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CLINICAL ARTICLE

Mapping the global neurosurgery workforce. Part 2: Trainee density

Saksham Gupta, MD,[1,2] Zsombor T. Gal, BA,[3] Tejas S. Athni, MS,[3] Chrystal Calderon, MBBS,[4] William É. Callison, PhD,[3] Olaoluwa E. Dada,[5] Winston Lie, MSc,[3] Carolyn Qian, BS,[3] Ramya Reddy, BS,[6] Myron Rolle, MD,[7] Ronnie E. Baticulon, MD,[8] Bipin Chaurasia, MS,[9] Ellianne J. Dos Santos Rubio, MD,[10] Yoshua Esquenazi, MD,[11] Alexandra J. Golby, MD,[1] Ahmad F. Pirzad, MD,[12] and Kee B. Park, MD, MPH,[2] on behalf of the WFNS Global Neurosurgery Committee, EANS Global and Humanitarian Neurosurgery Committee, and CAANS Executive Leadership Committee

[1]Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts; [2]Department of Global Health and Social Medicine, Program for Global Surgery and Social Change, Harvard Medical School, Boston, Massachusetts; [3]Harvard Medical School, Boston, Massachusetts; [4]Department of Neurosurgery, University of the West Indies, St. Augustine, Trinidad and Tobago; [5]College of Medicine, University of Ibadan, Oyo State, Nigeria; [6]University of Florida College of Medicine, Gainesville, Florida; [7]Department of Neurosurgery, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts; [8]Department of Neurosciences, Division of Neurosurgery, Philippine General Hospital, University of the Philippines, Manila, National Capital Region, Philippines; [9]Department of Neurosurgery, Neurosurgery Clinic, Birgunj, Madesh Province, Nepal; [10]Department of Neurosurgery, Curaçao Medical Center, Willemstad, Curaçao; [11]Department of Neurosurgery, The University of Texas Health Science Center, Houston, Texas; and [12]Department of Neurosurgery, Kabul University of Medical Sciences, Kabul, Afghanistan

OBJECTIVE A sustainable neurosurgery workforce depends on robust training pipelines, but the size and distribution of the global neurosurgery trainee workforce has not been described. The objective of this study was to identify the types of training programs that exist in the global neurosurgery workforce, the support that trainees receive, the diversity of trainee experiences, and the accreditation processes that exist to regulate training programs.

METHODS This study was a subanalysis of a cross-sectional survey administered online in all 193 countries and 26 territories, independent states, and disputed regions as defined by the World Bank and United Nations. Participants were identified through neurosurgery society leadership, the personal contacts of the coauthors, and bibliometric and search engine searches. Population-weighted statistics were constructed and segregated by country income level and WHO regions.

RESULTS Data were obtained for 187 countries (96.9%) and 25 additional territories, states, and disputed regions (96.2%). There were an estimated 1261 training programs and 10,546 trainees within the regions sampled, representing a global pooled density of 0.14 neurosurgery trainees per 100,000 people and a median national density of 0.06 trainees per 100,000 people. There was a higher density in high-income countries (HICs; 0.48 trainees per 100,000 people) compared with upper-middle-income countries (0.09 per 100,000), lower-middle-income countries (0.06 per 100,000), and low-income countries (LICs; 0.07 per 100,000). The WHO European (0.36 per 100,000) and Americas (0.27 per 100,000) regions had the highest trainee densities, while the Southeast Asia (0.04 per 100,000) and African (0.05 per 100,000) regions had the lowest densities. Among countries with training programs, LICs had the poorest availability of subspecialty training and resources such as cadaver laboratories and conference stipends for trainees. Training program accreditation processes were more common in HICs (81.8%) than in low- and middle-income countries (LMICs; 69.2%) with training programs.

CONCLUSIONS The authors estimate that there are at least 1261 neurosurgery training programs with 10,546 total trainees worldwide. The density of neurosurgery trainees was disproportionately higher in HICs than LMICs, and the WHO European and Americas regions had the highest trainee densities. The trainee workforce in LICs had the poorest access to subspecialty training and advanced resources.

