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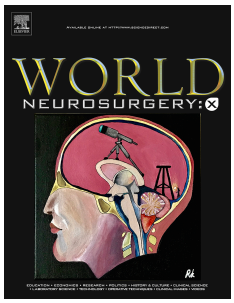

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INTRODUCTION

Health system strengthening for neurosurgery has continued to gain prominence in policy discussions and scientific literature as the global neurosurgical community strives to build capacity and improve timely access to safe and affordable neurosurgical care.[1-4] The advent of the Lancet Commission "Global Surgery 2030" report and the 2015 World Health Assembly Resolution 68.15 on emergency and essential surgery catalyzed investigations into the neurosurgical burden of disease and global workforce deficits.[1,2,4-9] For instance, the current neurosurgical workforce is estimated to be around 50,000 neurosurgeons worldwide, but due to the burden of neurosurgical disease and unequal distribution of provider densities,[10] many low-and middle-income countries (LMICs) have a neurosurgical capacity of only 1-10% of the minimum recommended neurosurgeon ratio per population, that is 0.01 to 0.1 neurosurgeons per 100,000 population.[11-13] Over 23,000 more neurosurgeons are needed in LMICs to address the 5 million essential neurosurgical cases that go untreated each year.[6] These untreated cases predominantly include traumatic brain injury, but also incorporate stroke, hydrocephalus, tumors, epilepsy, and infection.[4-9] To address these issues, a systems-level approach is required.

The components of a health system, as outlined by the World Health Organization, include health service delivery, workforce, health information systems, access to essential medicines, financing, and leadership/governance.[14] Within these six-building blocks, there are many barriers that must be addressed in order to improve care provision. To expand the neurosurgical workforce, significant planning and investment are required to provide sufficient resources and methods of training for young neurosurgeons. However, variation in training needs across countries is not well understood. Elucidating the service delivery challenges for neurosurgical providers can inform future resource development and investments in supply management.

The World Federation of Neurosurgical Societies (WFNS) is committed to global improvement in neurosurgical care and recognizes that there is a paucity of studies that assess the needs of young neurosurgeons across economies. This cross-sectional survey performed by the WFNS Young Neurosurgeons committee aimed to elucidate key needs of young neurosurgeons, their access to education and equipment, and the hurdles they face in daily practice. The results presented here report findings of two additional content areas not presented in Part I, which includes perceptions on barriers and hurdles to deliver adequate neurosurgical care to local populations. These findings are intended to guide the structure of and investment in training programs to improve service delivery and facilitate timely access to safe and affordable neurosurgical care.

MATERIAL AND METHODS

Survey Design, Dissemination, and Study Variables

The WFNS Young Neurosurgeons Committee aims to represent and promote the interests of Young Neurosurgeons, defined as residents, fellows, and consultants who are within 10 years of completing residency. The Committee works to improve knowledge, surgical skills, research capability, and career opportunities for young neurosurgeons worldwide in alignment with the WFNS mission of benefiting patients and improving neurosurgical care.[15]

This cross-sectional study consisted of a web-based survey performed between April 25 and November 30, 2018; details of the full methodology are as published previously (Part I paper; *co-submission, under review*). This paper focuses specifically on questions related to hurdles in daily practice and the personal needs of trainees. Respondents consisted of a non-probabilistic sample of neurosurgeons invited though electronic mailing lists of continental

and various neurosurgical societies, email to personal contacts, and social media platforms (Twitter, Facebook and WhatsApp).

Statistical Analysis

Data were analysed using commercially available software (IBM SPSS Statistics 25 and Microsoft Excel 2016) to generate descriptive statistics. Responses were categorised according to the 2018 World Bank Income classifications of high-income countries (HICs), upper-middle income countries (UMICs), lower-middle income countries (LMICs), and low-income countries (LICs).[16] Descriptive statistical analysis included chi-squared tests, and ANOVA for categorical and continuous variables, respectively. Multiple comparison adjustments were implemented where appropriate given survey question structure. Point estimates are presented with estimated 95% confidence intervals.

RESULTS

Demographics

A total of 953 individuals completed the survey; completion was defined as 100% response to compulsory questions. Due to the wide dissemination of the questionnaire through social media platforms, calculation of a response rate was not possible. Categorised according to World Bank Income classifications, there were 431 respondents from HICs, 228 from UMICs, 255 from LMICs, and 39 from LICs. A more detailed examination of the respondents' demographics, scope of clinical practice, and nuances in access to training and equipment resources (e.g., computed tomography (CT) or Magnetic Resonance Imaging (MRI)) is reported in a separate publication by Gnanakumar et al. (Part I paper; *co-submission, under review*).

