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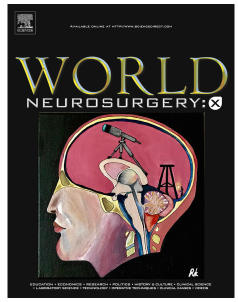

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INTRODUCTION

There is an urgent need to substantially increase the neurosurgical workforce as part of global surgical system strengthening to prevent death and disability for patients with neurological disease. The global burden of neurosurgical disease is estimated to be 22.6 million patients per annum, of whom 13.8 million need therapeutic surgical intervention.[1] While there are an estimated 49,940 neurosurgeons in the world, they are unequally distributed; neurosurgeon densities range from 0 to 58.95 (standardised to per 1 million population) between countries.[2] In low and middle income countries, more than 5 million essential neurosurgical cases are not performed each year due to lack of access to services.[1] These are mostly in Sub-Saharan Africa and East Asia where the ratio of neurosurgeon density to disease burden is critically low.[3] It is estimated that 23,300 additional neurosurgeons are required in order to eliminate the operative deficit.[1] In light of these geographic disparities, it is critical that neurosurgical staff are distributed according to the population needs.

The global neurosurgical community has responded to the disparity by developing a consensus and putting neurosurgery on the global surgery and health policy agenda.[4,5] The publication of the Lancet Commission "Global Surgery 2030" report inspired the neurosurgical community to create the field of Global Neurosurgery, defined by *Park et al., 2016* as: "an area for study, research, practice, and advocacy that places priority on improving health outcomes and achieving health equity for all people worldwide affected by neurosurgical conditions or have a need for neurosurgical care".[6,7] An international group of neurosurgeons convened to publish the Global Neurosurgery Consensus Document, which describes seven areas required to expand access to neurosurgery worldwide, particularly in LMICs: workforce, prehospital care, training and education, research, equipment, innovation, and advocacy (www.globalneurosurgery.org).

Training and education are critical in this effort to address neurosurgical inequities. Progress is being made in recruiting physicians, improving the number and quality of training programmes, and retaining existing surgeons in their home nations. The Foundation for International Education in

Neurological Surgery (FIENS, www.fiens.org) and the World Federation of Neurosurgical Societies (WFNS,www.wfns.org) have spearheaded initiatives to train neurosurgeons in LMICs over the past decades. A plethora of other projects dedicated to building capacity are underway, such as Africa 100, the All India Institute of Medical Sciences Neurosurgery Education and Training School, and CURE International.[7,8]

Young neurosurgeons across the economic spectrum have different educational experiences and thus different needs due to variation in training programmes, availability of academic opportunities, and access to equipment and expertise in local health systems. There is a paucity of studies that assess the needs of young neurosurgeons internationally. We surveyed the key needs of young neurosurgeons, their access to education and equipment, and the hurdles they face in daily practice. This paper highlights the demographics of young neurosurgeons and nuances in their access to training and equipment. Our goal is that the Global Neurosurgery community may use these insights to tailor context specific interventions to the needs of our growing neurosurgical workforce.

METHODS

Survey Design and Dissemination

The WFNS Young Neurosurgeons committee aims to represent and promote the interests of Young Neurosurgeons worldwide. The committee defines Young Neurosurgeons as residents, fellows, and consultants (within 10 years after the end of residency training). It aims to act as an advocate and conduit for developing the knowledge, surgical skills, research capability, and career opportunities for young neurosurgeons worldwide in order to align with the WFNS mission of benefiting patients and improving neurosurgical care.

The committee performed a cross-sectional study consisting of a self-administered survey, developed by the committee itself. Thirty open-ended, multiple-choice questions (see Appendix 1), assessed the following: survey respondents' demographics; the type of Centre they worked in; access to imaging facilities and essential operating equipment; access to education and training; hurdles in daily practice; and the personal needs of trainees. We designed a concise survey to achieve high response rates whilst obtaining the maximum amount of useful data possible. The survey was developed and piloted by members of the WFNS Young Neurosurgeons Committee and then approved by the leadership of the WFNS.

The web-based survey link was distributed by the electronic mailing lists of continental, regional, national, and interest-based neurosurgical societies, email to personal contacts and social media platforms (Twitter, Facebook and WhatsApp). The link directed the respondents to Qualtrics where the survey could be completed online between April 25th to November 30th of 2018.

Inclusion and Exclusion Criteria

All survey responses by self-identified young neurosurgeons who completed all mandatory questions were included. All responses by non-young neurosurgeons or incomplete surveys were excluded.

Statistical Analysis

Due to the wide dissemination of the questionnaire through social media platforms, calculation of a response rate was not possible. For descriptive purposes, categorical variables were presented with absolute and relative frequencies with estimated 95% confidence intervals. These were compared by means of the chi-squared test for trend, considering the ordinal nature of the World Bank income groups stratification. Adjusted standardised residuals were analysed when applicable.

All tests were 2-sided and final p values under 0.05 were considered statistically significant. Multiple comparisons were implemented based on survey question structure. All analyses were conducted with the SPSS software (IBM Corp. SPSS Statistics, Windows, version 24.0. Armonk, NY).

RESULTS

The survey was completed by 1,294 respondents and a total of 953 completed surveys were included in the final analysis, representing a completion rate of 73.6%.