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KEYWORDS neurosurgery workforce; capacity building; global neurosurgery; education

ABBREVIATIONS COSECSA = College of Surgeons of East, Central, and Southern Africa; HIC = high-income country; LIC = low-income country; LMIC = low- and middle-income country; LoMIC = lower-middle-income country; UpMIC = upper-middle-income country; WB = World Bank.

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A sustainable neurosurgery workforce depends on the development and maintenance of robust training systems that prepare medical graduates to manage its population's neurosurgery needs.[1] There is a tremendous variation of neurosurgery training practices across the world. Some countries rely on apprenticeship models with individual neurosurgeons, while others have standardized and regulated training requirements. Some countries have no trainees in place to sustain their future workforce.[2]

The main purpose of trainees is education so that they can join the consultant workforce, but they also use their training to provide value to the hospitals in which they work, often providing around-the-clock coverage for emergency services and operating rooms. One United States institution estimated the collective work of their on-call neurosurgery residents could generate more than $1.6 million annually in potential reimbursements.[3]

In this study, we sought to provide the first systematic estimation of the density of neurosurgery trainees and opportunities. These data are designed to help neurosurgeons, neurosurgery departments, and neurosurgery societies guide their educational efforts to improve access to neurosurgery training worldwide.

Methods

Objectives

The primary objective of this study was to quantify the number and distribution of neurosurgery trainees around the world. Secondary objectives included identifying the types of training programs that exist, the support that trainees receive, the diversity of trainee experiences, and the accreditation processes that exist to regulate training programs. This study was exempted from review by the Harvard Medical School IRB.

Study Design and Data Sources

The study protocol is detailed in our companion paper.[45] Briefly, this paper is a subanalysis of a global cross-sectional survey with a hierarchical sample collection that was administered between October 2022 and March 2023 (Supplementary Fig. 1). Survey results were elicited from representatives in the 193 countries and 26 territories, independent states, and disputed regions defined by the World Bank (WB) and United Nations. All participants were either attending neurosurgeons, residents or fellows in neurosurgery, or general surgeons (n = 1) with medical doctorate degrees or equivalents (i.e., MBBS, MBBCh, etc.). Data were not obtained for 6 countries (Cuba, Iraq, Nigeria, Qatar, Tajikistan, and Turkey) and 1 independent economy (Macau), and the data available represented 96.9% of all countries and 95.4% of the global population. Countries with a population of fewer than 80,000 people were assumed to have no neurosurgery trainees if online public information was available about their hospitals and indicated no existing neurosurgery services.

Countries were classified by 2021 WB designation into low-income countries (LICs), lower-middle-income countries (LoMICs), upper-middle-income countries (UpMICs), and high-income countries (HICs).[4] All non-HICs are collectively referred to as low- and middle-income countries (LMICs).

Statistical Analysis

All statistical analysis was performed in R (version 4.2.1, The R Project). Descriptive population-weighted statistics were calculated. Given the near-complete data collection, trainee densities in this study were assumed to be representative of global trainee densities.

Results

Survey Respondents

There were 171 survey respondents who provided data for 187 (96.9%) of 193 countries and 25 (96.2%) of 26 additional territories, independent states, and disputed regions as defined. The median age of the participants was 43 (interquartile range 36–55) years and 12.3% were women. Respondents included leaders of neurosurgery societies (n = 4, 2.3%), department chairs (n = 30, 17.5%), consultant neurosurgeons (n = 102, 59.6%), and residents and fellows (n = 29, 17.0%), among others. Most respondents had affiliations with organized neurosurgery societies (81.9%) and were practicing in LMICs (63.7%).

