monthly answers
Q24 – Do you feel that working as a physician during the pandemic has negatively impacted your interpersonal relationships with family and friends?	Yes No
Q25 – How do you feel about adapting your clinical duties in the face of the pandemic?	I believe it is reasonable I believe it has been unreasonable Unsure
Q26 – I feel that the pandemic has negatively impacted the cumulative experience of my residency training thus far.	True False Unsure
Q27 – Do you feel that the pandemic will ultimately affect your chances of getting the fellowship/job of your choice?	Yes No Not pursuing a fellowship
Q28 – Is your overall perception of a medical career impacted by the pandemic?	I have a more favorable perception of my career I have a less favorable perception of my career My perception of medicine has not changed
Q29 – Do you think telemedicine is effective in evaluating neurosurgical patients?	Yes, for all diagnoses No Yes, for a limited number of diagnoses
Q30 – Did attendings/faculty at your institution utilize tele-supervision of procedures, sign-out, or anything else during the pandemic? If so, how often?	Yes, any time it was applicable Yes, most of the time Yes, occasionally Yes, rarely They didn't utilize telesupervision at my institution

in the Qualtrics platform and disseminated anonymously either indirectly by contacting program directors or directly via email and Twitter feed to participants. Only eligible participants could proceed with the questionnaire. Responses were collected via the Qualtrics web interface. The recorded survey responses could only be accessed by an authorized author (EM). The completed responses could not be altered. Multiple survey participation was dismissed by Qualtrics via internet protocol address examination.

2.4. Data analysis and ethics

No recorded response was excluded in this study. Descriptive statistics and graphics were used for the characterization of questionnaire inputs using Microsoft Excel and Qualtrics. No imputation or correction was carried out for missing data. Missing data were removed from the corresponding analysis. No sensitivity analysis was performed. As data were collected anonymously and no intervention was performed, consent for participation was not sought and Institutional Review Board evaluation was waived.

3. Results

3.1. Demographics

A total of 59 in-training residents participated in the survey, accounting for a participation rate of 3.7% out of the 1572 eligible participants. Among these, 43 (72.9%) identified as male, 14 (23.7%) as female, and 2 chose not to disclose their gender. Majority of responses were recorded between January 2023–May 2023 (60%) followed by July 2022–December 2022 (21.7%) and May 2022–June 2022 (18.3%). The responses were distributed across 25 different U.S. states, with a higher concentration reported from Arizona and Pennsylvania. Participants encompassed all years of training, ranging from PGY1 to PGY7, with PGY5 being the most represented (11/59; 18.6%) (Refer to Fig. 1). The majority of responses (66.1%) were derived from residents in their later years of training (i.e., PGY4-PGY7). Regarding Covid vaccination status, 76.3% (45/59) reported having received three or more doses, with 38 out of 59 (64.4%) receiving their most recent dose in 2021, while 14 participants received their latest dose in 2022. Seven residents did not specify the year of their most recent vaccination.

3.2. Telemedicine and tele-education

During the pandemic, the implementation of telemedicine and tele-education emerged as crucial mechanisms for sustaining effective education and training for neurosurgical residents. Notably, 36 respondents reported a reduction in work hours and medical exposure, but 32 of them indicated that this altered work environment has reverted to pre-pandemic conditions. Among the virtual educational approaches, virtual lecture series (54 responses), standalone virtual lectures (53 responses), virtual discussions, and journal clubs (53 responses) were most favored. In contrast, the virtual anatomy lab was the least utilized (6 responses), with a preference for in-person anatomy lab reported by many (29 responses). Assigned reading was also less favored (23 responses).