Respondent Demographics and Scope of Clinical Practice

In terms of the World Bank country economic groups, 431 (45.2%) respondents were from high-income countries (HICs), 228 (23.9%) upper-middle income countries (UMICs), 255 (26.8%) lower-middle income countries (LMICs) and 39 (4.1%) from low-income countries (LICs). A complete list of respondents by World Bank classification is provided in Appendix 2.

The basic demographic data and scope of practice of survey respondents is shown in Table 1. There was no difference in age across economic groups. The largest cohort were those aged between 30-35 years of age, representing 40% of respondents. A significantly greater proportion of respondents were male across all income groups, but this disparity was more pronounced among the lower income group ($p<0.001$). The HICs respondents tended to be less frequently based in areas with populations >1.5 million and more commonly in cities between 50,000 and 1.5 million people ($p<0.001$). While only 33.9% of respondents in HICs were based in areas with populations more than 1.5 million, in LICs this figure was 66.7%. Level of practice of respondents across the income groups was broadly similar for residents (41.3%) and fellows (10.5%). Consultants (Attendings), those having completed neurosurgical training, with less than 5 years after the end of residency comprised a higher proportion of the respondents in the lower income groups. The majority of respondents (78.3%) regarded their job appointment as purely clinical and this was consistent across all income groups. Those from HICs and LICs were more likely to work only at university or teaching hospitals than those from LMICs and UMICs, whose observed proportion at private and mixed private/public hospitals were higher ($p<0.001$).

The most popular subspecialty interests were spinal surgery and neuro-oncology, followed by cerebrovascular surgery, neurotrauma and skull base surgery (Table 2). Higher income groups had a trend towards higher interest in neuro-oncology (p=0.004), and less interest in neurotrauma (p=0.018), cerebrovascular (p=0.001), and skull base surgery (p=0.013). Neuro-endoscopy interest as a subspecialty was higher for UMICs and LMICs than HICs or LICs (p<0.001). All income groups had on average more than two subspecialty interests, although the mean values for the UMICs (2.9 ± 1.8) and LMICs (2.8 ±1.8) were higher (ANOVA post-hoc tests, p<0.001) than the HICs (2.3 ± 1.4). The LICs had a mean number of subspecialty interests of 2.5 ± 1.7.

Neurosurgical Services - General Characteristics and Availability of Key Features

A summary of the survey results regarding general neurosurgical services characteristics and availability of resources are shown in Table 3. The respondents from HICs tended to work in hospitals with a higher number of beds, especially in the > 1000 bed category (p<0.001). Also, a higher income group was associated with higher proportions of dedicated neurosurgical wards (p<0.001). Twenty-five to fifty neurosurgical bed units were the most common type (37.8%), with under 10% of centres having more than 100 beds. No centres in LICs had more than 100 beds.

Access to equipment and services highlights some significant differences between high and low-income settings. Access to computed tomography (CT) scanners and mechanical ventilators in the intensive care unit (ICU) were near universal (98.6% and 96.4%, respectively) and without significant differences across income groups. All other surveyed resources were less accessible the lower the country income (all p < 0.001). While 98.6% had magnetic resonance imaging (MRI) access in HICs, this fell to 66.7% in LICs.

There was access to catheter angiography for 90.3% of HIC respondents, but only 10.3% in LICs. Similarly, access to operating microscopes, image guidance systems, and high-speed drills was over 90% in HICs, but fell to as low as 12.8% in the case of image guidance systems in LICs. Although there was widespread access to ICU beds across all income groups, with roughly 100% having access in HICs, almost 10% lacked access in LICs. A total of 92.1% of respondents had access to specialists in rehabilitation in HICs, but was as low as 48.7% in LICs.

Education and Training

Questions ascertaining dedicated time for neurosurgical education is shown in Table 4 and found that majority of respondents (71.4%) had education opportunities, with a higher frequency reported by individuals in LMICs and LICs (78.43% and 76.92%, respectively, $p=0.006$). In contrast, 68.2% of HICs and 68.4% of UMICs respondents had dedicated teaching. Around half of the respondents in HICs and LMICs had a journal club held in their department, compared to roughly 30% of those in UMICs and LICs ($p=0.015$). Across all groups there was limited access (17.8%) to regular hands-on cadaveric training courses. This was lowest for the UMICs group (8.3%, $p=0.008$). A total of 77.3% of the respondents were members of national neurosurgical societies, which was most concentrated in HICs, where 82.8% were members, in contrast only 66.7% were members in LICs ($p=0.005$). The majority of respondents (60.0%) reported never having attended a WFNS conference or WFNS supported meeting. This was significantly greater in HICs, where 68.7% had never attended a WFNS conference or supported meeting, in comparison to greater attendance frequency among the lower income group ($p<0.001$).

DISCUSSION

This international survey is the most up-to-date, and to our knowledge, the most comprehensive study of the global practice and perspectives of young neurosurgeons. As nearly one thousand complete responses were obtained from a distribution of high, upper-middle, lower-middle, and low-income countries, these data provide a cross-sectional look at the state of the field, and elucidate opportunities for investment and improvement in efforts to meet the 2030 goals for mitigating the global burden of neurosurgical disease.

