Current attitudes toward neuroanatomy: a comparative cross-sectional survey of neurosurgeons from the United Kingdom and around the world.

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Abstract

Objective: How attitudes towards neuroanatomy and preferences of studying resources vary by grade or geographical location amongst neurosurgeons is currently unknown. The impact of the COVID-19 pandemic on anatomy learning habits is also yet to be elucidated. In this study we explore these objectives, aiming to guide the development of future neurosurgeon-tailored anatomy education and resources.

Methods: This was a 2-stage, cross-sectional survey. A local pilot survey was followed by a structured 17-item questionnaire which was distributed to neurosurgical trainees and consultants via social media, newsletters, and mailing lists. Survey data was collected from 20/09/2021 to 20/12/2021. Grade and nationality differences in sentiment agreement and frequency were statistically compared.

Results: A total of 365 responses were received, with an overall survey response rate of 23.2% (25% U.K. response rate; 15.2-30.7% international response rate). Overall, neuroanatomy is highly regarded among most neurosurgeons and takes a central role in their professional identity. Yet, 69% of neurosurgeons stated they would like to spend more time learning neuroanatomy. Frequent prompts to study included perceived operative complexity (90%), lack of familiarity (92%) and teaching (89%) whereas factors such as operative responsibility and patient risk significantly varied by grade. Grade-dependent obstacles limiting neuroanatomy learning included financial barriers and lack of motivation, with personal commitments barriers significantly varying across geographical location. Surgical relevance (89%), accessibility (90%) and image quality (90%) were important factors when selecting anatomy resources, with cost and up-to-datedness being significantly more important to trainees than consultants. Online image searches, case-based and multidisciplinary discussions were the most frequently used learning method outside of theater. Finally, the COVID-19 pandemic saw a shift towards online or virtual resources, whilst also causing a greater impact on neuroanatomy learning amongst trainees and U.K.-based neurosurgeons.

Conclusions: Attitudes towards neuroanatomy and preferences of resources vary by grade and location of neurosurgeons. Although neuroanatomy is a highly regarded, barriers exist which impede those who wish to pursue further neuroanatomy learning. Neurosurgical training programs should tailor anatomy education according to the seniority and background of their residents. Furthermore, resources that are surgically relevant, accessible and of high image-quality or more likely to be better utilized. Remedial learning after the COVID-19 pandemic must account for persistent gaps in teaching, utilizing cadaveric and operative exposure which cannot be replicated virtually.

Introduction:

The pioneering neurosurgeon and educator Dr. Albert L. Rhoton once stated: “microsurgical neuroanatomy [is] the science most fundamental to neurosurgery”.[1] Indeed, a detailed understanding of surgical neuroanatomy lies at the heart of safe operative practice,[2] and neuroanatomy remains a core component of neurosurgical curricula both in the United Kingdom (U.K.) and worldwide.[3–5] Despite this, formal neuroanatomy education varies widely among neurosurgical training programs. With a busy clinical schedule and lacking formal direction, for many residents studying neuroanatomy is often guided by the day's theatre list or to pass board examinations, rather than a structured approach which allows for more in-depth learning. As emphasised within the surgical literature, "anatomy must not be taught at the operating table through the window of the operation. It should be studied and understood before the trainee gets to the operating table".[6]

While there has been a call to increase postgraduate anatomy teaching in various surgical subspecialties,[7–11] it is unclear if these sentiments are widely held within neurosurgery.

There exists a wide range of neuroanatomy resources to assist neurosurgeons in their learning.[12] While printed or online neuroanatomy atlases are widely used,[13] it is commonplace for trainees to supplement their study at their own expense with other didactic teaching courses and in-person or computer-based resources.[10,13,14] This may reflect a lack of organized instruction, or an intrinsic difficulty in mastering neuroanatomy.[10] Role- and generational-related differences within and between neurosurgeons and residents may exacerbate this problem further. Different program structures and availability of local resources may influence the learning mindset of neurosurgeons-in-training.[15–17]

Of recent concern is the impact of the COVID-19 pandemic on postgraduate neuroanatomical training. Global restriction of elective surgeries,[18–21] increased use of telemedicine,[22] and redeployment of neurosurgical trainees to departments under greater strain have led to decreased clinical and operative exposure.[19,23,24] Face-to-face instruction, particularly of microsurgical and cadaveric-based teaching, has also been severely impacted.[25–30] Consequently, many neurosurgeons turned to webinars and other virtual methods during this period as a learning replacement.[23,31] However online teaching may not compensate for learning opportunities gained from dissection or surgical experience.[26] As such, it is unclear what the precise impact of the pandemic has been on neuroanatomical training. Without this information, it is difficult to propose appropriate methods for remediation.

The purpose of this study is to describe neurosurgeons' views on learning neuroanatomy using the results of a two-stage cross-sectional, comparative survey. We test whether these attitudes differ by seniority, and between U.K. and international cohorts. Furthermore, we investigate the incentives that encourage and the barriers that impede anatomy learning, as well as the study modalities used and how these may have been affected due to the COVID-19 pandemic. Collectively, these findings would help guide recommendations for neurosurgical training programs and help tailor future anatomy teaching resources.

Methods:

Reporting guidelines

The Checklist for Reporting Results of Internet E-Survey (CHERRIES) from the EQUATOR library of guidelines were adhered to throughout this study.[32]

Ethics

A low risk, ethics waiver was obtained from the academic institutional review board for this study (June 30th, 2021). All data collected were non-sensitive and non-identifiable.

Survey design and distribution

This was a two-stage, comparative cross-sectional study incorporating: (i) a qualitative pilot survey to identify major topics which were systematically investigated using (ii) a quantitative structured survey.