3.3. Remote didactic learning

All participating residents reported an increased reliance on remote platforms (e.g., Zoom, GoToMeeting, Skype) for didactic lectures and conferences (Fig. 2). Nearly half (29/59) felt an increase in remote didactic learning since the pandemic, while a majority (32/59, 54.2%) perceived no change in the overall amount of didactic instruction. A subset (17/59, 28.8%) reported an increase in time allocated to board examination preparation over surgical training. Furthermore, the majority of residents (32/59, 54.2%) have reinstated in-person instruction and conferences since the onset of the pandemic. Conversely, the

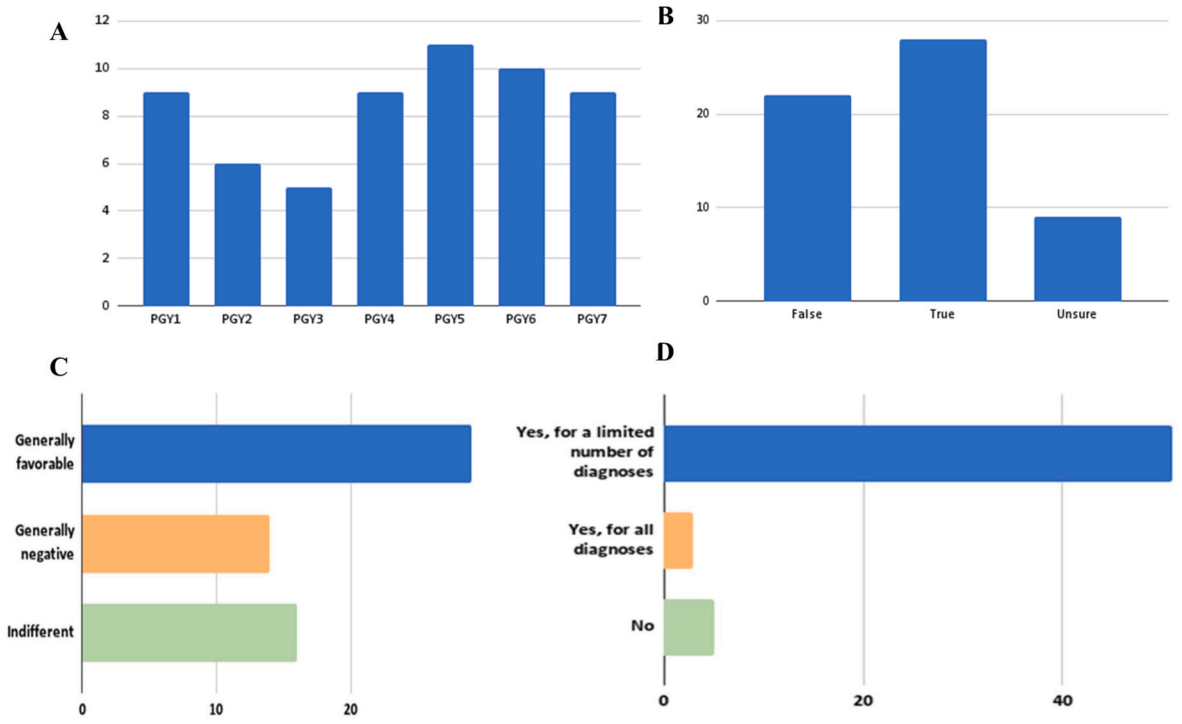

Fig. 1. (A) Distribution of residents based on their year of training at the time of survey response. (B) Residents' perceptions of how the pandemic and its circumstances have influenced their overall training. (C) Residents' attitudes towards virtual didactics and tele-education. (D) Residents' responses when queried about the perceived benefits of virtual patient visits and telemedicine.