Demographics

The clustering of respondents and, by inference, concentration of neurosurgical centres shed light on the rural-urban divide; it highlights that neurosurgeons in LIC were more likely to be based in larger urban areas, with few found in smaller towns and rural regions. Combined with factors such as poor transport infrastructure and access to the urban centres where these neurosurgeons are based, people in rural areas have more limited access to neurosurgical care than their urban counterparts. Factors such as time to intervention and access to trained personnel are strong determinants of mortality and poor outcome. Hence, training and access to equipment, as well as retention of specialists in rural areas are critical to outcomes. Alternative approaches including telemedicine, mobile neurosurgical units, training of other specialists on emergency neurosurgery should be carefully considered as neurosurgical capacity is strengthened. Other styles of care including partnerships with neurosurgeons based in large urban centres should also be explored.[9]

Nearly 80% of respondents identified as male, with the result being only slightly more pronounced in lower income settings. This is consistent with the literature which suggests under 6% of practicing neurosurgeons in North America are female.[10] However, the representation of women in training programs is more numerous than in those neurosurgeons well into their careers. Efforts are underway to address this stark disparity, in particular the Women in Neurosurgery (WINS) organisation. WINS was founded in 1989 and has strived to identify barriers such as lack of female mentors, unconscious biases, harassment, salary inequalities amongst others and solutions to mitigate them.[11] Barriers to practice for female neurosurgeons appear to have decreased within Europe.[12] Less literature exists on the barriers that female neurosurgeons in other parts of the world and in LIC face and how they may be overcome.

Resources/Capacity

The survey shows marked disparities in resource distribution across country income groups. Encouragingly, nearly all survey respondents reported having access to a CT scanner (98.6%). CT scans are an essential tool in neurosurgery, particularly for diagnosis and prognosis in neurotrauma or acute stroke that may require emergency intervention.[13] Delays in acquiring the scan may lead to worse patient outcomes.[14,15] While novel, portable, affordable technologies are being trialled for low resource settings, such as handheld near-infrared spectroscopy devices for traumatic intracranial hematomas, CT scans remain the gold standard for rapid and accurate head imaging in neurotrauma. Multiple studies have also demonstrated that the advent of CT imaging reduces mortality in the setting of CNS infections, which are more frequent in lower income settings.[16–19] While the reported rate of CT access was high, there is likely bias in the survey respondents being in urban settings such as university teaching hospitals, and there is likely still a great need for scaling up access to CTs in less populated areas. Additionally, the survey did not qualify whether access to scanning was consistent or not. The recently published *Comprehensive Policy Recommendations for Head and Spine Injury Care in LMICs* discussed the importance of having CT-access as part of a neurotrauma centre within 4 hours from 80% of the population. Access to MRI was also correlated to income group, with only 67% of LIC respondents reporting access. Neurosurgeons rely on MRI for higher resolution definition of intracranial pathologies such as tumours, stroke, infection, vascular anomalies, and soft tissue injuries within the spine. While it may not be economically feasible to implement MRI technology in all hospitals where neurosurgical care is delivered, having appropriate referral networks for MRI imaging is needed.

Approximately 90% of HIC respondents reported access to angiography, compared to 10% in LICs. The global burden of stroke is a strong impetus to invest in interventional stroke treatment with angiography. The 2013 Global Burden of Disease study showed that stroke was the second most common cause of deaths (11.8% of all deaths) worldwide, after ischemic heart disease (14.8% of all deaths), and the third most common cause of disability.[20] Importantly, the study illuminated a concerning significant increase in stroke-related disability-adjusted life years and deaths in developing countries, but not developed countries, likely secondary to increasing metabolic and other non-communicable diseases in these countries.[21] Aneurysmal subarachnoid haemorrhage (aSAH) also faces a geographic mismatch between disease burden and treatment availability. In a 2018 meta-analysis of aSAH that included 58 studies from 31 different countries, Hughes et al. found a wide variation of aSAH across WHO regions from 0.71 to 12.38 per 100,000 persons, with almost two-thirds of the burden in low- and middle-income countries.[22] While the key to reducing the global burden of stroke is more effective prevention (reduction of hypertension, hyperlipidaemia, diabetes, smoking), the continual increase in stroke incidence argues for adding angiography to the armamentarium of more hospitals and neurosurgeons worldwide, backed by effective systems to allow patients to access these services in a timely manner.

Other operative tools and equipment were also lacking in lower resource settings. While there was over 90% access to operating microscopes, image guidance systems, and high-speed drills in HICs, access to these tools fell as low as 12.82% in LICs. These are critical to the safe and effective practice of neurosurgery, especially microneurosurgery, and if unavailable will inherently limit a neurosurgical practice to more basic treatments, care, and training.

The results regarding access to ICU indicated that more than 90% of respondents had access to ICU beds across all income groups. Nevertheless, access does not necessarily mean that access is adequate and consistent for all patients who may need it.[23] This may also reflect on what is defined as an

ICU bed, as this is likely to vary regionally. Additionally, ICU beds are often shared with other specialties making the access limited or inadequate in some cases. Surgeries are frequently postponed since the limited critical care beds are usually occupied. In general, it is accepted that critical care capacity is limited in many LMICs and this issue was also highlighted as a barrier in the second part of the survey (see part II paper - co-submission).

