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A Tale of Two Cities: Residents' Operative Experience in the United Kingdom and Germany During the Coronavirus Disease 2019 Pandemic

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■ **BACKGROUND:** The coronavirus disease 2019 (COVID-19) pandemic has had a detrimental effect on residents' operative training. Our aim was to identify the proportion of procedures performed by residents across 2 neurosurgical centers (1 in the United Kingdom and 1 in Germany) during the pandemic-affected months of March 2020–May 2020, inclusive, compared with March 2019–May 2019, inclusive.

■ **METHODS:** All neurosurgical procedures performed at the United Kingdom and German institutions, between March 1, 2019 and May 31, 2019 (pre-COVID months) and March 1, 2020 and May 31, 2020 (COVID months), were extracted and operative notes evaluated. Statistical analysis was performed on SPSS version 22.

■ **RESULTS:** There was a statistically significant reduction in operative volume in the United Kingdom center from the pre-COVID months to the COVID months ($\chi^2(5) = 84.917$; $P < 0.001$) but no significant difference in the operative volume in the German center ($P = 0.61$). A Mann-Whitney U test showed a statistically significant difference in the volume of residents operating in the COVID months compared with pre-COVID months in both United Kingdom and German centers ($P < 0.001$). The average number of procedures performed by residents in the United Kingdom center as the primary surgeon decreased from 82 to 72 per month (pre-COVID vs. COVID months), whereas German residents' operating volume increased from 68 to 89 per month (pre-COVID vs. COVID months).

■ **CONCLUSIONS:** The COVID-19 pandemic has significantly reduced the volume of operating by neurosurgical

residents in the United Kingdom center, whereas residents in the German center performed more procedures compared with 2019. This finding may reflect variations in national practice on maintaining surgical activities and provision of critical care beds during the first wave of the pandemic.

INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) pandemic spread rapidly worldwide in 2020, with >150 million confirmed cases and 3 million deaths reported at the time of writing.¹ The United Kingdom and Germany have been severely affected, with around 4 million and 3 million cases, respectively,¹ since January 2020.

Health care services in both nations extensively reorganized to be able to accommodate this increased demand. In the United Kingdom, all elective operations were postponed² and a country-wide lockdown was enforced on March 23, 2020³ to limit community transmission. Within the United Kingdom neurosurgery community, the Society of British Neurosurgeons published guidelines on triaging cases so that life-threatening and sight-threatening conditions were prioritized for surgery⁴ during the pandemic. Similar guidance was being followed worldwide.^{5,6} The lockdown was eased on May 10, 2020⁷; however, a second wave of the pandemic emerged in September 2020⁸ and a second national lockdown was enforced from November 5, 2020 until December 2, 2020.⁹ The emergence of a new, highly infectious variant in December 2020¹⁰ led to severe

Key words

- COVID-19
- Neurosurgery
- Pandemics
- Residents
- Surgical education

Abbreviations and Acronyms

COVID-19: Coronavirus disease 2019
CSF: Cerebrospinal fluid

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strain on health care resources¹¹ and a third national lockdown was implemented on January 5, 2021.¹²

In Germany, the government also postponed all elective operations to preserve capacity in intensive care units and maintain adequate staffing to care for the surge in COVID-19 cases. A nationwide lockdown was enforced on March 22, 2020.¹³ The German Society of Neurosurgery (*Deutsche Gesellschaft für Neurochirurgie*) also published guidelines¹⁴ similar to the Society of British Neurosurgeons on triaging operations during the pandemic. Because of the emergence of a second wave of infections in October 2020, new restrictions to public life were implemented on November 2, 2020,¹⁵ after the first national lockdown restrictions had been gradually eased from June 2020.¹⁶ Further limitations to socializing were required from December 1, 2020¹⁷ and, as evidence emerged of a highly transmissible variant in the United Kingdom, a second national lockdown was enforced from January 11, 2021.¹⁸