Trainee Workforce and Training Programs

There were an estimated 1261 training programs with 10,546 neurosurgery trainees in the countries and other regions sampled worldwide (excluding Cuba, Iraq, Qatar, Macau, Nigeria, Tajikistan, and Turkey), representing a pooled global trainee density of 0.14 per 100,000 people and a median trainee density of 0.06 per 100,000 people (Fig. 1). The pooled trainee densities in HICs, UpMICs, LoMICs, and LICs were 0.48, 0.09, 0.06, and 0.07 trainees per 100,000 people, respectively (Fig. 2A). The WHO Southeast Asia and African regions had the lowest pooled trainee density (0.04 and 0.05 trainees per 100,000 people, respectively; Fig. 2B). The WHO European and Americas regions had the highest density (0.36 and 0.27 trainees per 100,000 people, respectively; Fig. 2B).

The majority of training programs were in HICs (n = 696) rather than LMICs (n = 531). There were no training programs in 22.4% of HICs and 35.2% of LMICs. Training programs varied by type: countries with training programs had postgraduate neurosurgery residencies (89.8%), neurosurgery fellowships after a general surgery residency (40.6%), and postgraduate neurosurgery apprenticeships with individual surgeons (39.1%). Among 109 countries that had training programs and available data on training accreditation, 81 programs (74.3%) had a formal accreditation process to certify their programs. There were accreditation processes in place in 36 (81.8%) of 44 HICs and 45 (69.2%) of 65 LMICs with available data on accreditation.

Subspecialization and Resources

Trainees in LICs tended to have less access to training in neurotrauma, neurocritical care, tumor, open vascular, endovascular, functional, pediatric, spine, and peripheral nerve surgery than trainees in UpMICs/LoMICs, who had