Education and Training

Surgical education has traditionally been dispensed in an apprenticeship-based model, the Halstedian "see one, do one, teach one" approach, where younger surgeons are taught the ropes under the watchful guidance of their more experienced teachers - typically in the live operating theatre.[24] However, as surgery has become more sub-specialised, coupled with restrictions on working hours in Europe and North America, case numbers performed during neurosurgical training appear to be declining.[25, 26] Focus has shifted towards other modalities of teaching including didactic and simulation teaching.[27,28,29] Dedicated time for neurosurgical education is important for trainees to develop their skills outside the operating theatre. Recent data suggest that the perceived quality of training directly influences the theoretical and practical skills set obtained by a resident at time of board-certification.[30] While this question probed at the availability of dedicated learning time, it did not expand on how much protected time was available and what constituted 'dedicated neurosurgical education', which will require further elucidation.

Cadaveric training offers an opportunity to complement learning in the theatre and can improve the trainees' anatomical knowledge and provide an opportunity to practice surgical techniques.[31] Our results suggest low utilisation (17.8%) of cadaveric training across the board. The results obtained in the current sample mirror the generally low to moderate satisfaction rate (about 22%) with the availability of opportunities for cadaveric training, documented by n=532 trainees from Europe.[32] This may be due to the costs associated with setting up and running a cadaveric training laboratory as well as questions as to whether cadaveric training is the most effective methods of training.[33,34] Ethical and religious concerns in some states may mean that legal frameworks may not exist for the provision of cadaveric simulation. There exist other teaching aids including 3D simulation tools that may also be equally or more effective compared to cadaveric training, albeit with their associated costs that may be prohibitive in lower income areas. This survey does not feature the use of other training modalities, which will be an important area of future work.[35] Among European trainees in 2015, only about 12% expressed satisfaction with the options for simulator teaching to enhance their training.[32] However, with technological advances and increasing implementation of simulators into the training programs of the (inter)national neurosurgical societies, their availability - at least in HICs & UMICs has likely increased to some extent over the last few years. Another facet not explored in this survey is collaboration between neurosurgeons in higher and lower income countries. Future work should look to characterise existing partnerships and the scope for developing new ones.

Limitations

As the survey was disseminated using electronic mailing lists of various neurosurgical societies, email to personal contacts and social media platforms, there was no way to ascertain response rate. Additionally, those without access to reliable internet, electronic devices and email are less likely to be captured in the study. The survey was administered in English, which limits respondents to those who are English speakers. Future region- or country-specific studies may want to translate surveys into local languages. There is also a strong likelihood of clustering of results with multiple respondents from the same institution. However, this is also indicative of the nature of neurosurgical practice with multiple surgeons often clustered at a few large centres. The role played by academic and research contacts in dissemination of the survey may have had an impact on the background of the respondent particularly with regards to the question enquiring whether the individual was paid solely for clinical work and/or research. Over 20% of respondents reported that they were paid to undertake some form of research, this figure may be higher than the neurosurgical community in general due to the nature of the survey's distribution. Further studies are required to corroborate and validate this result. Furthermore, most respondents were reporting from an urban setting, so ongoing practices and resources in rural or remote parts of these countries remain to be elucidated. This is critical given the clear access inequity for rural populations and need for additional neurosurgical care.

These subjective needs and requests from countries should be interpreted with caution in their generalisation to global settings. While this survey provides a reference for resource strategies, partnership development, and system improvement, there will still be country and hospital specific needs that will need to be addressed on a more individualised basis. The social, political, and educational challenges that limit access to neurosurgical care should be assessed at a country- and region-specific level to understand unique factors.

The scope of our survey is limited to studying demographics; access to imaging, equipment, education and training; as well as hurdles and personal needs. Other systems such as ancillary staff, anaesthesia and supply chains, which are part and parcel of neurosurgical care, have not yet been studied. While there have been prior ground-level surveys of these resources by many national agencies, there are none specific to global neurosurgery. Questions about surgical equipment and resources assume that these are accessible, functional, affordable, and that surgeons are proficient in their use, which may not be true. We did not define or quantify access, which limits our current interpretation of barriers facing young neurosurgeons to their own perspective, and not a quantifiable study of logistical barriers.

CONCLUSIONS

With nearly a thousand participants, this survey is the most comprehensive understanding of the demographic characteristics of current young neurosurgeons and the challenges they face in their daily practice and development. We confirmed differences depending on the economic locality within which they practice. In lower income countries young neurosurgeons have limited access to equipment and training modalities that are usually more widely available, albeit not extensively exploited, in high income settings. We hope these results will drive more detailed studies into the demographic, equipment and training disparities that exist. Furthermore, we hope the national health planners and the global neurosurgical community pay heed to these disparities and strive to ameliorate them through encouraging female participation, access to training, education and equipment.