These changing practice patterns have affected the training of neurosurgical residents worldwide. Evidence from the United States,^{19–22} Australia,²³ and Indonesia²⁴ has shown a drastic decrease in operating volume and a global survey of neurosurgeons suggested that the number of operations had reduced by up to half in some countries.²⁵ Spinal surgery, in particular, has been greatly affected.^{20,26,27} Similar issues have been noted across Europe, in reports from Italy,^{28,29} France,²⁷ and Germany.²⁶ This reduction in institutional surgical volume has concerned neurosurgical trainees and training program directors about the effect that this will have on developing operative competencies,^{19,30,31} especially for senior residents.^{29,32} Apart from operative training, resident exposure to outpatient clinics and research activities has also been curtailed,^{33,34} with resultant anxieties about career prospects.³²

Although the literature clearly shows a decrease in operative volume during the COVID-19 pandemic, it is unclear whether the procedures that have been performed have had any resident involvement at all. Neither is it apparent which subspecialties have seen a decrease in procedures performed by residents. The training impact on European trainees has also not been fully established.

Our primary aim, therefore, was to identify the proportion of procedures that were performed by a resident as the lead surgeon across 2 high-volume European neurosurgical centers (1 in the United Kingdom and 1 in Germany) during the first wave of the pandemic; in the months of March 2020–May 2020, inclusive, compared with residents' operating volume between March 2019 and May 2019, inclusive (as a baseline). The secondary aim was to identify any differences among the type of procedures that were affected during the pandemic.

METHODS

Study Setting

This was a retrospective observational study conducted at 2 major European neurosurgical centers.

The neurosurgical department in the United Kingdom center is based at a level 1 trauma center and serves a population of >3 million people. Thirteen consultant neurosurgeons provide the full spectrum of adult and pediatric neurosurgical services, with 71

inpatient beds. Ten residents, of varying experience, support the service. Four dedicated neurosurgical theaters are run on weekdays, including a dedicated emergency theater. The department is a high-volume center and one of the busiest in the United Kingdom for both cranial and spinal neurosurgery.³⁵

The German department is one of Germany's 25 university hospitals, with a catchment population of 1.3 million. Fourteen consultants provide adult and pediatric neurosurgical services, supported by 11 residents of varying experience, with 35 inpatient beds. There are 3 dedicated neurosurgical theaters on weekdays.

Neurosurgical Training in the United Kingdom

The United Kingdom neurosurgical training program^{36,37} lasts for 8 years and is open to application after medical graduates complete 2 years of internship after graduation (foundation years). A minimum total of 1200 procedures, across all subspecialties, should be performed by residents by the end of training before they are certified to practice independently.³⁸

Neurosurgical Training in Germany

In Germany, neurosurgical training programs differ from region to region. In general, the neurosurgical training program lasts for 6 years. In the area of Westphalia, where the German center is located, trainees are expected to perform around 1000 procedures before certification. This total includes, for example, 100 spinal procedures, 50 supratentorial and infratentorial operations, and 50 traumatic brain injury–related operations.

Data Collection and Analysis

All neurosurgical procedures performed at the United Kingdom and German institutions, between March 1, 2019 and May 31, 2019 and March 1, 2020 and May 31, 2020, were extracted from their respective operating theater databases. Operative notes were evaluated to identify the lead surgeon and the surgery was coded as being performed by either a resident or a consultant. Patient demographics, procedure date, urgency of the procedure, and the procedure type were captured on an Excel (Microsoft, Redmond, Washington, USA) spreadsheet.

Included procedures were categorized using procedure codes from the theater databases. Procedures were categorized as follows: 1) cranial/spinal trauma including subdural collections; 2) oncology (cranial/spinal); 3) pituitary and related surgery; 4) degenerative spine; 5) neurovascular including stroke-related; 6) pediatric (other); 7) shunts/other cerebrospinal fluid (CSF)-related including endoscopic third ventriculostomy, external ventricular drain, and intracranial pressure monitoring; 8) functional/pain procedures; 9) adult hindbrain hernias/congenital anomaly repair; 10) craniofacial reconstruction including cranioplasty; 11) epilepsy-related surgery including deep brain stimulation/vagal nerve stimulation; 12) wound/other postoperative complication; and 13) washout and/or drainage of spontaneous infections or abscesses.

Statistical analysis was performed on SPSS version 22 (IBM Corp., Armonk, New York, USA). Differences between the number of procedures over time were evaluated by χ^2 testing. A Mann-Whitney U test was used to compare mean resident operating volumes between 2019 and 2020.

Ethical approval was not sought because this study was performed under the auspices of service evaluation and clinical audit.