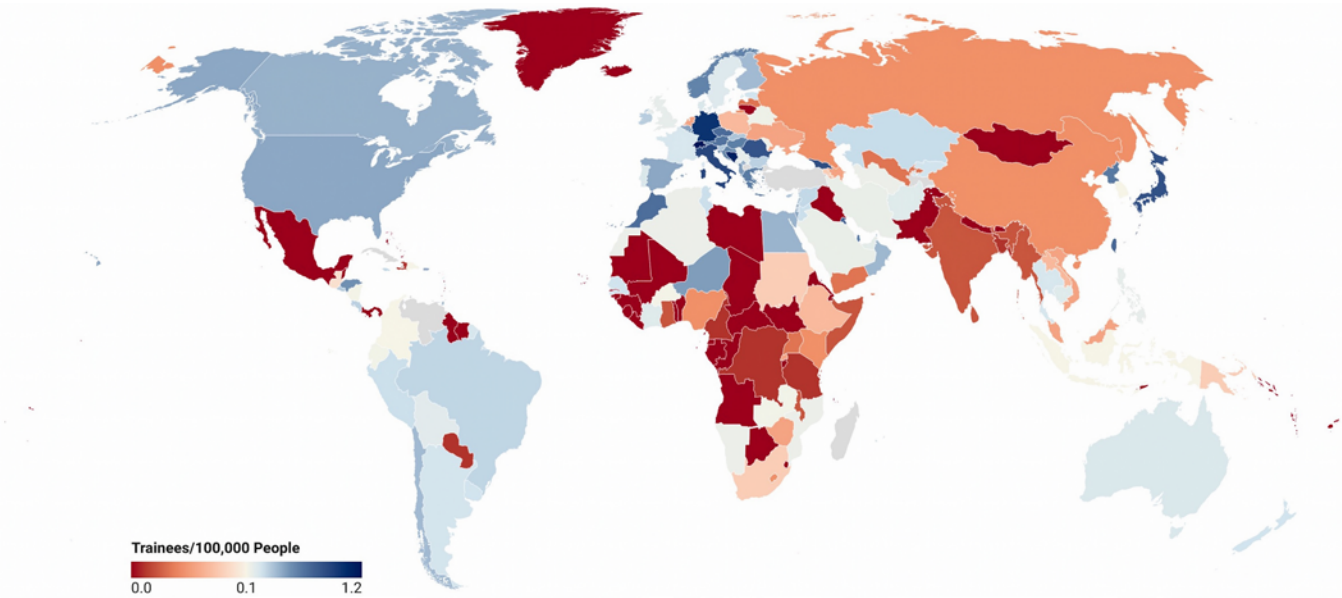

FIG. 1. Map showing the neurosurgery trainee density per 100,000 people. Countries near the average national median density (0.1 trainees per 100,000 people) are demonstrated in *white*, those increasingly above the median are demonstrated in increasingly *dark blue*, and those increasingly below the median are demonstrated in increasingly *dark red*. This figure was created with Datawrapper (Datawrapper GmbH).

less access than trainees in HICs (Fig. 3). The greatest differences between HICs and LICs were in the percentage of trainees with exposure to functional and movement disorder surgery (57.4% vs 4.0%) and endovascular neurosurgery (54.9% vs 6.4%). Furthermore, trainees in LICs had lower access to cadaver laboratories and stipends for conferences and clinical travel (Fig. 3).

Discussion

We estimate that there are approximately 1261 neurosurgery training programs and 10,546 trainees worldwide, and that the density of trainees is many times higher in HICs than UpMICs, LoMICs, and LICs. We identified several regional disparities in trainee workforce density, including fewer trainees per population in the WHO Southeast Asia and African regions. Trainees in LICs also had the least exposure to subspecialty training. These data serve as a baseline estimate to measure and monitor the growth of the neurosurgery trainee workforce. Although there is no recommended per capita density of neurosurgery trainees, the wide discrepancy between HICs and LMICs suggests that there is a dire need for more trainees, formal training programs, and subspecialization training in LMICs. These data can also help organizations and societies plan their educational outreach and development efforts.

Data Evaluation

Improving surgical educational opportunities has been identified as a priority in LMICs.[5] Similar to other surgical subspecialties, fewer neurosurgery training programs and a smaller trainee density was identified in LMICs compared with HICs. This disparity is likely linked to other

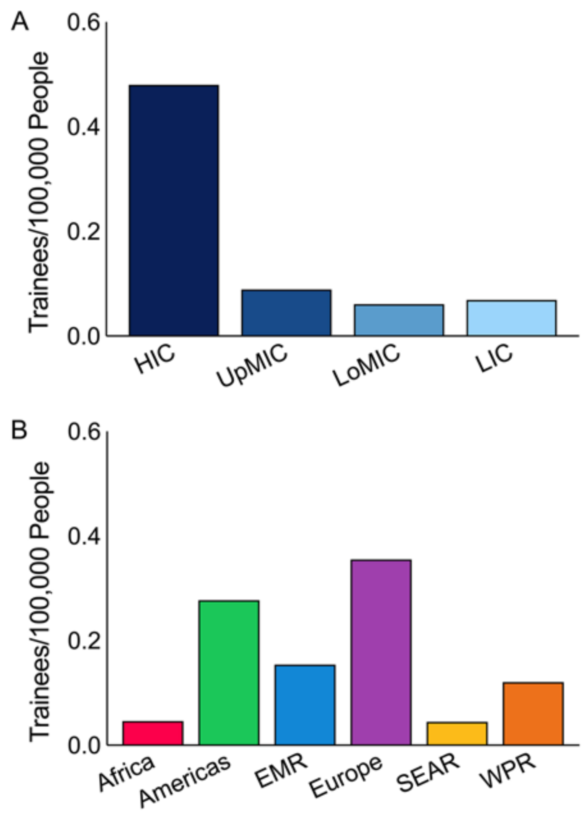

FIG. 2. Bar graphs of neurosurgery trainee density according to country income levels (**A**) and WHO regions (**B**). EMR = Eastern Mediterranean region; SEAR = Southeast Asia region; WPR = Western Pacific region.