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Table 1: Demographics and Scope of Practice						
Variable	**High-income Economies**	**Upper-middle-income Economies**	**Lower-middle-income Economies**	**Low-income Economies**	**Total**	**p-value**
Age (in years)						0.931
< 30	79/431 (18.3%; 15 - 22.3%)	42/228 (18.4%; 13.9 - 24%)	44/255 (17.3%; 13.1 - 22.4%)	9/39 (23.1%; 12.7 - 38.3%)	174/953 (18.3%; 15.9 - 20.8%)	
30-35	177/431 (41.1%; 36.5 - 45.8%)	96/228 (42.1%; 35.9 - 48.6%)	103/255 (40.4%; 34.6 - 46.5%)	16/39 (41%; 27.1 - 56.6%)	392/953 (41.1%; 38.1 - 44.3%)	
36-40	121/431 (28.1%; 24 - 32.5%)	64/228 (28.1%; 22.6 - 34.2%)	78/255 (30.6%; 25.3 - 36.5%)	9/39 (23.1%; 12.7 - 38.3%)	272/953 (28.5%; 25.8 - 31.5%)	
41 or more	54/431 (12.5%; 9.7 - 16%)	26/228 (11.4%; 7.9 - 16.2%)	30/255 (11.8%; 8.4 - 16.3%)	5/39 (12.8%; 5.6 - 26.7%)	115/953 (12.1%; 10.2 - 14.3%)	
Female Sex	124/431 (28.8%; 24.7 - 33.2%)	41/228 (18%; 13.5 - 23.5%)	26/255 (10.2%; 7.1 - 14.5%)	2/39 (5.1%; 1.4 - 16.9%)	193/953 (20.3%; 17.8 - 22.9%)	<0.001
Town/City Population Size						<0.001
>1.5 million	146/431 (33.9%; 29.6 - 38.5%)	136/228 (59.7%; 53.2 - 65.8%)	155/255 (60.8%; 54.7 - 66.6%)	26/39 (66.7%; 51 - 79.4%)	463/953 (48.6%; 45.4 - 51.8%)	
500 000 - 1.5 million	117/431 (27.2%; 23.2 - 31.5%)	42/228 (18.4%; 13.9 - 24%)	55/255 (21.6%; 17 - 27%)	7/39 (18%; 9 - 32.7%)	221/953 (23.2%; 20.6 - 26%)	
200 000 - 500 000	87/431 (20.2%; 16.7 - 24.2%)	21/228 (9.2%; 6.1 - 13.7%)	36/255 (14.1%; 10.4 - 18.9%)	4/39 (10.3%; 4.1 - 23.6%)	148/953 (15.5%; 13.4 - 18%)	
50 000 - 200 000	73/431 (16.9%; 13.7 - 20.8%)	21/228 (9.2%; 6.1 - 13.7%)	8/255 (3.1%; 1.6 - 6%)	2/39 (5.1%; 1.4 - 16.9%)	104/953 (10.9%; 9.1 - 13.1%)	
<50 000	8/431 (1.9%; 1 - 3.6%)	8/228 (3.5%; 1.8 - 6.8%)	1/255 (0.4%; 0.1 - 2.2%)	0/39 (0%; 0 - 9%)	17/953 (1.8%; 1.1 - 2.8%)	
Level of Practice						0.016
Resident (< 5 years after graduating from medical school)	98/431 (22.7%; 19 - 26.9%)	42/228 (18.4%; 13.9 - 24%)	40/255 (15.7%; 11.7 - 20.7%)	8/39 (20.5%; 10.8 - 35.5%)	188/953 (19.7%; 17.3 - 22.4%)	
Resident (≥5 years after graduating from medical school)	98/431 (22.7%; 19 - 26.9%)	51/228 (22.4%; 17.4 - 28.2%)	50/255 (19.6%; 15.2 - 24.9%)	7/39 (18%; 9 - 32.7%)	206/953 (21.6%; 19.1 - 24.3%)	
Fellow (additional training near the end or after the end of residency)	52/431 (12.1%; 9.3 - 15.5%)	14/228 (6.1%; 3.7 - 10%)	32/255 (12.6%; 9 - 17.2%)	2/39 (5.1%; 1.4 - 16.9%)	100/953 (10.5%; 8.7 - 12.6%)	
Consultant (< 5 years after finishing residency)	106/431 (24.6%; 20.8 - 28.9%)	57/228 (25%; 19.8 - 31%)	89/255 (34.9%; 29.3 - 40.9%)	16/39 (41%; 27.1 - 56.6%)	268/953 (28.1%; 25.4 - 31.1%)	
Consultant (≥5 years after finishing residency)	72/431 (16.7%; 13.5 - 20.5%)	58/228 (25.4%; 20.2 - 31.5%)	40/255 (15.7%; 11.7 - 20.7%)	4/39 (10.3%; 4.1 - 23.6%)	174/953 (18.3%; 15.9 - 20.8%)	
Other	5/431 (1.2%; 0.5 - 2.7%)	6/228 (2.6%; 1.2 - 5.6%)	4/255 (1.6%; 0.6 - 4%)	2/39 (5.1%; 1.4 - 16.9%)	17/953 (1.8%; 1.1 - 2.8%)	
Job Appointment Type						0.471
Clinical	339/431 (78.7%; 74.5 - 82.3%)	179/228 (78.5%; 72.7 - 83.4%)	202/255 (79.2%; 73.8 - 83.8%)	26/39 (66.7%; 51 - 79.4%)	746/953 (78.3%; 75.6 - 80.8%)	
Clinical and academic	89/431 (20.7%; 17.1 - 24.7%)	47/228 (20.6%; 15.9 - 26.3%)	50/255 (19.6%; 15.2 - 24.9%)	13/39 (33.3%; 20.6 - 49%)	199/953 (20.9%; 18.4 - 23.6%)	
Research only	3/431 (0.7%; 0.2 -	2/228 (0.9%; 0.2 -	3/255 (1.2%; 0.4 -	0/39 (0%; 0 -	8/953 (0.8%; 0.4 -	