In the pilot survey, neurosurgeons ranging between intern to consultant grades within our institution were interviewed using a predefined set of open-ended questions (**Supplementary Methods**). Answers recorded from this pilot group were used to produce a framework of pertinent topics related to neuroanatomy for the final, 17-item structured survey (**Supplementary Methods**). These topics included: (1) attitudes towards neuroanatomy, specifically how much participants valued the subject and its importance in the neurosurgical identity; (2) incentives and barriers to studying; (3) anatomy study habits and resources and (4) the impact of the COVID-19 pandemic on neuroanatomy learning.

Neurosurgical consultants and trainees were targeted in this study. Non-neurosurgical specialties were excluded. The link to the study was shared via various neurosurgical societies' newsletters and electronic mailing lists. Suitable societies were identified and contacted via email through the World Federation of Neurosurgical Societies webpage (www.wfns.org*).* The survey was also shared via social media platforms, including *Twitter* and *Facebook*.

To increase our response rate, a reminder email was sent after 1 week to neurosurgical societies who did not respond to the original email and after 3 weeks as follow-up posts on social media. The survey was hosted on the Qualtrics XM platform (www.qualtrics.com*).* To prevent duplicate results, a web cookie-based duplicate protection feature was implemented. The chance to be entered into a draw for a monetary voucher was offered upon survey completion. All data were collected in a 3-month period from September to December 2021. A complete response was one in which a full themed section of the survey was answered, allowing for appropriate statistical tests to be conducted.

Statistical analysis

Participants were initially classified into consultants and residents. Residents were then subdivided according to the number of postgraduate years (PGY) of neurosurgical experience they completed: 8+ (fellow), 5–7 (senior registrar / resident), 2–4 (junior registrar / resident), and 1 (intern). These subcategories were defined according to the natural progression in the British system of training and matched for international trainees based on the years of experience. Consultants were subdivided into junior and senior roles depending on whether they had ≥ 5 years of attending experience (by which point they would be revalidated and in a substantive post).

Sentiment-based or attitude-related questions were structured using a 5-point Likert scale (1 = strongly disagree / extremely unlikely to 5 = strongly agree / extremely likely). Answers from these were compared and aggregated with a second ‘opposing’ statement to assess response fidelity. All Likert-type responses were converted to continuous data.[33]

The Shapiro-Wilk test and inspection of the data histogram were used to assess for data normality. Data heteroscedasticity was assessed using Bartlett’s test of homoscedasticity. If parametric data, an ANOVA and post-hoc independent samples t-tests were used to investigate differences; otherwise, a Kruskal-Wallis and post-hoc Dunn’s tests were performed. For non-parametric data with only two categories, a Mann-Whitney U test was performed directly. Frequency data were tested using a χ^2 or Fisher’s-Exact test depending on the minimum number of participants. All post-hoc tests were multiple comparison-corrected using the Holm-Bonferroni method. A p-value of < 0.05 was considered significant throughout. All statistical analyses were carried out in Python (v = 3.8.1) using *scipy* and *statsmodels* libraries. For brevity, the group average and p-values are reported in the article, with the full omnibus test and significant post-hoc statistics reported in detail in the **Supplementary Results**. To compare ordered categorical data, an ordinal logistic regression model was fitted.

Results:

Participants

A total of 365 survey responses from 32 countries were received, 267 of which were complete (Table 1, Fig. 1, **Supplementary Methods**). Although surgeon grade significantly differed by nationality (χ^2=19.07, p = 0.002), when exclusively comparing the proportion of junior and senior consultants, no significant difference was found. Similarly, there was no significant difference when comparing postgraduate years of experience against nationality among trainees.

Table 1
Survey responses by grade and nationality

			U.K.	**International**	**p-value**
Received responses			172	193	-
Total completed responses			121	146	-
Grade	Consultant / Attending (%)	> 5 years in post	38 (31.4)	51 (34.9)	χ^2, p = 0.002
		< 5 years in post	5 (4.1)	20 (13.7)	
	Registrar / Resident (%)	PGY 8+ (fellow)	17 (14.0)	11 (7.5)	
		PGY 5–7 (senior)	10 (8.3)	21 (14.4)	
		PGY 2–4 (junior)	40 (33.1)	25 (17.1)	
	FY / Intern (%)	PGY 1	11 (9.1)	18 (12.3)	
Median postgraduate years for trainee neurosurgeons [IQR]			4 [2–6]	4 [2–6]	Mann Whitney, p = 0.45

U.K. = United Kingdom; FY = foundation year; PGY = post-graduate year; IQR = interquartile range.

Geographical distribution and response rate

Based on total responses received, the response rate was calculated for U.K. and international cohorts where workforce data was available. The U.K. response rate was 25% (172 of an estimated neurosurgical workforce of 688)[34]. Outside of the U.K., the response rate varied: as high as 30.7% in countries such as Belgium (50/163)[35] but lower in others, where only a few responded (**Supplementary Methods**).

Attitudes towards neuroanatomy

Figure 2 illustrates sentiments related to studying neuroanatomy. The majority of neurosurgeons (62%) identified that they ought to be an expert in neuroanatomy to be a neurosurgeon and agreed that studying the subject was relevant to their day-to-day clinical role (55%). While many neurosurgeons indicated that studying neuroanatomy was enjoyable or were neutral towards it, a notable proportion (23%) disagreed. For these sentiment-based statements, there were no significant differences in the level of agreement when respondent grade or nationality were compared. In contrast, the degree to which neurosurgeons agreed that they 'would like to spend more time learning neuroanatomy' was significantly associated with grade but not nationality (**Supplementary Results**). Significant differences were found between the senior consultant group who had the lowest mean level of agreement (3.26) as compared to PGY8+ (3.82, p = 0.02) with trending differences when compared to PGY2-4 (3.44, p = 0.10), PGY5-7 (3.76, p = 0.09).