Barriers in Delivering an Adequate Neurosurgical Service

About one quarter of global respondents (25.8%) identified that local neurosurgical needs were adequately met (**Table 1**). There was a graduated reduction from 38.8% in HICs to 10.3% in LICs ($p<0.0001$). Over half of respondents in LMICs and LICs reported inadequate or no insurance coverage for a significant number of people. The limited number of trained neurosurgeons was seen as a barrier for 12.5%, 29.8%, 69.2%, and 23.9% of respondents from HICs, UMICs, LMICs, and LICs, respectively ($p<0.0001$). Similar patterns were seen for limitations arising from a dearth of space and resources. Over 30% of individuals from UMICs and LMICs, and over 50% from LICs expressed that the paucity of neurosurgical beds was a barrier to care delivery ($p<0.001$), whilst over 40% of respondents from UMICs and LMICs, and over 50% from LICs reported challenges regarding intensive care unit (ICU) beds ($p<0.01$).

Perceived access to essential imaging modalities was another barrier associated with significant differences across country income classes. Among LICs, 25.6% of respondents identified challenges in CT accessibility ($p<0.0001$), and 46.2% for MRI ($p<0.0001$). Regarding equipment, lack of access to tools such as a microscope, high speed drills, or bipolar cautery were identified as barriers identified by 5.1%, 30.7%, 45.9% and 53.9% of respondents from HICs, UMICs, LMICs, and LICs, respectively ($p<0.0001$).

Finally, relating to the spectrum of care, limitations in organized primary care were respectively highlighted as barriers by 12.1%, 25.4%, 34.1% and 25.6% of HIC, UMIC, LMIC, and LIC respondents ($p=0.02$). A lack of organised pre-hospital and emergency hospital care was identified by 9.7%, 25.9%, 42.4%, and 53.9% of those from HICs, UMICs, LMICs, and LICs ($p<0.0001$); an analogous trend was evident for organised rehabilitation care ($p<0.001$). Overall, increased hurdles endured by those practicing in lower income countries was further demonstrated by the fact that respondents identified on average 1.34

hurdles impeding their practice in HICs, compared to an average of 5.0 for LICs (ANOVA, $p<0.05$ with Bonferroni correction demonstrating significant difference between HICs and both LMICs [$p<0.003$] and LICs [$p<0.001$] but not UMICs [$p=0.136$]).

Barriers in Personal Practice

A similar pattern emerged related to personal barriers encountered during daily care provision (**Table 2**). The most common reported challenge identified was limited opportunities to conduct research (48.4% total, 34.6% for HICs, 57.5% for UMICs, 61.6% for LMICs, and 61.5% for LICs; $p=0.03$). Other significant differences observed in barriers associated with income class included lack of regular access to the advice of experienced/senior colleagues (12.3%, 22.4%, 21.2% and 41.0% of individuals from HICs, UMICs, LMICs, and LICs, respectively; $p<0.001$), lack of access to neurosurgical journals (11.8%, 26.3%, 25.1% and 64.1% of individuals from HICs, UMICs, LMICs, and LICs, respectively, $p<0.0001$), and lack of access to neurosurgical textbooks (7.4% HIC, 16.2% UMIC, 17.3% LMIC, and 25.6% LIC; $p=0.02$). Barriers that were similar across income groups included access to a mentor (over 24% for all, highest in LICs, 38.5%), lack of hands-on opportunities for surgical training (average 44.6%, highest in LICs, 56.4%) and organised teaching/training sessions (average 44.6%, highest in LICs, 51.3%). Regarding working conditions and culture, 41.6% individuals listed long work hours as a challenge, whilst 40.9% noted poor work/life balance and 13.2% reported bullying and harassment issues; these obstacles were present across all income groups. Similar to the hurdles affecting local provision of care, HICs respondents reported an average of 2.6 issues, while neurosurgeons in LICs reported 4.5 ($p=0.86$).

Requested Areas of Improvement

When asked to list three areas in which the WFNS could facilitate the respondent's personal goals and the goals of their neurosurgical service, there were 1673 responses from 953 individuals. Results span categories of system improvement, education, and technical training. **Figure 1** displays broad categories of knowledge-based training, technical training, networking/mentorship, and resources, by income class, while **Figure 2** depicts the overall detailed responses.

Of the 1673 individual requests for improvement, the most frequent request was for research (384 individuals, 40.3%), followed by additional education opportunities (296 individuals, 31.1%), and additional subspecialty or fellowship training requests (232 respondents, 24.3%). Specific sub-specialties of interest are shown in **Figure 3**. Of those who mentioned a specific subspecialty (130/232), the majority requested training in cerebrovascular (n=26), spine (n=25) and skull base (n=21). Regarding non-technical training, many individuals requested additional venues to continue medical education through courses and conferences, or online courses. For technical training, there were 171 and 71 requests for skills courses/workshops and cadaver dissection opportunities, respectively.