	2%)	3.2%)	3.4%)	9%)	1.7%)	
Main Place of Work						<0.001
University / Teaching Hospital	307/431 (71.2%; 66.8 - 75.3%)	124/228 (54.4%; 47.9 - 60.7%)	147/255 (57.7%; 51.5 - 63.6%)	27/39 (69.2%; 53.6 - 81.4%)	605/953 (63.5%; 60.4 - 66.5%)	
Other Public Hospital	77/431 (17.9%; 14.5 - 21.8%)	49/228 (21.5%; 16.7 - 27.3%)	26/255 (10.2%; 7.1 - 14.5%)	7/39 (18%; 9 - 32.7%)	159/953 (16.7%; 14.5 - 19.2%)	
Private Hospital	21/431 (4.9%; 3.2 - 7.3%)	21/228 (9.2%; 6.1 - 13.7%)	41/255 (16.1%; 12.1 - 21.1%)	1/39 (2.6%; 0.5 - 13.2%)	84/953 (19.2%; 7.2 - 10.8%)	
Mixed Public and Private Hospital	26/431 (6%; 4.2 - 8.7%)	34/228 (14.9%; 10.9 - 20.1%)	41/255 (16.1%; 12.1 - 21.1%)	4/39 (10.3%; 4.1 - 23.6%)	105/953 (11%; 9.2 - 13.2%)	

Table Legend: Summary of young neurosurgery respondents (n=953) demographic characteristics and scope of clinical practice by World Bank Income Classification. Data presented as absolute and relative frequencies with 95% confidence interval.

Table 2: Respondents Main Subspecialty Interests						
Subspecialty	**High-income Economies**	**Upper-middle-income Economies**	**Lower-middle-income Economies**	**Low-income Economies**	**Total**	**p-value**
Cerebrovascular Surgery	132/431 (30.6%; 26.5 - 35.1%)	99/228 (43.4%; 37.2 - 49.9%)	111/255 (43.5%; 37.6 - 49.7%)	16/39 (41%; 27.1 - 56.6%)	358/953 (37.6%; 34.6 - 40.7%)	0.001
Functional Neurosurgery	69/431 (16%; 12.9 - 19.8%)	37/228 (16.2%; 12 - 21.6%)	51/255 (20.0%; 15.6 – 25.3%)	5/39 (12.8%; 5.6 - 26.7%)	162/953 (17%; 14.8 - 19.5%)	0.424
Neuro-endoscopy	76/431 (17.6%; 14.3 - 21.5%)	69/228 (30.3%; 24.7 - 36.5%)	84/255 (32.9%; 27.5 - 38.9%)	8/39 (20.5%; 10.8 - 35.5%)	237/953 (24.9%; 22.2 - 27.7%)	<0.001
Neuro-oncology	196/431 (45.5%; 40.8 - 50.2%)	104/228 (36.5%; 24.7 - 36.5%)	93/255 (36.5%; 30.8 - 42.5%)	10/39 (25.6%; 14.6 - 41.1%)	403/953 (42.3%; 39.2 - 45.5%)	0.004
Neurotrauma	133/431 (30.9%; 26.7 - 35.4%)	102/228 (44.7%; 38.4 - 51.2%)	100/255 (39.2%; 33.4 - 45.3%)	15/39 (38.5%; 24.9 - 54.1%)	350/953 (36.7%; 33.7 - 39.8%)	0.018
Paediatric Neurosurgery	80/431 (18.6%; 15.2 - 22.5%)	59/228 (25.9%; 20.6 - 31.9%)	61/255 (23.9%; 19.1 - 29.5%)	10/39 (25.6%; 14.6 - 41.1%)	210/953 (22%; 19.5 - 24.8%)	0.058
Skull Base Surgery	127/431 (29.5%; 25.4 - 33.9%)	78/228 (34.2%; 28.4 - 40.6%)	96/255 (37.7%; 31.9 - 43.7%)	16/39 (41%; 27.1 - 56.6%)	317/953 (33.3%; 30.3 - 36.3%)	0.013
Spinal Surgery	167/431 (38.8%; 34.3 - 43.4%)	110/228 (48.3%; 41.9 - 54.7%)	119/255 (46.7%; 40.6 - 52.8%)	16/39 (41%; 27.1 - 56.6%)	412/953 (43.2%; 40.1 - 46.4%)	0.065
Other	19/431 (4.4%; 2.8 - 6.8%)	7/228 (3.1%; 1.5 - 6.2%)	9/255 (3.5%; 1.9 - 6.6%)	1/39 (2.6%; 0.5 - 13.2%)	36/953 (3.8%; 2.7 - 5.2%)	0.417
Table Legend: Young neurosurgery responses on main subspecialty interests by World Bank Income Classification (n=953) presented as absolute and relative frequencies with 95% confidence interval.						