Incentives and barriers to studying neuroanatomy

Factors promoting or hindering neuroanatomy learning were divided into 4 categories, namely, those related to: (i) the operation; (ii) choice of anatomy resource; (iii) personal factors; and (iv) external factors.

A lack of familiarity with the procedure, its perceived complexity, the role or responsibility of the surgeon and patient risk were frequently rated across the cohort as factors prompting neuroanatomy revision (71–92%), in contrast to operative length (Fig. 3A). Operative length and the surgeon's operative responsibility significantly differed by grade but not by nationality (**Supplementary Results**). Length of procedure was a more likely prompt for studying in the PGY8 + group compared to senior consultants (mean likelihood = 3.46 vs. 2.71, p = 0.05) [Figure 3B]. Similarly, the PGY8 + group rated the risks to the patient (4.50) as a likelier incentive for studying, trending more than both junior consultants (3.78, p = 0.06) and senior consultants (3.95, p = 0.09). The role and responsibility of the participant surgeon in the operation was again rated higher among junior registrars compared to senior consultants (4.34 vs. 3.8, p = 0.02).

When choosing an anatomy resource, surgical relevance, accessibility, and image quality were widely regarded (~ 90%) as very or extremely important (Fig. 3C). In contrast, the cost, how up-to-date the resource was, and whether there existed a means of assessment carried more divergent views. Significant differences were found between neurosurgical grades for these factors on omnibus tests (**Supplementary Results**). PGY8 + trainees placed more emphasis on cost and having an up-to-date resource (mean importance: cost = 4.17; up-to-date = 4.30) than senior consultants (cost = 3.43, p = 0.02; up-to-date = 3.72, p = 0.05) [Figure 3D]. When comparing nationalities, being up-to-date (4.06) and assessment ability (3.05) were appraised significantly more by international neurosurgeons as compared to those in the U.K. (up-to-date = 3.71, p < 0.01; assessment = 2.66, p = 0.01).

Contrary to the variable importance placed on resource cost, individual financial barriers were thought of as an obstacle to studying among many neurosurgeons (81%) [Figure 4A]. This specifically varied by grade (**Supplementary Results**), with PGY8 + and PGY5-7 most likely to state this as a barrier to studying (mean likelihood = 3.65 and 3.58 respectively), significantly more than senior consultants (2.72, p = 0.03 and 0.05 respectively) [Figure 4B]. The PGY8 + group were also more likely to state a lack of motivation as a barrier to studying (mean likelihood = 3.13), significantly more than the PGY5-7 group (2.04, p = 0.04) and trending more than senior consultants (2.28, p = 0.06). Personal commitments as a barrier did not vary by grade but did significantly vary between nationalities, with U.K. neurosurgeons stating a significantly higher likelihood (3.90) of this limiting their learning as compared to their international counterparts (3.54, p = 0.02).

Both teaching (89%) and examinations (79%) were considered to have a high degree of likelihood as an incentive for studying neuroanatomy (Fig. 4C). While teaching as a factor did not vary by grade, examinations and pressure from colleagues did significantly vary (**Supplementary Results**). Examinations were a likely motivator for interns (mean likelihood = 4.67) and PGY2-4 (4.29), both significantly more than senior consultants (3.69, $p = 0.001$ and $p = 0.04$ respectively) [Figure 4D]. No external factors were associated with differences in nationality.

Neuroanatomy studying habits and resources

The fraction of operations in which the neuroanatomy was revised for, significantly varied by grade (χ^2 = 63, $p < 0.0001$) but not by nationality. Assuming an approximate fraction of 0.75 and 0.25 for more than and less than half respectively (Fig. 5A), PGY8 + trainees were found to revise the most, for approximately 62% of their operations, as compared to PGY3-4 residents who revised for 46% (Fig. 5B). All training grades revised for a significantly greater number of cases compared to senior consultants who only revised the neuroanatomy for 35% (Dunn's test, $p = < 0.05$ to < 0.001). This significance persisted when treating the data as categorical (**Supplementary Results**).

Figure 6 describes which anatomy resources were used, and how frequently in the 12 months prior to the survey. Across the whole cohort (Fig. 6A), 84% of respondents stated they had only used cadaveric-based resources once or never in that period whereas 75% stated they used didactic methods between once a month to once a year. In contrast, the resources most frequently usedi.e., once a week or more, were case-based discussions [CBD] (56%), online image searching (45%) and multidisciplinary team meetings (44%), other than operations themselves,

Following ordinal logistic regression, significant differences were found between trainees and consultants, and between U.K. and international neurosurgeons in frequency of resource use (Fig. 6B). Trainees utilized didactic learning, textbooks, social media, CBD, e-learning, and web-based image searches significantly more frequently than consultants after controlling for nationality (**Supplementary Results**). Similarly, international neurosurgeons were found to use didactic methods, textbooks, CBD and e-learning significantly more frequently than their British counterparts.

Whereas the institutional availability of resources between the U.K. and abroad was not significantly differen, neurosurgeons from the U.K. used textbooks significantly less (χ^2 = 15, $p < 0.001$) compared to their international counterparts (Fig. 6C).

Impact of COVID-19 on neuroanatomy learning

87% of participants agreed there were fewer operative opportunities because of the COVID-19 pandemic (Fig. 7A). 67% felt that they had reduced motivation to study due to poor physical or mental health. International surgeons (mean agreement = 4.05) stated they agreed with this latter statement more than British surgeons (3.75, $p = 0.002$) [Figure 7B]. Surprisingly, when asked if the COVID-19 pandemic reduced the amount or quality of their neuroanatomy learning, only 30% of the survey cohort agreed, although this varied significantly by both grade and nationality (**Supplementary Results**). PGY2-4's (mean agreement = 3.15) felt significantly more affected than senior consultants (2.41, $p = 0.005$), and U.K. neurosurgeons felt a greater impact of COVID-19 (2.87) as compared to their international counterparts (2.56, $p = 0.03$).