DISCUSSION

This survey is the most current and, to our knowledge, the most comprehensive cross-sectional examination of the global barriers young neurosurgeons are encountering during neurosurgical training and service delivery. It is critical that the Global Neurosurgery community is aware of these challenges so there can be a systematic response to empower the neurosurgical workforce and mitigate the global burden of neurosurgical disease.[4] Overall, the factors individuals identified as barriers to optimal training and care provision closely mirrored the requests to the WFNS Young Neurosurgeons committee for improvement in the subsequent section. They can be categorized into desired improvements in resources for

service delivery, neurosurgical education (non-technical skills), and continued development of technical skills. Current efforts and opportunities for future investment are described.

Service Delivery

The challenges in service delivery span the spectrum of healthcare delivery, and respondents identified these barriers arising from primary care, emergency services, hospital bed availability, and rehabilitation. Interestingly, even respondents from HICs desired access to more beds, though this finding does not account for the significant differences in baseline bed numbers. These hurdles necessitate tremendous investment in infrastructure at every level. For this reason, there was a recent development of the "*Comprehensive Policy Recommendations for Head and Spine Injury Care in LMICs.*[17]" This document focuses on emergency care, but investing in trauma infrastructure enables improvements in the flow of elective cases as well. The recommendations span neurotrauma surveillance, prevention, prehospital care, hospital care, and rehabilitation stages and it discusses all in the context of infrastructure, workforce, service delivery, financing, information management, and governance.

The scarcity of equipment for procedures was another major obstacle. The WFNS Foundation is currently working with medical equipment sponsors to provide high quality neurosurgical equipment at an affordable cost to neurosurgeons in economically challenged countries who are devoted to neurosurgery and their patients. As of December 2018, the WFNS Foundation has dispatched 58 neurosurgical kits to Asia and Australasia, 16 neurosurgical kits to the Middle East, 24 neurosurgical kits to Europe, 18 neurosurgical kits to Latin America, and 125 neurosurgical kits to Africa.[18] While equipment donations will

advance care in the short term, local health systems are called to invest in sustainable resource support. Additionally, innovation in low-cost devices and procedures can improve long-term cost effectiveness. For example, the University of Cape Town, South Africa, developed the Cape Town Stereotactic Pointer as a low-cost, simple device to obviate the use of frames and devices associated with traditional stereotactic techniques.[19] Handheld near-infrared spectroscopy devices are being increasingly used to triage and diagnose patients with intracranial haematomas, which can be a vital tool when or where CTs scanner are unavailable.[20] We believe that neurosurgeons will need to continue partnering with engineers, industry, and other disciplines to further the development of low-cost innovation for neurosurgical care delivery.

Neurosurgical Education (Non-technical Skills)

Our survey demonstrates strong interest among trainees for research opportunities. Strengthening networks between local and national or international centres is needed to create opportunities for local trainee involvement. On the WFNS website there are multiple postings for clinical and research observers and fellows; trainees are encouraged to apply and universities are encouraged to continue funding these efforts.[24] Additionally, large collaborative studies that invite global participation are increasing in prevalence. A recent example is the National Institute for Health Research (NIHR) Unit on Global Surgery's establishment of transnational research hubs to coordinate surgical research, including conducting international randomised clinical trials.[21] Specific to neurosurgery, the NIHR Global Health Research Group on Neurotrauma, hosted at the University of Cambridge, UK is conducting a prospective, multi-centre, international cohort study of outcomes following emergency surgery for traumatic brain injury where local trainees can contribute to data collection on outcomes and follow-up both pre-and post-intervention (Global Neurotrauma

Outcomes Study).[22] Moreover, these initiatives can provide funding for trainees who wish to contribute more by undertaking PhD research. The same group has a specific theme that aims to nurture the TBI research capacity in LMICs.[22b] The Group is facilitating this with the funding of i) research fellow posts in each participating institution, ii) exchanges between institutions, and iii) courses focused on clinical care and research methodology. InterSurgeon is another free service that brings together neurosurgeons who wish to collaborate in clinical practice, participate in the provision of training and education or share equipment and other resources.[23]