Table 1. Patient Demographics, Operative Volumes, and Types of Procedures Performed in the United Kingdom and German Centers, Respectively

	United Kingdom Center	German Center
Patient demographics		
Total procedures performed (n)	1249	960
Age (years), median (range)	55 (0–90)	49 (0–92)
Males (%)	50.5	49.1
Procedure types by center, n (%)		
Degenerative spine	372 (29.8)	126 (13.1)
Shunts and other cerebrospinal fluid—related including endoscopic third ventriculostomy, external ventricular drain, and intracranial pressure monitoring	246 (19.7)	133 (13.9)
Oncology (cranial and spinal)	235 (18.8)	298 (31.0)
Functional and pain	103 (8.2)	72 (7.5)
Cranial or spinal trauma including subdural collections	97 (7.8)	91 (9.5)
Wound or other postoperative complication	64 (5.1)	53 (5.5)
Neurovascular including stroke-related	39 (3.1)	11 (1.1)
Adult hindbrain hernias and congenital anomaly repair	22 (1.8)	15 (1.6)
Washout and/or drainage of spontaneous infections or abscesses	17 (1.4)	22 (2.3)
Pituitary and related surgery	16 (1.3)	38 (4.0)
Craniofacial reconstruction including cranioplasty	15 (1.2)	15 (1.6)
Epilepsy-related surgery including deep brain stimulation and vagal nerve stimulation	12 (1.0)	25 (2.6)
Pediatric (other)	11 (0.9)	61 (6.4)

Patient consent was not sought because the data set was anonymized and consent is implied for the purposes of clinical audit.

RESULTS

Demographics

Patient demographics, overall operative volumes, and types of procedures performed in both centers during the study period are shown in [Table 1](#).

Change in Operative Volume

[Figure 1](#) shows the change in operative volumes between the 2 centers before and during the COVID pandemic.

There was a statistically significant reduction in operative volume in the United Kingdom center from the pre-COVID months to the COVID months ($\chi^2(5) = 84.917$; $P < 0.001$), with the total number of procedures decreasing by 39.8% between these 2

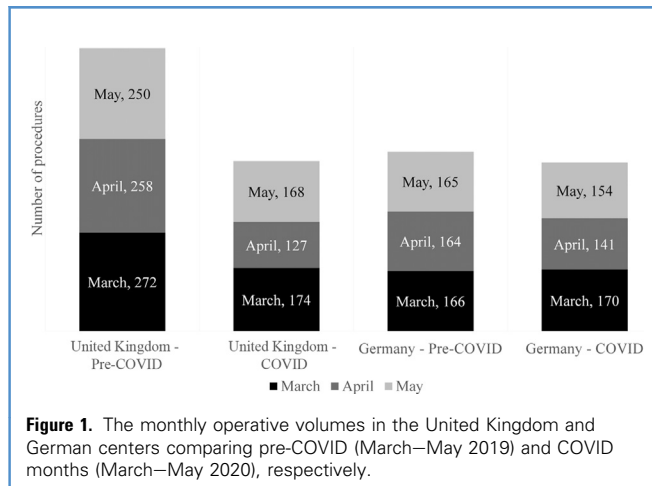


Figure 1. The monthly operative volumes in the United Kingdom and German centers comparing pre-COVID (March–May 2019) and COVID months (March–May 2020), respectively.

periods. There was a smaller reduction in the total operative volume in the German center from the pre-COVID months to the COVID months (8%), compared with the United Kingdom center. However, there was no significant difference in the operative volume across the study period ($\chi^2(5) = 3.588$; $P = 0.61$) in the German center.

Residents' Operative Experience

There were statistically significant differences between the proportion of operations performed by residents as the primary surgeon between the pre-COVID months and COVID months in both the United Kingdom ($\chi^2(5) = 35.483$; $P < 0.001$) and the German ($\chi^2(5) = 33.865$; $P < 0.001$) centers.

In the United Kingdom center, residents performed, on average, less than a third of procedures (31.6%) as the primary surgeon in the pre-COVID months, whereas in the German center, residents were the primary surgeons in 41.4% of procedures in the pre-COVID months. During the COVID months, United Kingdom residents performed almost half of procedures as the primary surgeon (45.1%), whereas German residents performed 58.0% of operations as the primary operator. Although the proportion of operations performed by residents was higher in both the United Kingdom and German centers in the first wave of the pandemic, the total number of procedures performed was lower in the United Kingdom center during the COVID months.