Table 3: Responses to Questions Regarding Access to Space, Equipment and Services						
Variables	**High-income Economies**	**Upper-middle-income Economies**	**Lower-middle-income Economies**	**Low-income Economies**	**Total**	**p-value**
Hospital Beds						<0.001
≤ 500 beds	104/ 431 (24.1%; 20.3 - 28.4%)	111/ 228 (48.7%; 42.3 - 55.1%)	116/ 255 (45.5%; 39.5 - 51.6%)	18/ 39 (46.2%; 31.6 - 61.4%)	349/ 953 (36.6%; 33.6 - 39.7%)	
500 to 1000 beds	173/ 431 (40.1%; 35.6 - 44.8%)	78/ 228 (34.2%; 28.4 - 40.6%)	75/ 255 (29.4%; 24.2 - 35.3%)	18/ 39 (46.2%; 31.6 - 61.4%)	344/ 953 (36.1%; 33.1 - 39.2%)	
> 1000 beds	154/ 431 (35.7%; 31.4 - 40.4%)	39/ 228 (17.1%; 12.8 - 22.5%)	64/ 255 (25.1%; 20.2 - 30.8%)	3/ 39 (7.7%; 2.7 - 20.3%)	260/ 953 (27.3%; 24.6 - 30.2%)	
Dedicated Neurosurgical Wards	371/ 431 (86.1%; 86.1 - 89%)	163/ 228 (71.5%; 65.3 - 77%)	184/ 255 (72.2%; 66.4 - 77.3%)	25/ 39 (64.1%; 48.4 - 77.3%)	743/ 953 (78%; 75.2 - 80.5%)	<0.001
Neurosurgical Beds						0.966
< 25	97/ 431 (22.5%; 18.8 - 26.7%)	77/ 228 (33.8%; 28 - 40.1%)	70/ 255 (27.5%; 22.3 - 33.2%)	17/ 39 (43.6%; 29.3 - 59%)	261/ 953 (27.4%; 24.7 - 30.3%)	
25-50	182/ 431 (42.2%; 37.7 - 46.9%)	83/ 228 (36.4%; 30.4 - 42.8%)	82/ 255 (32.2%; 26.7 - 38.1%)	13/ 39 (33.3%; 20.6 - 49%)	360/ 953 (37.8%; 34.8 - 40.9%)	
50-75	89/ 431 (20.7%; 17.1 - 24.7%)	30/ 228 (13.2%; 9.4 - 18.2%)	44/ 255 (17.3%; 13.1 - 22.4%)	7/ 39 (18%; 9 - 32.7%)	170/ 953 (17.8%; 15.5 - 20.4%)	
75-100	35/ 431 (8.1%; 5.9 - 11.1%)	18/ 228 (7.9%; 5.1 - 12.1%)	24/ 255 (9.4%; 6.4 - 13.6%)	2/ 39 (5.1%; 1.4 - 16.9%)	79/ 953 (8.3%; 6.7 - 10.2%)	
> 100	28/ 431 (6.5%; 4.5 - 9.2%)	20/ 228 (8.8%; 5.8 - 13.2%)	35/ 255 (13.7%; 10 - 18.5%)	0/ 39 (0%; 0 - 9%)	83/ 953 (8.7%; 7.1 - 10.7%)	
Equipment and Services Access						
Computed tomography	426/ 431 (98.8%; 97.3 - 99.5%)	225/ 228 (98.7%; 96.2 - 99.6%)	250/ 255 (98%; 95.5 - 99.2%)	39/ 39 (100%; 91 - 100%)	940/ 953 (98.6%; 97.7 - 99.2%)	0.690
Magnetic resonance imaging	425/ 431 (98.6%; 97 - 99.4%)	198/ 228 (86.8%; 81.8 - 90.6%)	229/ 255 (89.8%; 85.5 - 92.9%)	26/ 39 (66.7%; 51 - 79.4%)	878/ 953 (92.1%; 90.3 - 93.7%)	<0.001
Catheter angiography	389/ 431 (90.3%; 87.1 - 92.7%)	149/ 228 (65.4%; 59 - 71.2%)	141/ 255 (55.3%; 49.2 - 61.3%)	4/ 39 (10.3%; 4.1 - 23.6%)	683/ 953 (71.7%; 68.7 - 74.4%)	<0.001
Operating microscope	427/ 431 (99.1%; 97.6 - 99.6%)	212/ 228 (93%; 88.9 - 95.6%)	212/ 255 (83.1%; 78.1 - 87.2%)	24/ 39 (61.5%; 45.9 - 75.1%)	875/ 953 (91.8%; 89.9 - 93.4%)	<0.001
Image guidance system (navigation)	388/ 431 (90%; 86.8 - 92.5%)	96/ 228 (42.1%; 35.9 - 48.6%)	86/ 255 (33.7%; 28.2 - 39.7%)	5/ 39 (12.8%; 5.6 - 26.7%)	575/ 953 (60.3%; 57.2 - 63.4%)	<0.001
High-speed drill	423/ 431 (98.1%; 96.4 - 99.1%)	198/ 228 (86.8%; 81.8 - 90.6%)	186/ 255 (72.9%; 67.2 - 78%)	17/ 39 (43.6%; 29.3 - 59%)	824/ 953 (86.5%; 84.1 - 88.5%)	<0.001
Intensive care unit	429/ 431 (99.5%; 98.3 - 99.9%)	225/ 228 (98.7%; 96.2 - 99.6%)	245/ 255 (96.1%; 92.9 - 97.9%)	36/ 39 (92.3%; 79.7 - 97.4%)	935/ 953 (98.1%; 97 - 98.8%)	<0.001
Mechanical ventilators in the ICU	409/ 431 (95.3%; 92.9 - 97%)	222/ 228 (98.7%; 96.2 - 99.6%)	235/ 255 (95.9%; 92.7 - 97.8%)	35/ 39 (97.2%; 85.8 - 99.5%)	901/ 953 (96.4%; 95 - 97.4%)	0.083
Rehabilitation specialists	397/ 431 (92.1%; 89.2 - 94.3%)	176/ 228 (77.2%; 71.3 - 82.2%)	178/ 255 (69.8%; 63.9 - 75.1%)	19/ 39 (48.7%; 33.9 - 63.8%)	770/ 953 (80.8%; 78.2 - 83.2%)	<0.001