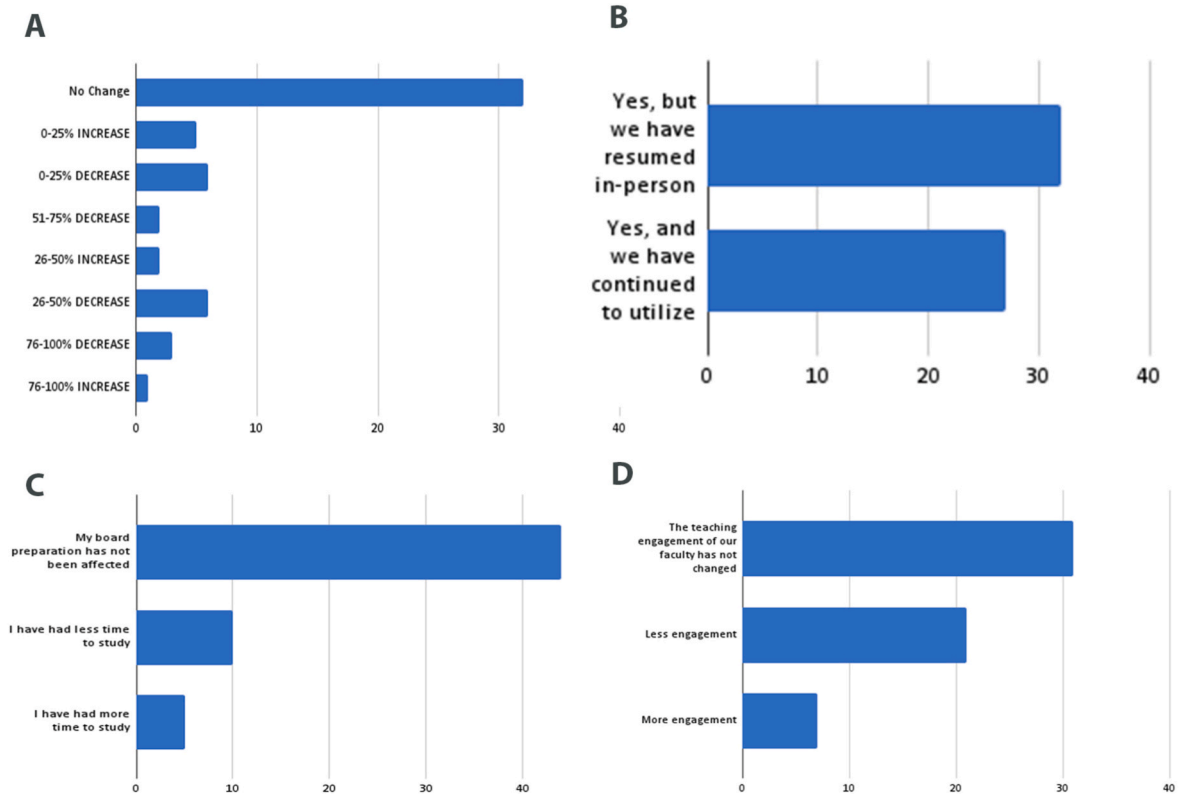

Fig. 2. Distribution of responses to questions. (A) In the past two years, how has the amount of organized didactic lectures your program provides to residents changed? (B) In the past two years, has your program incorporated remote platforms such as Zoom, GoToMeeting, Skype, etc. for academic conferences/formal didactics? (C) Do you believe that the COVID pandemic has affected the amount of time you have had to study for written boards? (D) Have you noticed more or less faculty engagement with resident education since the COVID pandemic?

remaining 27 participants indicated that their institutions continue to rely on remote platforms for didactic lectures and conferences. In summary, resident sentiments towards remote didactic learning were generally positive: 29 out of 59 residents reported favorable feelings, 16 expressed indifference, and 14 conveyed negative feelings towards remote didactic instruction (Fig. 1).

3.4. Telemedicine in patient care and learning

Residents were asked to report their experiences with using Telemedicine to care for patients, and how telemedicine/supervision was used to mediate their learning. A significant majority (51/59, 86.4%) of neurosurgical residents found telemedicine to be an effective means of evaluating neurosurgical patients, albeit for a limited range of diagnoses (Fig. 1). Conversely, out of the remaining 8 participants, 3 reported telemedicine as being an effective avenue of evaluating patients for all diagnoses, and 5 expressed telemedicine as never being an effective evaluating practice for any neurosurgical patient. Regarding Telesupervision in neurosurgical resident education, 30 of the 57 respondents indicated that it was never utilized to oversee their procedures. For those who reported its use, 70% stated it was employed on a "rare" or "occasional" basis.