A Mann-Whitney U test showed a statistically significant difference in the volume of residents operating in the COVID months compared with pre-COVID months in both United Kingdom ($Z = -4.043$; $P < 0.001$) and German ($Z = -5.346$; $P < 0.001$) centers. The average number of procedures performed by residents in the United Kingdom center as the primary surgeon decreased from 82 per month (pre-COVID months) to 72 per month (COVID months). However, German residents' operating volume as the primary surgeon increased from 68 per month (pre-COVID months) to 89 per month (COVID months).

Differences by Procedure Type

Overall, at least 75% of procedures performed at both centers belonged to 5 categories: 1) cranial or spinal trauma including subdural collections; 2) oncology (cranial and spinal); 3) degenerative spine; 4) shunts and other CSF-related procedures including endoscopic third ventriculostomy, external ventricular drain, and intracranial pressure monitoring; and 5) functional and pain. Degenerative spine procedures were the commonest procedure type performed in the United Kingdom center, whereas oncology procedures were the commonest type in the German center (Table 1).

Figure 2 shows the change in the overall operative volumes for the 5 commonest procedure types during the study period, from the pre-COVID months to the COVID months, in both centers. There was a statistically significant difference in the volumes of these 5 commonest procedures across the study period in the United Kingdom center ($\chi^2(20) = 75.859$; $P < 0.001$). The volumes of degenerative spine and functional/pain procedures decreased by 83.7% and 92.0%, respectively, between March 2019 and April 2020. In the German center, there was no significant difference in the volumes of these 5 procedure types during the study period ($\chi^2(20) = 29.907$; $P = 0.071$).

Resident Operating and Procedure Type

Figure 3 shows the residents' operative volumes in both United Kingdom and German centers, stratified by the 5 commonest procedures performed in both units, in 2019 (pre-COVID months) and 2020 (COVID months).

A Mann-Whitney U test showed a statistically significant difference in residents' operative volumes when performing the 5 commonest procedures at the United Kingdom center, between 2019 and 2020 ($Z = -2.083$; $P = 0.037$). Of these 5 commonest procedure types in the United Kingdom center, a decrease in resident operating was noted between 2019 and 2020 for 3 procedure types: 1) functional and pain (64.3% decrease); 2)

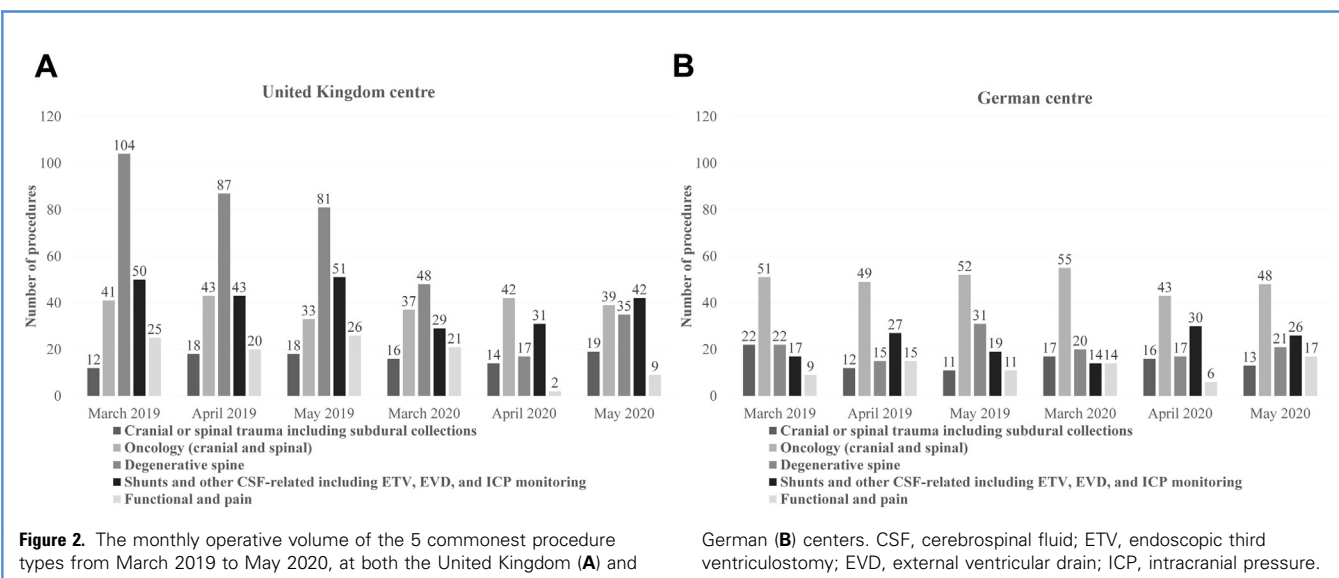
degenerative spine (27.1% decrease); and 3) shunts and CSF-related procedures (14.7% decrease).