When asked how their use of anatomy resources changed during the pandemic, online learning (including the use of online atlases) [83%], webinars (79%) and image-based searches (such as through Pinterest® and Google® Images) [74%] increased most across respondents. Cadaveric (-87%) and in-person didactic teaching (-85%) had the largest negative change.

Discussion:

To the best of our knowledge, this is the first international survey exploring attitudes towards neuroanatomy amongst neurosurgeons. While previous work has explored issues related to anatomy education among surgical trainees,[7–11] and the impact of COVID-19 on surgical training,[25,27–30,36,37] there has been limited investigation into the value of neuroanatomy and how it is studied. We found that neuroanatomy is highly regarded among most neurosurgeons and takes a central role in their professional identity. Common prompts to study neuroanatomy included perceived operative complexity, lack of procedure familiarity and teaching. Several grade- or nationality-dependent obstacles were identified that limited neuroanatomy learning including finances, personal commitments, and motivation. Online image searches and CBD were the most frequently used opportunities for learning outside of theatre, while surgical relevance, accessibility and image quality were considered most important when choosing a resource. The COVID-19 pandemic significantly impacted operative exposure and motivation to study neuroanatomy and led to a shift towards online resource use. This impact was also mediated by neurosurgical grade and nationality.

Most respondents agreed that expertise in neuroanatomy was important to being a neurosurgeon, and over half stated that studying it was useful in everyday clinical work. A strong evidence base exists within and outside of neurosurgery demonstrating a correlation between clinical performance and objective assessment of surgeons' anatomical proficiency.[38,39] Despite anatomy expertise representing an intrinsic aspect of the neurosurgical professional identity,[40–42] around a quarter of respondents stated they did not enjoy studying neuroanatomy and a smaller fraction believed that studying neuroanatomy was not relevant. It is unclear whether carrying these sentiments may impact learning and clinical performance.

Regardless of their valence toward the subject, most neurosurgeons stated they wanted to spend more time learning neuroanatomy. This was significantly greater for trainees rather than senior consultants, and corresponded with the difference in the proportion of operations for which the operative anatomy was revised. Both these examples illustrate that the need for continuing anatomy education among consultants may be less. This could be related to their increased competency and more experience with an increasingly specific set of operations.[43,44] Given their technical ability and logistical efficiency,[43,44] it is somewhat unsurprising that consultants perceived the degree of operative responsibility, operative patient risks and operative duration as less of a study prompt as compared to juniors. In contrast, lack of familiarity regarding the procedure and its perceived complexity remained important factors among all neurosurgeons regardless of grade or nationality.

Barriers preventing neurosurgeons from studying neuroanatomy differed significantly by grade and nationality. Financial obstacles were a greater barrier to senior residents and fellows compared with senior consultants. Senior residents may be faced with growing professional and personal expenses which are not met by the gradually increasing scale of remuneration as training progresses.[45] Concurrently, senior residents also rated cost as being most important when choosing a resource.

Universally, teaching was a significant external factor in encouraging neuroanatomy learning among all grades, in line with previous evidence which confirmed that neurosurgeons are typically active within the teaching faculty at both under- and postgraduate level.[46–48] In comparison, the stressors of examinations and peer pressure as a motivation for studying were felt particularly by interns and junior registrars. Consultants are generally unencumbered with examinations and likely feel less pressure within the departmental hierarchy as compared to trainees.[49,50] We would expect consultants to be less provoked by these external stresses, and accordingly, we demonstrate less likelihood of these factors in promoting anatomical learning in this group.

Neurosurgeons utilize a diverse range of resources to learn neuroanatomy. Outside of operations, those used most frequently included case-based and multidisciplinary discussions, and online search mediums. That these resources are highly accessible, surgically relevant and facilitate viewing of high-quality images, tallies with our findings that the same factors were declared as most important in the survey. Textbooks, e-learning and social media were regularly used, more so among trainees than consultants. The rise in use of social media among neurosurgical trainees specifically, has previously been well documented.[51,52] International respondents chose resources which were more up-to-date and incorporated a means of assessment. Despite the availability of resources at their institutions being similar to the U.K, they also appeared to utilize certain resources with greater frequency. These differences based on nationality may reflect different training systems with emphasis on certain learning regimens or cultural preferences.[53]

In line with previous literature,[18–21,25,30,36,37] our survey collectively highlighted fewer operative opportunities as a result of COVID-19. Nevertheless, 50% of respondents disagreed that their neuroanatomy learning was affected by COVID-19. Whereas junior and U.K.-based trainees reported being most impacted in terms of quantity or quality of learning, international neurosurgeons stated they had reduced motivation to learn due to poor health during the pandemic. These differences could represent the variable rates of infection among healthcare staff between countries, and differing levels of anatomy learning opportunities available at institutional or regional levels.[54–58] Despite the positive response to online teaching during the pandemic, the inability to replicate a cadaveric or operative experience as well as technical issues and webinar overload[59] means that virtual neuroanatomy learning may not suffice as a complete learning method.

We acknowledge several limitations in this work. Although responses ranged between 15–31% for certain countries, in others, only a handful of neurosurgeons answered the survey. Several methods were attempted to increase the response rate, including a two-stage mailing process, three-month survey window and promotion across social media platforms. Despite this, the final rate was below epidemiological best practice, and risks a selection bias. Furthermore, comparing all countries individually would require considerably more statistical power. We have attempted to mitigate this by a careful statistical analysis which was sensitive to factors thought to impact upon the variance, namely grade of surgeon and dichotomous location. We note, separately, that high response rates are often difficult to obtain in surveys targeted toward surgeons[60,61] and our rate was well above similar work in both surgical[62–65] and neurosurgical cohorts.[66] We also acknowledge the discrepancy between response and completion rate, with many surgeons failing to fully answer the survey. This would need to be considered in future survey designs.