3.5. Impact on access to teaching environments

Of the participating residents, 36 (61.0%) reported experiencing limitations on their access to teaching environments since the onset of the pandemic. Among these, 20 indicated that these restrictions have since been lifted. Conversely, 23 residents (39%) reported no restrictions on their program's teaching environment.

3.6. Effects on elective surgeries

The Covid-19 pandemic exerted significant influence on the volume of elective surgeries performed nationwide. Respondents reported varying degrees of restrictions, with 28 residents indicating elective surgeries were restricted 2–5 times, 15 reporting >5 restrictions, and 16 stating restrictions occurred either once or never in the past two years. Notably, 25 of the 59 respondents reported complete cancellations of elective surgeries 2–5 times in the same period, impacting their educational experiences. Moreover, 13 residents (22.0%) reported >5 cancellations, while nearly 17% never experienced cancellations.

3.7. Engagement with faculty

While most residents reported no change in faculty engagement, 21 responses (35.6%) noted reduced faculty engagement towards residents. Conversely, 7 residents reported increased engagement from faculty since the pandemic (Fig. 2).

3.8. Impact on interpersonal relationships and resident experience

A substantial portion (23/59, 39%) of neurosurgical residents reported negative impacts on their interpersonal relationships due to their roles as physicians during the pandemic. However, 36 participants expressed no negative impact on these ties. Regarding the overall resident experience, 28 residents (47.5%) reported a negative impact, while 22 stated no adverse effects. Nine participants were uncertain about the pandemic's impact on their resident experience.

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3.9. Perception of training changes

The majority (45/59, 76.3%) of participating residents felt that the changes to their training were reasonable given the global health situation. Furthermore, 32 residents reported no change in their perception of medicine due to the pandemic, while 24 expressed a less favorable perception, and 3 reported a more positive perception.

4. Discussion

The Covid-19 pandemic has ushered in unprecedented challenges for various sectors, including neurosurgical education. Through a comprehensive survey-based approach, we sought to illuminate the extent of its influence on the training and practice of current neurosurgical residents. The alterations imposed upon resident training processes were consistently experienced, encapsulating restrictions within the operating room, an adaptation to telemedicine and tele-education, and a discernible decrease in morale.

4.1. Surgical backlog and its ramifications

A pronounced consequence of the pandemic has been the emergence of a surgical backlog, attributed primarily to the reallocation of surgical resources towards non-surgical patients.[13] This backlog, exacerbated by factors such as physician burnout and reduced staff size, has led to reduction in the availability of critical hospital resources, including beds and surgical facilities.[14] This has had discernible repercussions on patient care, particularly within the realm of neurosurgery. Globally, more than 28 million surgical procedures were either postponed or canceled during the pandemic's apex,[15] aligning with our own survey findings. This surge in surgical backlogs and cancellations has had far-reaching implications on neurosurgical education. Our data supports that a majority of neurosurgical residents encountered limitations in accessing essential teaching spaces during their educational journey. The full extent of the impact on neurosurgical education may only become fully apparent several years down the line, as these residents transition into independent, practicing surgeons. Consequently, a thorough consideration and preparation for potential future crises is paramount in light of the enduring effects of the pandemic on neurosurgical training and practice.

4.2. Telemedicine and its pervasive role in education

In response to the exigencies of the pandemic, neurosurgical education underwent a paradigm shift towards telemedicine and tele-education.[16] This shift was uniformly experienced among residents, signifying a notable alteration in educational modalities. While some residents continue to navigate this shift, others have reverted to a more conventional form of neurosurgical training. Notably, this evolution in resident education has led to a surge in remote learning facilitated by didactic lectures. Intriguingly, residents' overall sentiments towards remote didactic learning were largely positive, indicating its broader acceptance and favorability among medical residents. Our survey attested to the commendable efforts undertaken by educational institutions across the nation to sustain resident education amidst the global pandemic.