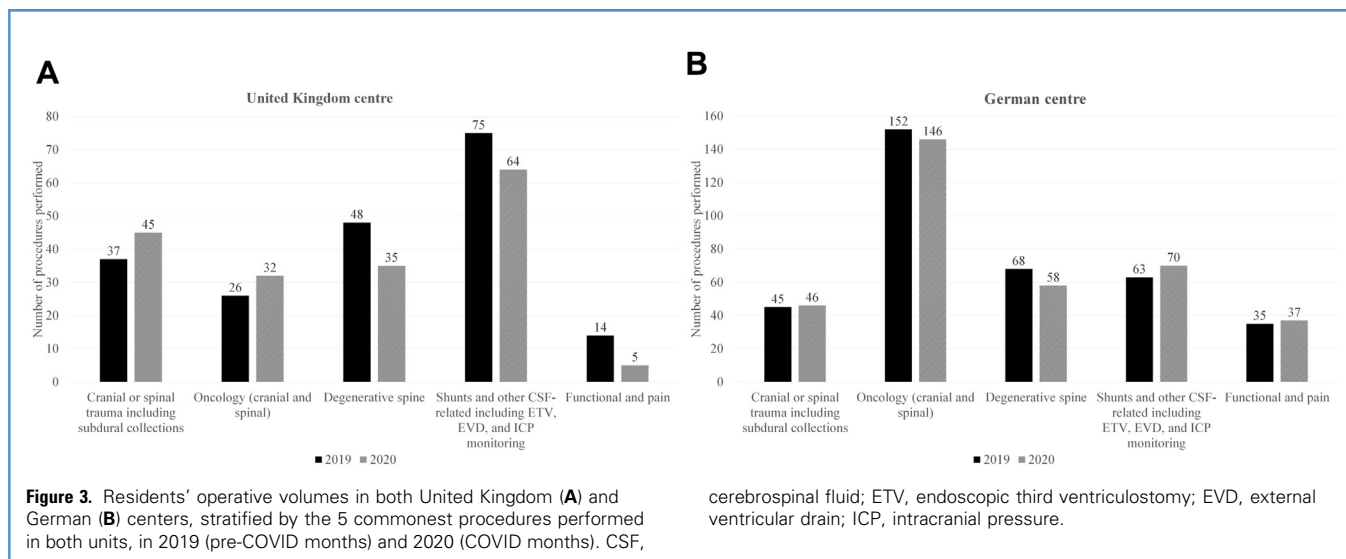
However, in Germany, residents' operative volumes when performing the 5 commonest procedure types were not significantly different between 2019 and 2020 (Mann-Whitney U; $Z = -0.316$; $P = 0.752$). German residents performed fewer degenerative spine procedures (14.7% decrease) and marginally fewer oncology procedures (3.95% decrease) in 2020 compared with 2019.

Consultants and Residents

Figure 4 shows the changes in the proportions of operations performed by residents and consultants, respectively, in each of the 5 commonest procedure types at both centers between 2019 and 2020.