Despite these limitations, we feel this survey provides a robust baseline estimate of neurosurgical attitudes and motivations toward studying neuroanatomy that is comprehensive across both staff and training neurosurgeons, in the absence of other postgraduate data. We emphasize the global reach of the survey with responses from six continents, and from both developing and developed nations. Finally, we highlight the breadth of topics covered and the two-stage framework in accumulating this information.

Conclusions:

Neuroanatomy is highly valued among neurosurgeons. It is important to recognize differences in attitudes towards neuroanatomy, and that a one-size-fits-all approach towards postgraduate teaching may be ineffective. We recommend that: (i) strategies to encourage neuroanatomy engagement should be tailored to reflect differences in grade and region, and aim to reduce barriers towards studying neuroanatomy, for example, financial costs and other commitments; (ii) future resources will be better received if they are surgically relevant, contain high quality images, and are easily accessible (the neuroanatomy section of *The Neurosurgical Atlas©* represents one such example).[67] Remedial learning after the COVID-19 pandemic must account for persistent gaps in teaching, such as cadaveric and operative exposure which cannot be replicated virtually. Training programs and educational institutions should tailor their neuroanatomy teaching accordingly whilst keeping these factors in mind.

Declarations

Disclosures:

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Conflicts of interest:

The authors declare no competing financial or non-financial interests.

Abbreviations

PGY Postgraduate year

CBD Case-based discussion

MDT Multi-disciplinary team meeting

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Figures

Figure 1

Geographical distribution of completed survey responses.

Size of the red circles corresponds to the number of responses from that country (see legend). Map underlay adapted and modified from OpenStreetMap ® under a CC BY-SA-2.0 license. Countries with at least 40 complete responses (U.K., Belgium and Romania) are labelled.

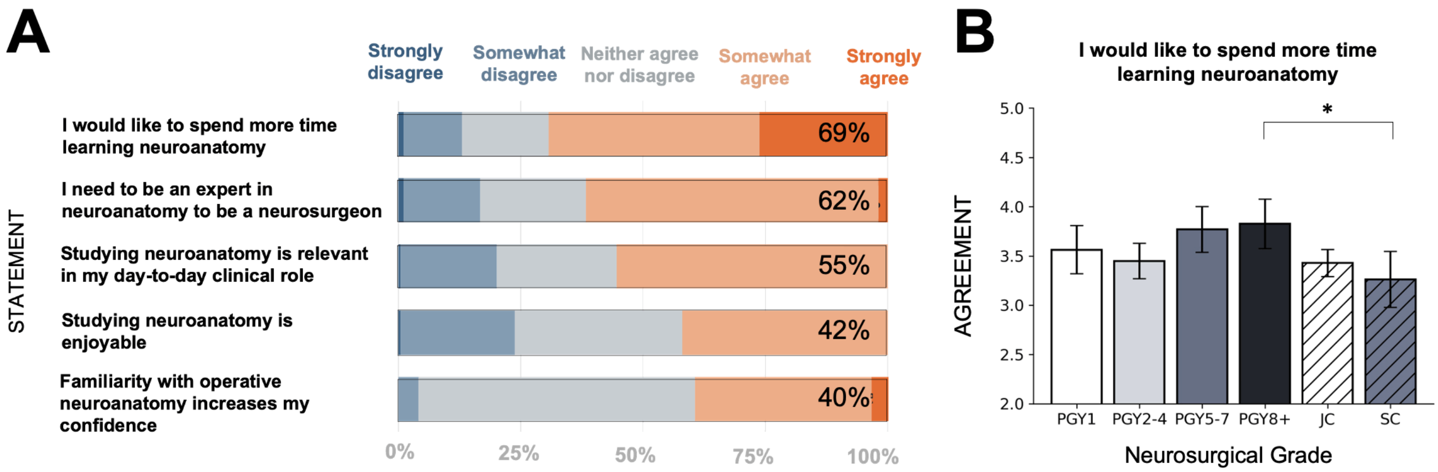

Figure 2

Attitudes toward neuroanatomy. Statements are presented on the left of the stacked bar chart (A). Percentages within the bars represent the number of surgeons who 'somewhat' or 'strongly' agreed to the statement. Neurosurgeons varied by grade regarding the statement that they would like to spend more time learning neuroanatomy (B). Error bars represent 95% confidence intervals on the subgroup mean. (PGY = postgraduate year; JC = junior consultant; SC = senior consultant; *p<0.05).