Barriers to access to journals, particularly in LICs, was raised as an impediment to personal development. Major impactful neurosurgical articles are published in journals such as *Journal of Neurosurgery*, *Neurosurgery, Acta Neurochirurgica and World Neurosurgery,* but paywalls and requisites for individual subscriptions can cost hundreds of dollars per annum. For young neurosurgeons in LICs and LMICs, this can be the equivalent of more than a month's salary. Therefore, we invite Open Access publication initiatives such as where authors pay towards the cost of making articles accessible for free. Indeed, many research funders, including UK Research Councils' and the Wellcome Trust, already require funded work to be made Open Access after an embargo period.[25,26] While many LMIC and LIC researchers may not be able to afford the article processing charge, additional grants for these researchers to publishing as open access should be considered.[27] Other initiatives include offering access to journals to researchers in developing countries at reduced or no cost.[28] Overall, the neurosurgical community should make a concerted effort to increase the accessibility of research articles to young neurosurgeons in LMIC and LICs. Additionally, the WFNS continues to support and broadcast opportunities for learning such as Live Surgery Seminars and educational courses that can be found at https://wfns.org/events. The WFNS Young Neurosurgeons committee has also initiated a series of monthly webinars, which

become immediately and permanently available to all on YouTube. While we acknowledge that access to reliable internet remains a challenge for many young neurosurgeons, there is constant advancement in the ease and affordability of accessing online material through smartphone and computer data, and this remains one of the most rapid and practical means of information dissemination.

Technical Skills and Fellowship

The survey elucidated the unmet need for additional technical training opportunities, with particular interest in technical skills workshops, cadaver labs, and clinical fellowship. As cadavers can be costly and difficult to obtain, low-cost simulation models may be a great solution.[29,30] For instance, a recent publication on subspecialty pediatric neurosurgery training employed a low-cost skill-based training model for neurosurgeons in low-resourced health systems. Trainees were oriented to an endoscopic simulation station outfitted with cranial models of infants with hydrocephalus, and each cranial model, designed from thin-cut radiographs, was 3D printed at a cost of roughly USD $4.[30] As 3D printing quality improves and cost declines, neurosurgical model development for training is encouraged. Additionally, the WFNS is continuing to work to offer regional skills training workshops. The European Association of Neurosurgical Societies and AOSpine offer high quality training courses, albeit priced at over $1000 each; solutions could be to lower fees for participants from LICs, or offer additional regional courses with support from industry and WFNS. The WFNS Young Neurosurgeons committee has also partnered with UpSurgeOn, a multidisciplinary team of neurosurgeons, developers, digital artists and artisans which envisioned a revolution of head, neck, otolaryngology, and spine surgery training using hi-tech/low-cost technology. This intends to bridge the gap between theoretical learning and practical training through physical models fused with augmented reality 3D models for psychomotor skill training using

hybrid solutions. The UpSurgeOn technologies, like AppSurgeOn Apps and UpSim Neurosurgical Box, have been designed for being affordable also for training in countries with limited facilities. Since March 2018, AppSurgeOn Apps hosts a real-time stream dedicated to WFNS YNF activities. The stream is able to reach around half million of users worldwide.

The most requested subspecialty fellowships were cerebrovascular and spine. The global burden of stroke and the paucity of angiography in lower income settings may be driving the cerebrovascular interest, but our survey did not distinguish between open versus endovascular training. However, it is important to consider both the epidemiology of disease and the cost-effectiveness of cerebrovascular interventions. In a study estimating the economic consequences of neurosurgical disease in LMICs, the majority of the losses can be attributed to stroke and traumatic brain injury.[31] However, in a cost-effectiveness analysis of mechanical thrombectomy in China, the addition of mechanical thrombectomy to intravenous tPA treatment compared with standard treatment alone yielded a lifetime gain of 0.794 quality-adjusted life years (QALYs) or US$9,690 per QALY gained.[32] Their probabilistic sensitivity analysis was run with a willingness-to-pay threshold of US$19,300 per QALY. Interestingly, few respondents identified additional interests in pediatrics training, despite the large global burden of congenital conditions and hydrocephalus,[7] and the cost per disability adjusted life-years averted ranges from $US59 to $126.[33] Furthermore, approximately only 330 pediatric neurosurgeons are taxed with caring for a population of 1.2 billion children.[5,34] There should be positive incentives for trainees to specialize in pediatric neurosurgery. Investing in subspecialty training should incorporate both the population need, based on disease burden, as well as cost-effectiveness strategies, and should be integrated into infrastructure development.[35]