Mann-Whitney U tests showed a significant difference in the proportion of operations performed by residents and consultants in both United Kingdom ($Z = -4.740$; $P < 0.001$) and German ($Z = -5.304$; $P < 0.001$) centers. In the United Kingdom center, of the 5 commonest procedures, residents performed a higher proportion of operations, comparing 2019 with 2020, in 4 of these categories (cranial/spinal trauma; oncology; degenerative spine; and CSF-related). The proportion of degenerative spine operations performed by residents nearly doubled from 2019 (17.7%) to 2020 (35.0%), whereas the proportion of cranial/spinal trauma, oncology, and CSF-related operations performed by residents increased from 2019 to 2020 by a similar percentage. In the German center, residents also performed a higher proportion of operations in 2020, compared with 2019, in 4 categories (oncology, degenerative spine, CSF-related, and functional/pain). The proportion of oncology operations performed by residents more than doubled from 2019 (30.3%) to 2020 (63.0%), and a similar case was evident for functional/pain procedures, with residents performing 27.0% of these cases in 2020 compared with 11.4% in 2019.





DISCUSSION

We report a multicenter comparison of European residents' operative experience during the COVID-19 pandemic to identify the impact on neurosurgical training as both countries grappled with the first wave of the pandemic.

Fewer Operations During the Pandemic

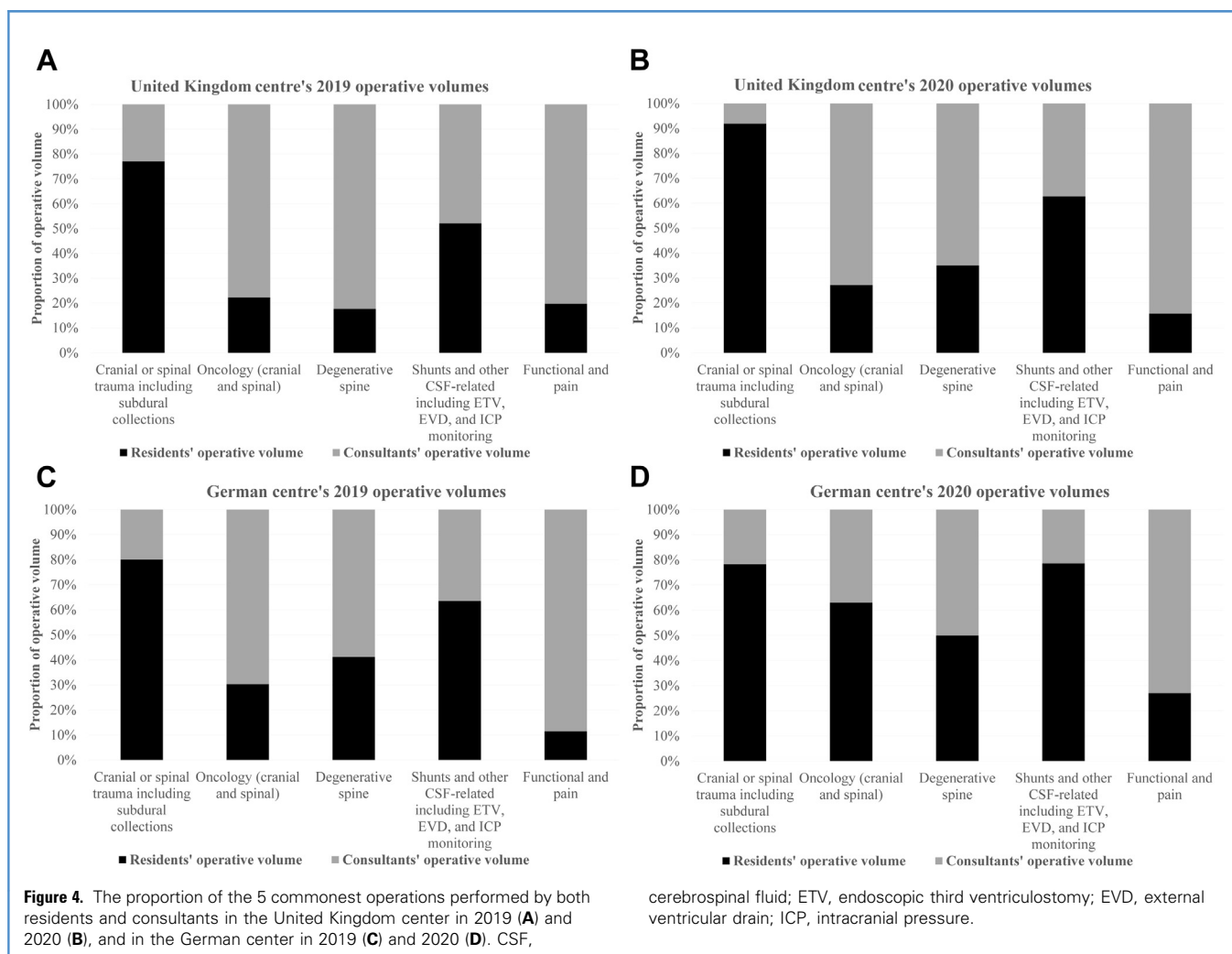
As expected, both centers reported a decrease in the overall volume of neurosurgical procedures performed during the COVID months compared with the pre-COVID months, with the United Kingdom center seeing a more drastic reduction in volume than the German center. This difference is likely to be the result of the nationwide cancellation of all elective operating in the United Kingdom,² as infections increased exponentially, to optimize resource use in the National Health Service. Lockdown measures in the United Kingdom³ strictly curtailed travel and social gatherings and road traffic volume decreased significantly³⁹; all these factors played a role in the decrease in trauma-related procedures during the COVID months. Fear of nosocomial transmission and appeals by the health service to the public to avoid accessing health care unless in an emergency⁴⁰ also kept patients away from hospitals, which may have delayed their presentation to neurosurgical services and, consequently, may have led to a decrease in the overall operative volume during the pandemic. Prioritization of procedures, according to national guidance,⁴ to operate only on those with life-threatening, limb-threatening, or vision-threatening illnesses also restricted the number of operations performed in the United Kingdom.