4.3. Stressors and strategies for adaptation

Despite the generally positive reception of the transition to remote learning, the training and experience of residents bore the brunt of the pandemic's impact. Within hospital settings, a surge in stress levels and heightened preoccupation with work-related matters during non-working hours was pervasive.[17] Additionally, concerns regarding challenges both within and outside the workplace, such as potential transfers to different units and the risk of contracting and transmitting the virus to

family members, were prevalent among staff members. These stressors exerted a discernible impact on hospital staff, including neurosurgical residents, during their training tenure. To mitigate these challenges, tele-education underwent refinements aimed at simulating a normative educational experience for residents as closely as possible. These adaptations encompassed the integration of routine virtual lectures, remote laboratories, and tele-supervision of resident surgeries, collectively fostering an environment conducive to effective learning. Notably, numerous neurosurgical academic forums transitioned from virtual e-conferencing during the pandemic to a hybrid format, exemplified by the Congress of Neurological Surgeons[8] and American Association of Neurological Surgeons.[7] Furthermore, new avenues for recurrent gatherings, such as Virtual Spine,[18] Neurosurgical Atlas,[19] and OU Morning Spine Conference, emerged, alongside established departmental meetings like grand rounds and morning reports, which adopted a hybrid approach, facilitating the inclusion of guest speakers from universities worldwide.

4.4. The evolution of telemedicine in patient care

The global shift towards telemedicine during the pandemic brought about significant transformations in healthcare delivery for attendings, residents, and patients alike. This shift was driven not only by the imperative of addressing the pandemic but also by the psychological impact of the health crisis.[20] Telemedicine emerged as a pivotal tool in expanding patient outreach while maintaining essential social distancing measures, thus ensuring the safety of care providers.[21] Beyond its role in increasing patient access, telemedicine supplanted traditional routine outpatient visits, offering greater convenience to patients. Despite these advancements, residents acknowledged the effectiveness of telemedicine in only a limited scope of diagnoses. This underscores the importance of offering telemedicine services alongside in-person visits, as the latter remain indispensable for comprehensive patient evaluation.

4.5. Advancements in digital health and telehealth

Digital health, synonymous with telehealth, presents an efficacious means of extending medical resources to patients regardless of their physical proximity to healthcare facilities, thereby ensuring judicious care.[22,23] This approach holds particular promise in addressing the healthcare needs of underserved and geographically distant populations. Noteworthy efforts have been directed towards employing virtual platforms for patients with chronic medical conditions, necessitating regular follow-ups, spanning primary care[24,25] and mental health services.[26] While challenges persist for conditions necessitating comprehensive examinations or procedures, telehealth interventions can still serve vital roles in triage, referrals, and post-treatment follow-up.[27] This introduces more convenient avenues for delivering care within clinical settings. Moreover, tele-stroke initiatives have substantially augmented access to critical treatments for patients in resource-limited environments.[28] In surgical contexts, innovative applications of tele-communication have been demonstrated, particularly in spinal surgery cases. During the pandemic, a notable shift towards virtual visits was observed, constituting approximately 40% of all consultations, in stark contrast to the pre-pandemic era.[29] Digital health platforms like Epic MyChart® have facilitated more interactive and convenient interactions between care providers and recipients, further streamlining healthcare engagement.[30,31] However, the effectiveness of telehealth initiatives and the quality of care delivered to patients remain areas requiring deeper investigation.