Currently, the WFNS office of Training Centers & Fellowship orchestrates fellowships at 23 post-graduate, two short-term, and four full program training centers. These are based around the world and include the U.S., U.K., China, Malaysia, Germany, France, Italy, Spain, Japan and more.[36] For these fellowships, the trainee is provided with a stipend for food and accommodation. The WFNS-Rabat Training Center with a faculty of 29 professors and teachers has trained 58 young neurosurgeons from 18 Sub Saharan African countries over an 18 year period (2002-2019).[37] Thirty of these have finished their training and moved back home to practice and teach neurosurgery in public hospitals. As part of its commitment to continuing medical education, the Center also organises three courses and workshops every year. Initiatives such as CURE Hydrocephalus and Spina Bifida offer subspecialty fellowships to neurosurgeons from LICs, allowing these young trainees to pursue their subspecialty interests. The Ethiopian partnership with the Norwegian University of Bergen and Foundation for International Education in Neurological Surgery (FIENS) facilitated an increase in neurosurgical capacity from two neurosurgeons in 2006 to 30 in 2019. Recently, a new East African training program was created in collaboration with The College of Surgeons of East Central and Southern African, with training sites in Tanzania, Uganda, Kenya and Ethiopia. Programs in Senegal, Zimbabwe and South Africa are also actively expanding their neurosurgical workforce. The benefits of these programs are that they are sensitive to the local context of culture, pathology and resource availability, and increase the likelihood of trainees to stay in their home countries and build neurosurgical capacity.

Future Directions

The WFNS will be taking this data into account as they advocate for investment in resources and education for young neurosurgeons. Additionally, neurosurgeons from HICs can partner with LICs as the begin to formulate their National Surgical Plans and strive to address the burden of neurosurgical disease in their respective countries. Sustainable partnerships between neurosurgery departments in high and lower income nations should continue to be developed in order to create opportunities for training, mentoring, and research, particularly in sub-Saharan Africa, Southeast Asia and Latin America. Professional national and regional neurosurgical societies have an opportunity to support their local communities of neurosurgeons to deliver high quality neurosurgical care via continuing surgical education, surgeon fellowship, peer evaluation, scientific exchange, organising manpower and funding for international initiatives, developing practice guidelines, and lobbying for federal support. These societies can provide a springboard from which to launch targeted interventions, including research, at a local level. We encourage young neurosurgeons to stay connected to the WFNS to seek out resources and opportunities as they arise, and we call on the global neurosurgical community to come together in these efforts.

Limitations

The major limitations of this study include issues related to convenience sampling methodologies which precluded response rate calculation, and the opinions of those without reliable internet, electronic devices, and email are less likely to be captured. Administering the survey in English limited respondents to those with sufficient English comprehension. Young neurosurgeons from many geographic areas, especially East Asia and Pacific, were not adequately represented; this may have resulted from survey distribution, language barriers, or other unknown factors. More goal-directed studies will be needed in the future to

capture these populations. Approximately 60% of respondents were from cities of greater than 0.5 million people, and over 80% were from cities with populations over 200,000, thus representing young neurosurgeons and trainees in more urban areas. However, this is also indicative of the nature of neurosurgical practice where multiple surgeons are often clustered in urban centres. The role played by academic and research contacts in dissemination of the survey may have introduced selection bias, particularly pertaining to the question regarding payment for clinical work versus research; over 20% of respondents reportedly receiving payment for research, and it was the top request for improvement in their current neurosurgical system. Finally, while there will still be country- and hospital-specific needs that will need addressed on a more country-and region-specific level to understand unique factors, this survey provides a broad overview of current barriers to training and service deliver for young neurosurgeons and can serve as a guide for resource strategies, partnership development, and system improvement.

CONCLUSION

This global survey aimed to elucidate current challenges faced by young neurosurgeons across economies. It revealed key health system barriers that can be improved with the development of national surgical plans, partnerships, and resource investments. It also underscored which areas of non-technical and technical skill development are a priority for young neurosurgeons, such as opportunities for research, access to peer review publications, skills-based workshops with cadavers or models, and desired fields of subspecialty training. While the WFNS will continue to work to improve these areas, we call on the global neurosurgical community to partner with us in these efforts.

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Table 1. Perceived Systemic Barriers to Meeting the Needs of the Local Population