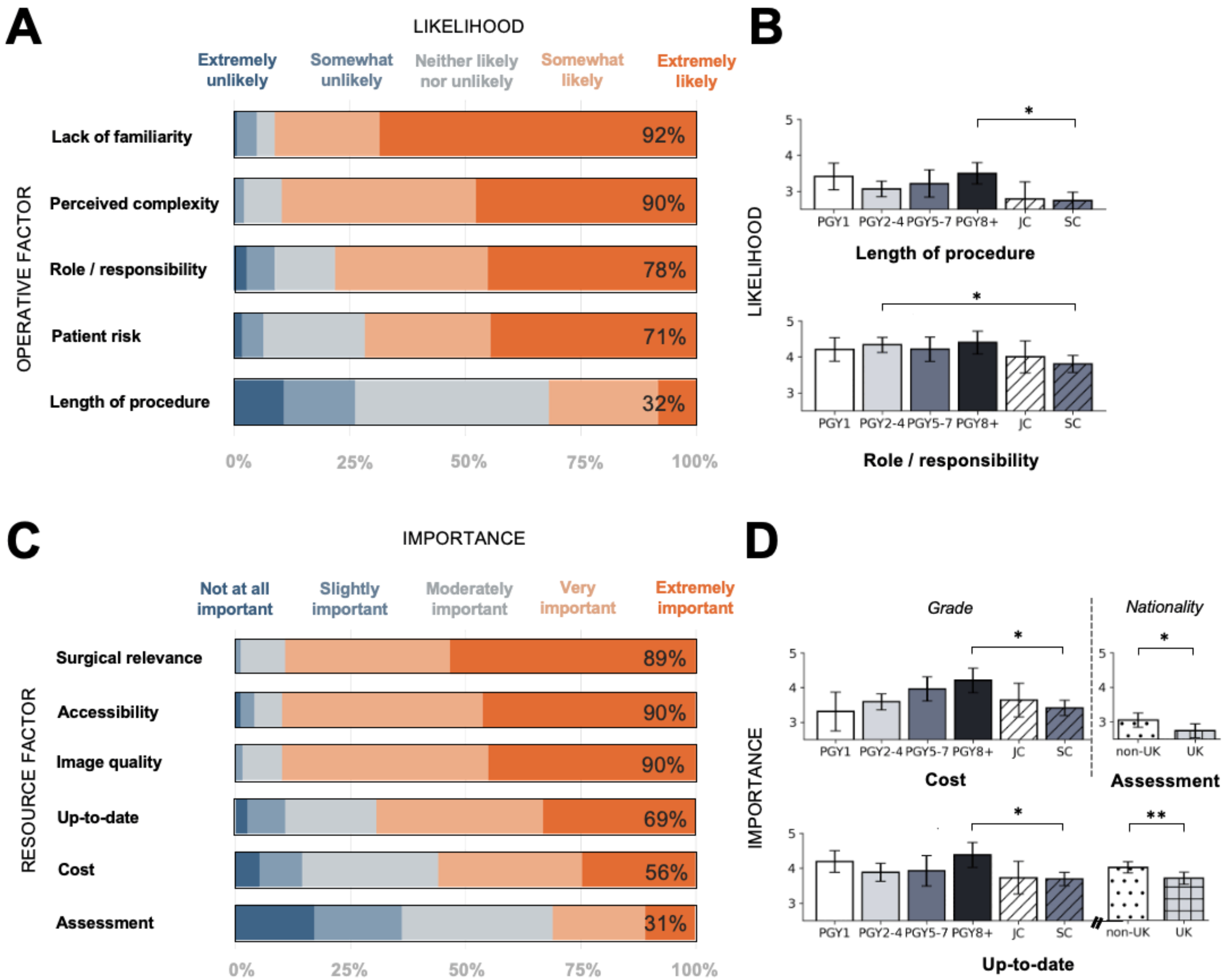

Figure 3

Incentives and barriers to studying neuroanatomy: operative (A,B) and resource factors (C,D). Factors are presented on the left of the stacked bar charts (A, C). Percentages within the bar represent the number of surgeons who felt that the factor was 'somewhat' or 'extremely' likely in prompting neuroanatomy study (A) or 'very' or 'extremely' important when choosing a resource (C). Error bars represent 95% confidence intervals on the subgroup mean. (PGY = postgraduate year; JC = junior consultant; SC = senior consultant; *p<0.05, **p<0.01).