4.6. Anticipating the path forward

Reflecting on the challenges posed by the Covid-19 health crisis, it becomes paramount to acknowledge the toll it has taken on neurosurgical residents. Such recognition is pivotal in comprehending the broader implications of the pandemic on neurosurgical training and the trajectory of neurosurgical medicine. The repercussions, spanning from reduced hands-on cases to extended work hours and heightened pandemic-related anxieties, have the potential to profoundly impact the morale of surgical personnel. Notably, our study unveils a notable decline in resident morale, with nearly 40% of participants citing negative impacts on their interpersonal relationships. Additionally, a significant majority of residents affirm that the Covid-19 pandemic has had an adverse effect on their overall residential experience. In light of these findings, it is imperative to accord due consideration to the well-being and morale of residents, as they represent the future vanguard of neurosurgical medicine. This is especially critical given the significant prevalence of increased stress and anxiety reported by a substantial portion of hospital staff, constituting approximately one third of the workforce.[17] As society advances, it becomes increasingly vital to prioritize the mental and emotional well-being of both practicing and trainee surgeons, as well as medical personnel at large. These individuals are at the forefront of the battle to safeguard the health of the human population, making their morale and livelihood of paramount importance.

4.7. Study limitations

It is important to acknowledge several limitations in this survey. The data collection took place towards the conclusion of the Covid-19 epidemic in the United States. Early respondents may have encountered a more severe impact of the crisis compared to those who participated at a later stage. As the pandemic advanced, healthcare providers may have exhibited reduced interest in Covid-related research, potentially leading to lower participation rates. Consequently, the number of neurosurgery residents responding to our questionnaire was limited, potentially introducing a sampling bias. However, we contend that this bias is marginal, given that responses were gathered from a substantial portion of programs nationwide and were evenly distributed across the seven years of residency training. Nonetheless, caution should be exercised in interpreting these findings, as they may not be entirely representative of the entire sample. Furthermore, it is worth noting that respondents in this study primarily consisted of surgical residents affiliated with larger academic institutions in urbanized regions of the country. This demographic makeup may differ from practitioners working in rural or private settings, where the impact of restrictions could be more pronounced.[32] On the contrary, our study specifically targeted academic neurosurgery, as it represents the training grounds for the future of the field. Consequently, gaining insights into how global crises like Covid-19 may influence the training in surgical specialties remains of paramount importance.

5. Conclusion

In conclusion, our survey underscores that the strategies adopted during the height of the Covid-19 pandemic continue to play a vital role in shaping neurosurgery training. Telemedicine has emerged as an indispensable tool, witnessing widespread adoption and integration. Concurrently, the inclusion of tele-education has augmented, affording residents supplementary avenues for learning. Nevertheless, it is imperative to underscore that conventional didactic courses and hands-on experiences continue to hold pivotal importance in ensuring a comprehensive training regimen for neurosurgical residents. These insights underscore the necessity of harmonizing technology-driven approaches with established methodologies to optimize neurosurgical education while upholding the delivery of high-caliber patient care.

Funding

This study did not receive any funding or financial support.

Availability of data

All data used for preparation of this work are available in Supplementary material S3.

CRediT authorship contribution statement

Esmaeil Mohammadi: Writing – original draft, Visualization, Data curation. **Lonnie Smith:** Writing – original draft, Visualization. **Ali F. Khan:** Writing – review & editing. **Benjamin Lee:** Data curation, Investigation. **Oslin Spencer:** Data curation, Investigation. **Fauziyya Muhammad:** Writing – review & editing. **Lance M. Villeneuve:** Writing – review & editing. **Ian F. Dunn:** Supervision, Resources. **Zachary A. Smith:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Chief resident Panayiotis E. Pelargos selflessly helped us with the design of questionnaire. Professors Karin R. Swartz, Christopher Graffeo, Andrew Jea, and Andrew M. Bauer, provided invaluable support and guidance during the survey. Their collective efforts enhanced the research, enriching our understanding of the subject. We are grateful for the invaluable support provided by the Council of State Neurosurgical Societies (CSNS) during the data collection process. Also, we would like to express our utmost appreciation for the exceptional hard work and unwavering dedication demonstrated by the neurosurgery residents throughout the country. Their tireless efforts have played an integral role in mitigating the impact of the pandemic and ensuring its eventual receding.

Abbreviations

CDC	Centers for Disease Control and Prevention
ACGME	Accreditation Council for Graduate Medical Education
PGY	Postgraduation year

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2024.100326.

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