However, in Germany, the German Society of Neurosurgery (*Deutsche Gesellschaft für Neurochirurgie*) declared all intracranial and spinal tumors as nonelective and encouraged centers to continue performing these procedures during the pandemic.¹⁴ Although road traffic accidents decreased in Germany during the pandemic⁴¹ (similar to the United Kingdom), the German center is a supraregional trauma center, and one of Germany's biggest

hospitals, so trauma and emergency services continued to be triaged to this center even as surrounding hospitals reduced their capacity. A decrease in spinal operations was also seen in the German center albeit not as dramatic as in the United Kingdom center, which likely reflects the decreased focus on spinal surgery, in general, at the German center. The overall increase in functional procedures is biased by the rebound in these operations in May 2020, as elective services resumed in the German center after April 2020. Another factor for the largely constant number of procedures may be the COVID-associated reduction in the performance of the surrounding departments.

Residents' Operative Volumes—Increased or Decreased?

The total number of procedures performed by United Kingdom residents decreased during the COVID months unlike in the German center. As the departmental operative volume decreased, it was natural to expect a decrease in the residents' operative volumes as well. Furthermore, because only life-threatening, limb-threatening, or vision-threatening elective cases were treated, the severity of the disease being treated placed the onus of responsibility on consultants to perform the procedure instead of supervising a resident. Concerns about time taken for the operation, if performed by a junior resident, may have also played a role. On the other hand, the lower departmental workload offered ample time for residents to be trained in theater, even with fewer cases being performed during the COVID months. United Kingdom residents performed significantly fewer wound-related and spinal procedures during the COVID months. The decrease in operative volume in 2020 explains the lower rates of wound-related complications that needed a return to theater, whereas the volume of spinal procedures was greatly reduced during the study period. In particular, the paucity of spinal procedures performed by residents could negatively affect training progression, including success in obtaining consultant posts, especially



considering that new consultant posts in the United Kingdom have predominantly been focused on spinal surgery as a subspecialty. Across the United Kingdom, the number of trainees who have finished training and are awaiting a consultant post, despite the United Kingdom having the lowest consultants per population ratio in Europe,⁴² is estimated to be >50, which is in addition to the number of nontrainee residents who are vying for the same posts. Although this study did not differentiate between trainee and nontrainee residents, the decrease in trainee operating during the pandemic could also be influenced by an increase in nontrainee numbers.

German residents performed more operations during the COVID months compared with 2019. This finding may be the result of an increase in the number of more experienced trainees in 2020 at the German center compared with 2019. The relatively smaller decrease in operative volume at the German center during the pandemic may also reflect a variation in governmental guidance on continuing surgical activities¹⁴ and provision of critical care beds⁴³ compared with the United Kingdom. Although

German residents performed fewer spinal and oncology procedures in 2020, this was not statistically significant and further emphasizes the ability of the German center to maintain operative volumes despite the restrictions imposed by the pandemic. The problems seen in the United Kingdom with senior trainees awaiting a consultant post are not applicable in Germany.