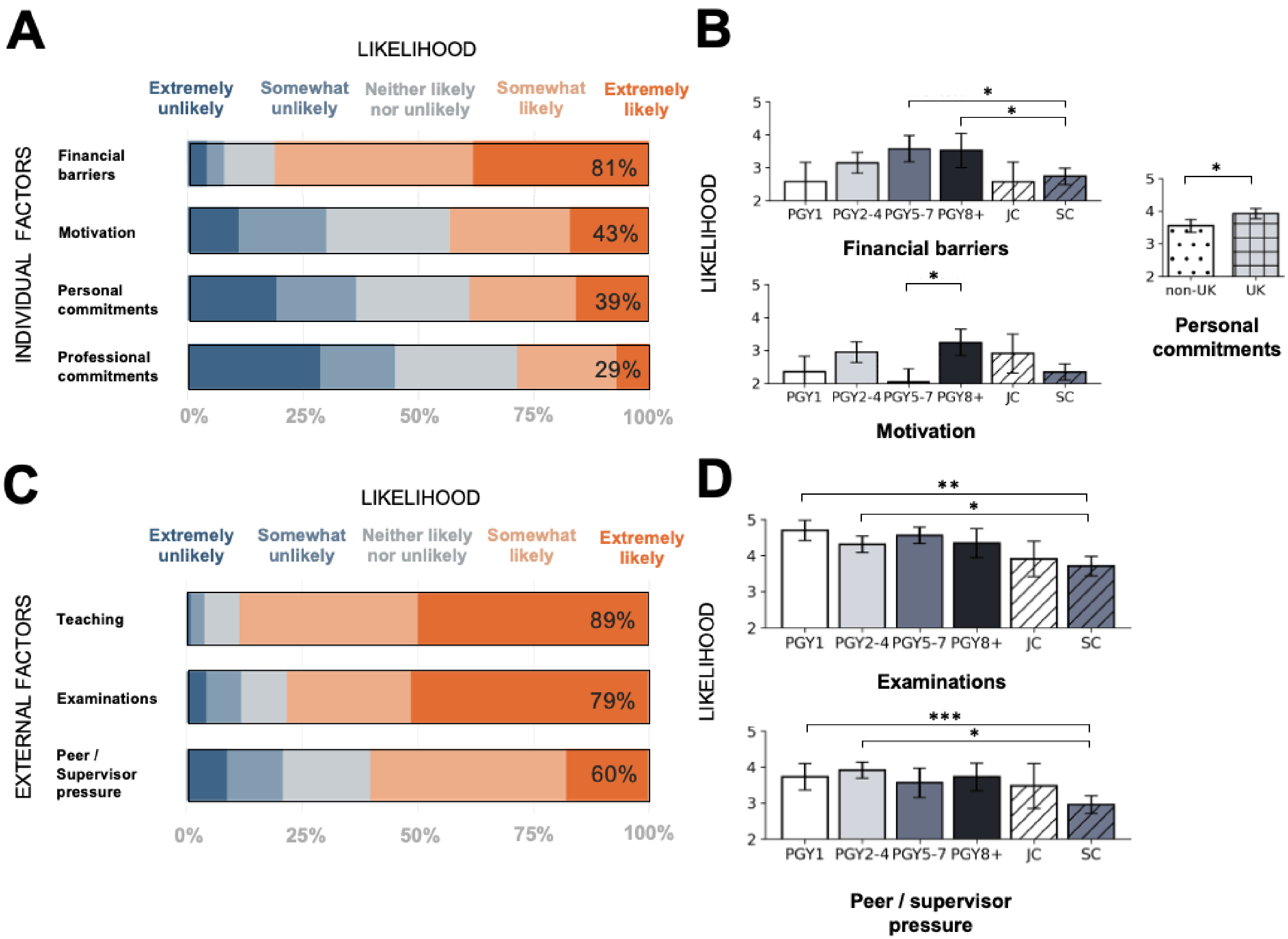

Figure 4

Incentives and barriers to studying neuroanatomy: individual (A,B) and external factors (C,D). Factors are presented on the left of the stacked bar charts (A, C). Percentages within the bars are representative of the number of surgeons who felt that the factor was 'somewhat' or 'extremely' likely to prevent them from studying (A) or 'very' or 'extremely' important in prompting study (C). Error bars represent 95% confidence intervals on the subgroup mean. (PGY = postgraduate year; JC = junior consultant; SC = senior consultant; *p<0.05, **p<0.01)

A

Fraction of operations revised for (%)	
All	14 (5.4)
More than half	61 (23.4)
Half	61 (23.4)
Less than half	110 (42.2)
None	11 (4.2)

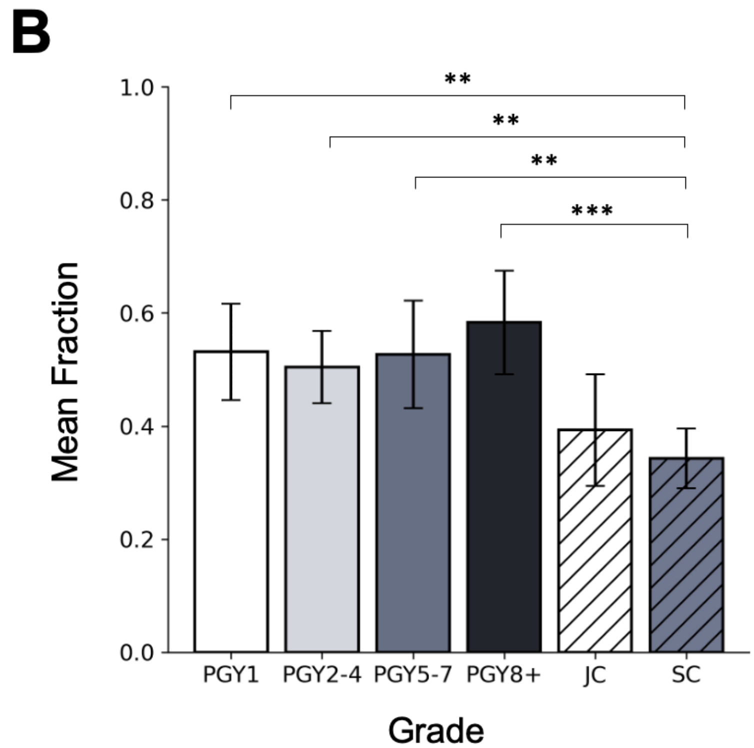

Figure 5

Number of operations the requisite neuroanatomy was revised for: across the whole survey cohort (A) and when subdivided by grade (B). Error bars represent 95% confidence intervals on the subgroup mean. (PGY = postgraduate year; JC = junior consultant; SC = senior consultant; *p<0.05, **p<0.01, ***p<0.001).