Table Legend: Summary of young neurosurgery respondents (n=953) as it relates to access to space, equipment and services by World Bank Income Classification. Data presented as absolute and relative frequencies with 95% confidence interval.

Table 4: Responses Pertaining to Training and Education						
Questions	**High-income Economies**	**Upper-middle-income Economies**	**Lower-middle-income Economies**	**Low-income Economies**	**Total**	**p-value**
Do you have time dedicated for neurosurgical education	294/431 (68.2%; 63.7 - 72.4%)	156/228 (68.4%; 62.1 - 74.1%)	200/255 (78.4%; 73 - 83%)	30/39 (76.9%; 61.7 - 87.4%)	680/953 (71.4%; 68.4 - 74.1%)	0.006
Do you have a departmental journal club?	224/431 (52%; 47.3 - 56.7%)	70/228 (30.7%; 25.1 - 37%)	123/255 (48.2%; 42.2 - 54.4%)	11/39 (28.2%; 16.6 - 43.8%)	428/953 (44.9%; 41.8 - 48.1%)	0.015
Do you have access to regular hands-on cadaveric training courses in your department?	103/431 (23.9%; 20.1 - 28.2%)	19/228 (8.3%; 5.4 - 12.6%)	40/255 (15.7%; 11.7 - 20.7%)	8/39 (20.5%; 10.8 - 35.5%)	170/953 (17.8%; 15.5 - 20.4%)	0.008
Are you a member of a national neurosurgical society	357/431 (82.8%; 79 - 86.1%)	159/228 (69.7%; 63.5 - 75.3%)	195/255 (76.5%; 70.9 - 81.3%)	26/39 (66.7%; 51 - 79.4%)	737/953 (77.3%; 74.6 - 79.9%)	0.005
Attended a WFNS conference or a WFNS supported meeting before						
Never	296/431 (68.7%; 64.2 - 72.9%)	117/228 (51.3%; 44.9 - 57.7%)	136/255 (53.3%; 47.2 - 59.4%)	18/39 (46.2%; 31.6 - 61.4%)	567/953 (59.5%; 56.4 - 62.6%)	<0.001
Once	77/431 (17.9%; 14.5 - 21.8%)	76/228 (33.3%; 27.5 - 39.7%)	69/255 (27.1%; 22 - 32.8%)	12/39 (30.8%; 18.6 - 46.4%)	234/953 (24.6%; 21.9 - 27.4%)	
Twice	25/431 (5.8%; 4 - 8.4%)	16/228 (7%; 4.4 - 11.1%)	23/255 (9%; 6.1 - 13.2%)	2/39 (5.1%; 1.4 - 16.9%)	66/953 (6.9%; 5.5 - 8.7%)	
More than 2 times	33/431 (7.7%; 5.5 - 10.6%)	19/228 (8.3%; 5.4 - 12.6%)	27/255 (10.6%; 7.4 - 15%)	7/39 (18%; 9 - 32.7%)	86/953 (9%; 7.4 - 11%)	

Table Legend: Summary of young neurosurgeons survey (n=953) as it relates to training and education by World Bank Income Classification. Data presented as absolute and relative frequencies with 95% confidence interval.

Abbreviations: aSAH, Aneurysmal subarachnoid haemorrhage; CT, Computed tomography; HICs, High-income countries; ICU, Intensive care unit; LICs, Low-income countries; LMICs, Low-middle income countries; MRI, Magnetic resonance imaging; UMICs, Upper-middle income countries; WINS, Women in Neurosurgery.

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P. David Adelson: Conceptualization, Writing - Review & Editing

Franco Servadei: Conceptualization, Writing - Review & Editing

Ignatius N Esene: Conceptualization, Data Curation, Writing - Review & Editing

Amro Al-Habib: Conceptualization, Writing - Review & Editing

Angelos G. Kolias: Conceptualization, Methodology, Investigation, Data Curation, Writing - Review & Editing