	High-income Economies (n=431)	Upper-middle-income Economies (n=228)	Lower-middle-income Economies (n=255)	Low-income Economies (n=39)	Total (n=953)	P-values
N/A-the neurosurgical care needs of my local population are perfectly covered	167 (38.8%; 34.3-43.4%)	47 (20.6%; 15.9-26.3%)	28 (11%; 7.7-15.4%)	4 (10.3%; 4.1-23.6%)	246 (25.8%; 23.1-28.7%)	<0.0001
Inadequate or no insurance coverage for significant number of people	36 (8.4%; 6.1-11.3%)	70 (30.7%; 25.1-37%)	150 (58.8%; 52.7-64.7%)	21 (53.9%; 38.6-68.4%)	277 (29.1%; 26.3-32%)	<0.0001
The limited number of trained neurosurgeons	54 (12.5%; 9.7-16%)	68 (29.8%; 24.3-36.1%)	79 (31%; 25.6-36.9%)	27 (69.2%; 53.6-81.4%)	228 (23.9%; 21.3-26.7%)	<0.0001
The limited number of neurosurgical beds	92 (21.4%; 17.7-25.5%)	75 (32.9%; 27.1-39.2%)	78 (30.6%; 25.3-36.5%)	21 (53.9%; 38.6-68.4%)	266 (27.9%; 25.2-30.8%)	<0.001
The limited number of ICU beds	104 (24.1%; 20.3-28.4%)	99 (43.4%; 37.2-49.9%)	124 (48.6%; 42.6-54.7%)	21 (53.9%; 38.6-68.4%)	348 (36.5%; 33.5-39.6%)	0.01
Lack of access to equipment necessary for microsurgery (e.g. microscope, drill, bipolar)	22 (5.1%; 3.4-7.6%)	70 (30.7%; 25.1-37%)	117 (45.9%; 39.9-52%)	21 (53.9%; 38.6-68.4%)	230 (24.1%; 21.5-27%)	<0.0001
Lack of regular / consistent access to CT	5 (1.2%; 0.5-2.7%)	8 (3.5%; 1.8-6.8%)	29 (11.4%; 8-15.9%)	10 (25.6%; 14.6-41.1%)	52 (5.5%; 4.2-7.1%)	<0.0001
Lack of regular access to MRI	30 (7%; 4.9-9.8%)	50 (21.9%; 17.1-27.7%)	55 (21.6%; 17-27%)	18 (46.2%; 31.6-61.4%)	153 (16.1%; 13.9-18.5%)	<0.0001
Lack of organised primary care	52 (12.1%; 9.3-15.5%)	58 (25.4%; 20.2-31.5%)	87 (34.1%; 28.6-40.1%)	10 (25.6%; 14.6-41.1%)	207 (21.7%; 19.2-24.5%)	0.02
Lack of organised pre-hospital / emergency hospital care	42 (9.7%; 7.3-12.9%)	59 (25.9%; 20.6-31.9%)	108 (42.4%; 36.4-48.5%)	21 (53.9%; 38.6-68.4%)	230 (24.1%; 21.5-27%)	<0.0001
Lack of organised rehabilitation care	79 (18.3%; 15-22.3%)	76 (33.3%; 27.5-39.7%)	105 (41.2%; 35.3-47.3%)	21 (53.9%; 38.6-68.4%)	281 (29.5%; 26.7-32.5%)	<0.001
Other	63 (14.6%; 11.6-18.3%)	16 (7%; 4.4-11.1%)	20 (7.8%; 5.1-11.8%)	4 (10.3%; 4.1-23.6%)	103 (10.8%; 9-12.9%)	0.2839

Table legend: Summary of young neurosurgery respondents (n=953) perceived systemic barriers to meeting the needs of the local population by World Bank Income Classification. Data are presented with absolute and relative frequencies and 95% confidence intervals.

Table 2: Perceived Personal Challenges Encountered in Daily Practice

	High-income Economies (n=431)	Upper-middle-income Economies (n=228)	Lower-middle-income Economies (n=255)	Low-income Economies (n=39)	Total (n=953)	P-values
N/A-there are no hurdles	56 (13%; 10.1-16.5%)	14 (6.1%; 3.7-10%)	8 (3.1%; 1.6-6.1%)	1 (2.6%; 0.5-13.2%)	79 (8.3%; 6.7-10.2%)	0.01
Lack of access to organised teaching / training sessions	157 (36.4%; 32-41.1%)	113 (49.6%; 43.1-56%)	126 (49.4%; 43.3-55.5%)	20 (51.3%; 36.2-66.1%)	416 (43.7%; 40.5-46.8%)	0.35
Limited number of opportunities for hands-on operating	187 (43.4%; 38.8-48.1%)	100 (43.9%; 37.6-50.4%)	116 (45.5%; 39.5-51.6%)	22 (56.4%; 41-70.7%)	425 (44.6%; 41.5-47.8%)	0.52
Long hours of work	162 (37.6%; 33.2-42.3%)	107 (46.9%; 40.6-53.4%)	111 (43.5%; 37.6-49.7%)	16 (41%; 27.1-56.6%)	396 (41.6%; 38.5-44.7%)	0.79
Poor work / life balance	153 (35.5%; 31.1-40.1%)	97 (42.5%; 36.3-49%)	122 (47.8%; 41.8-54%)	18 (46.2%; 31.6-61.4%)	390 (40.9%; 37.8-44.1%)	0.59
Bullying and harassment issues	53 (12.3%; 9.5-15.7%)	33 (14.5%; 10.5-19.6%)	36 (14.1%; 10.4-18.9%)	4 (10.3%; 4.1-23.6%)	126 (13.2%; 11.2-15.5%)	0.76
Lack of regular access to the advice of experienced / senior colleagues	53 (12.3%; 9.5-15.7%)	51 (22.4%; 17.4-28.2%)	54 (21.2%; 16.6-26.6%)	16 (41%; 27.1-56.6%)	174 (18.3%; 15.9-20.8%)	<0.001
Lack of a mentor	110 (25.5%; 21.6-29.8%)	55 (24.1%; 19-30.1%)	65 (25.5%; 20.5-31.2%)	15 (38.5%; 24.9-54.1%)	245 (25.7%; 23-28.6%)	0.17
Lack of access to neurosurgical journals	51 (11.8%; 9.1-15.2%)	60 (26.3%; 21-32.4%)	84 (25.1%; 20.2-30.8%)	25 (64.1%; 48.4-77.3%)	220 (28.6%; 20.5-25.9%)	<0.0001
Lack of access to neurosurgical textbooks	32 (7.4%; 5.3-10.3%)	37 (16.2%; 12-21.6%)	44 (17.3%; 13.1-22.4%)	10 (25.6%; 14.6-41.1%)	123 (12.9%; 10.9-15.2%)	0.02
Limited opportunities to do research	149 (34.6%; 30.2-39.2%)	131 (57.5%; 51-63.7%)	157 (61.6%; 55.5-67.3%)	24 (61.5%; 45.9-75.1%)	461 (48.4%; 45.2-51.5%)	0.03
Other	25 (5.8%; 4-8.4%)	10 (4.4%; 2.4-7.9%)	16 (6.3%; 3.9-9.9%)	4 (10.3%; 4.1-23.6%)	55 (5.8%; 4.5-7.4%)	0.40