Nevertheless, the proportion of operations performed by residents in both centers was higher during the COVID months. This finding reflects a large decrease in the operations performed by consultants, in areas such as functional/pain, pituitary, or pediatric procedures. In both centers, the commonest types of procedures performed by residents remained the same during the COVID months compared with the pre-COVID months. United Kingdom and German residents performed significantly higher proportions of degenerative spine and oncology procedures, respectively, in 2020, which may indicate a relatively lower complexity of procedures that were being performed.

Implications for Training

Similar results have been evident in other surgical specialties. Operative volume and residents' operative volume were reported to be lower in oral and maxillofacial surgery,^{44,45} orthopedic surgery,⁴⁶⁻⁴⁸ otolaryngology,^{49,50} cardiothoracic surgery,^{51,52} urology,⁵³⁻⁵⁵ ophthalmology,^{56,57} vascular surgery,⁵⁸ plastic surgery,^{59,60} and general surgery.^{61,62} Outside surgery, resident training was also hampered by the pandemic in radiology,^{63,64} endoscopy,⁶⁵ and anesthetics.⁶⁶

Across specialties, residents have reported increased rates of anxiety and depression,^{51,62,63,65,67} stress,⁶⁸ and burnout^{62,65,67} as well as fear of transmission^{49,61} during the pandemic, which have negatively affected trainee wellbeing when their training is already a concern. The lack of operative training may also require residents to extend their training to be able to meet minimum requirements for certification, which is of concern in United Kingdom neurosurgery especially, because the training program is already 8 years long. Furthermore, United Kingdom neurosurgical training programs are faced with a workforce crisis whereby prospects for a consultant post are limited for senior trainees and likely to worsen over the next few years. Lower operative numbers during training will impair trainees' competitiveness when applying for consultant posts.

Strategies to mitigate the impact of the pandemic on neurosurgical training and enhance resident education may include the use of high-fidelity surgical simulation, e-learning activities and webinars, virtual lectures, and operative video-based education.⁶⁹⁻⁷⁵ Whether these educational methods will be able to replace the dearth of operative training is unclear and will only become evident in time.

Strengths and Limitations

The strength of this study is based on its multicenter setting, across 2 countries, in 2 high-volume neurosurgical centers, which ensures the robustness of the data set. Limitations include the retrospective nature of the data collection and associated accuracy of the respective databases. The 2 centers compared in this study are high-volume centers within their own countries and operative volumes can be comparable to other high-volume centers within the United Kingdom and Germany, respectively. However, we acknowledge that our findings may not be directly applicable to centers elsewhere, especially those in resource-limited countries.

It is also not feasible to establish whether the lower operative volumes in 2020 will delay training for some, or all, residents and by how long, because this data set is not available in the public domain and will require longer follow-up over the next 5–10 years to determine the impact on residents' ability complete their training as a result of COVID on operative numbers. Further work involving multiple centers within each nation and incorporating trainee logbook data will serve to clarify whether this concern is legitimate.

CONCLUSIONS

The COVID-19 pandemic has significantly reduced the volume of operating by neurosurgical residents in the United Kingdom center, whereas residents in the German center performed more procedures compared with 2019, which may be related to variation in governmental guidance on maintaining surgical activities during the pandemic and provision of critical care beds. The impact on training, especially in the United Kingdom center, is likely to be long lasting because residents may struggle to achieve the necessary operative volumes required for certification and additional training time may be required.

This report remains the first of its kind to examine the effects of the first wave of the COVID-19 pandemic on training in a niche surgical subspecialty across 2 major European centers. We believe that our findings are a surrogate for reflecting on the way national health care policy, in a European setting, has affected the provision of non-COVID health care services, and its impact on future neurosurgeons.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Nithish Jayakumar: Methodology, Investigation, Formal analysis, Writing – original draft, Visualization. **Sönke Hellwig:** Methodology, Investigation, Formal analysis, Validation, Writing – review & editing. **Callum Allison:** Methodology, Investigation, Formal analysis, Validation, Writing – review & editing. **Walter Stummer:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Markus Holling:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Surash Surash:** Conceptualization, Methodology, Writing – review & editing, Supervision.

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