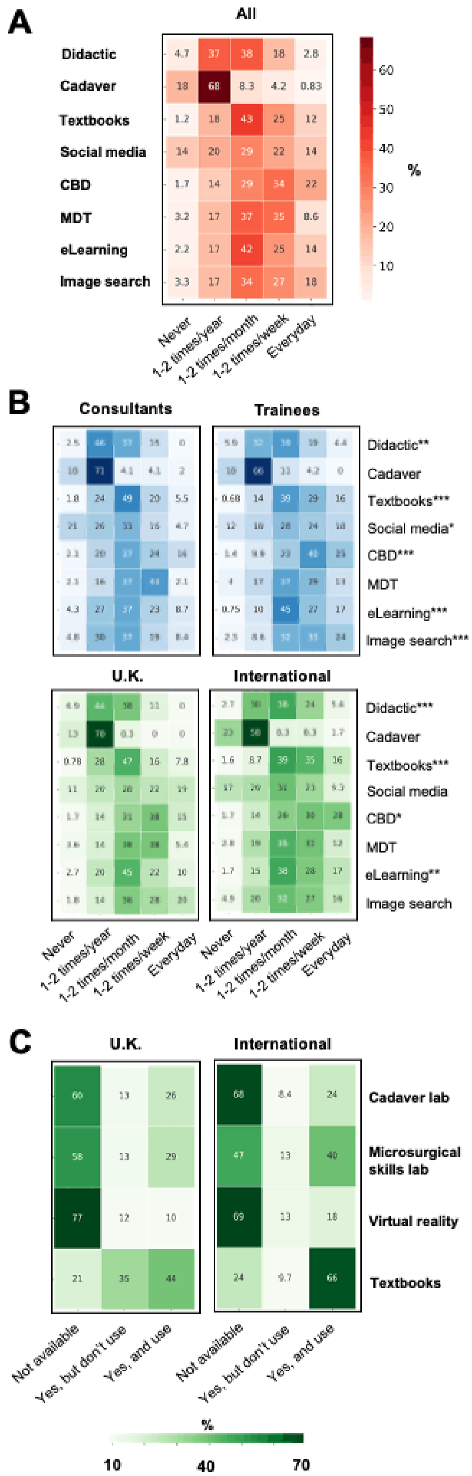

Figure 6

Heatmap of anatomy resource usage in the 12-month period prior to taking the survey for the whole cohort (A), when divided by grade and nationality (B) and by institutional availability (C). (CBD = case-based discussion, including morning handovers; MDT = multidisciplinary team meeting, *p<0.05, **p<0.01, ***p<0.001).

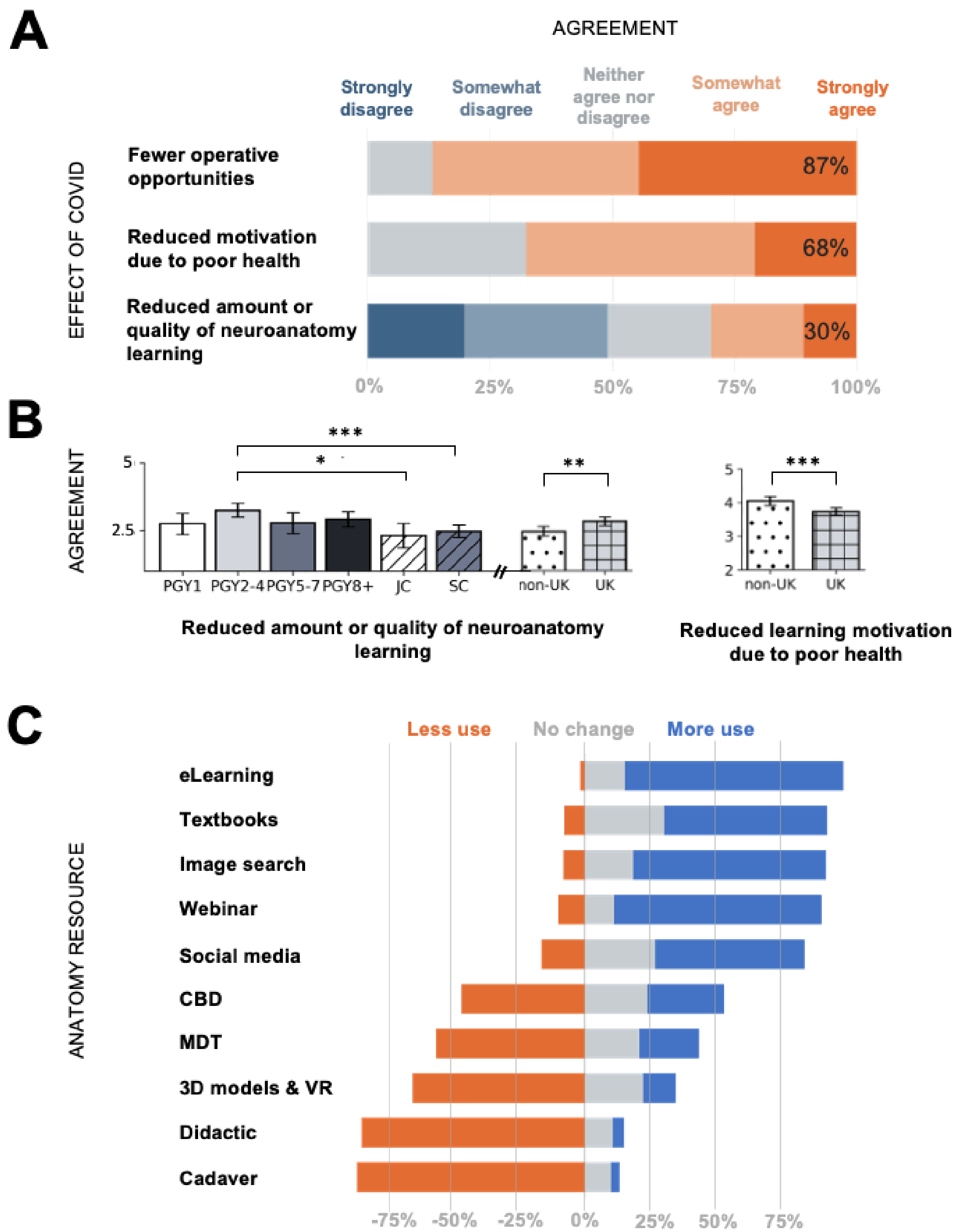

Figure 7

Impact of the COVID-19 pandemic on neuroanatomy learning: (A,B) and use of resources (C).

Percentages within the bars are representative of the number of surgeons who somewhat or strongly agreed to the statement. (PGY = postgraduate year; JC = junior consultant; SC = senior consultant; CBD = case-based discussion; MDT = multidisciplinary team meeting; VR = virtual reality; *p<0.05, **p<0.01, ***p<0.001).

Supplementary Files

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- SupplementalFile.docx