Table legend: Summary of young neurosurgery respondents (n=953) perceived personal challenges encountered in daily practice by World Bank Income Classification. Data are presented with absolute and relative frequencies and 95% confidence intervals.

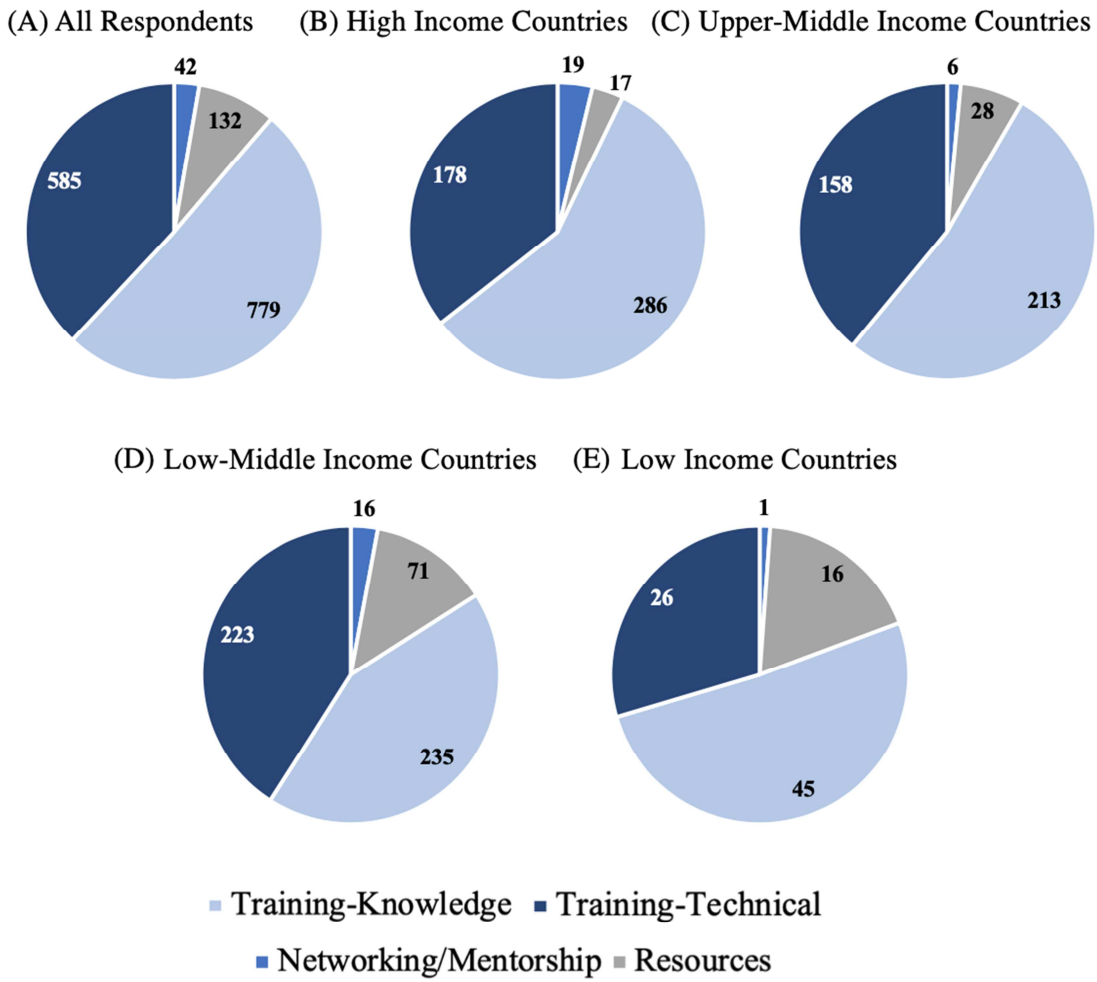

Figure 1: Categorization of respondent requests into categories of knowledge-based training, technical training, networking/mentorship, and resources. A. Overall respondents, B-E by World Bank Income Classification.

Figure 2: Detailed categorization of respondents' requests for improvement in their current neurosurgical system. Of the 1673 individual requests for system improvement, the most frequent request was for research (384 individuals), followed by additional education (296 individuals), and additional subspecialty or fellowship training requests (232 respondents). The subspecialties of interest are depicted below. Twenty-five percent of fellowship requests came from HICs, 26.3% from UMICs, 44.0% from LMICs, and 4.74% from LICs.

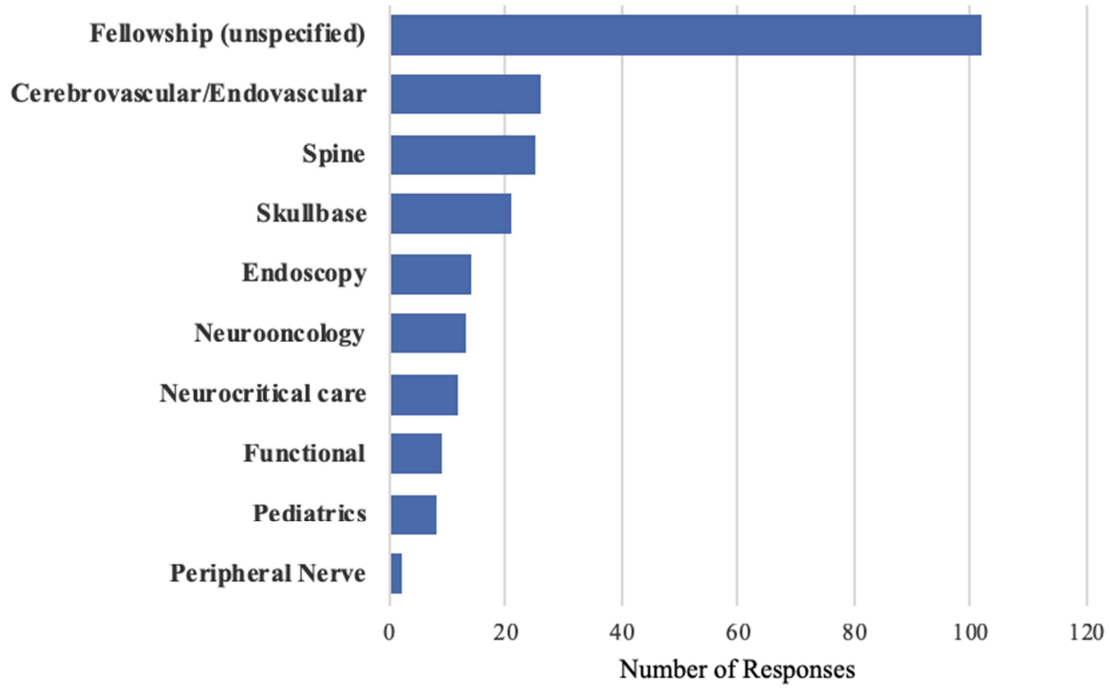

Figure 3: Requested Fellowships from Young Neurosurgery Respondents. A total of 232 individuals expressed interest in additional fellowship training. Of the specified fields (102 unspecified), the majority requested training in cerebrovascular (n=26), spine (n=25) and skull base (n=21).

Abbreviations: CT, Computed tomography; FIENS, Foundation for International Education in Neurological Surgery; HICs, High-income countries; ICU, Intensive care unit; LICs, Low-income countries; LMICs, Low-middle income countries; MRI, Magnetic resonance imaging; NIHR, National Institute for Health Research; QALYs, Quality-adjusted life years; TBI, Traumatic brain injury; UMICs, Upper-middle income countries; WFNS, World Federation of Neurosurgical Societies.

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