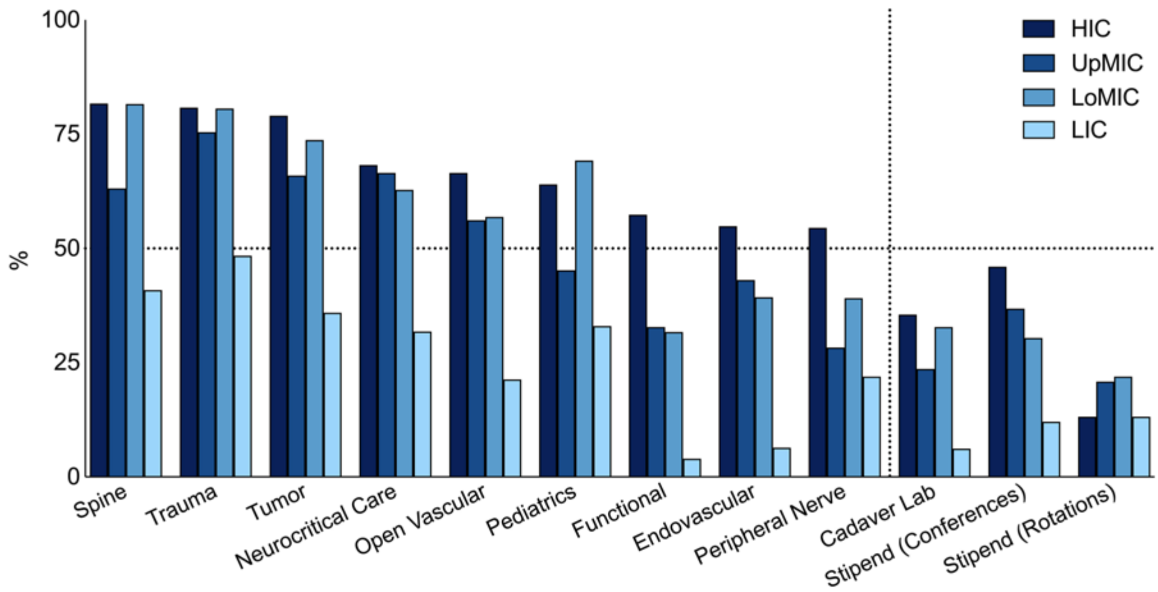

FIG. 3. Bar graph of the proportion of trainees in HICs, UpMICs, LoMICs, and LICs with access to various subspecialty training and training resources (cadaver laboratories and stipends). Only countries with trainees are included. The *vertical dotted line* separates training availability in specific neurosurgery subspecialties (*left side of the line*) and extra general materials available to trainees (*right side of the line*).

drivers of worse medical outcomes overall in LMICs, including less robust health systems, less medical infrastructure, and less financing for healthcare and medical education. This study also expands upon prior work identifying the relative lack of subspecialty training opportunities, cadaveric dissection laboratories, and resources for research in certain LMIC contexts.[6–8] We found that neurosurgery trainees in lower-income countries tended to have less exposure to subspecialty topics and access to resources for training and research. This difference was especially stark for functional and vascular surgery, which limits the ability of trainees in LICs to provide care for epilepsy and stroke (Fig. 3). Disparities in exposure to spine and peripheral nerve surgery were also identified, but these disparities do not account for the quantity of trainees in other specialties who overlap in managing these conditions (i.e., orthopedics or plastic surgery).

There is also room for improvement for trainee subspecialization training in HICs, especially given the known associations with a focused and subspecialized practice and clinical outcomes for complex neurosurgery.[9–12] There is momentum and pressure in HICs to increase trainee exposure to topics in global neurosurgery. For example, surveys and working groups have demonstrated that trainees and consultants in HICs feel high levels of interest, but have limited opportunities for involvement during training and into their careers.[13–15]

The WHO Southeast Asia and African regions had the lowest trainee densities. Southeast Asia contains a diverse range of nations, including the highly population-dense Bangladesh and India, and the island-based Indonesia, Sri Lanka, and the Maldives. Each of these geographies brings their own challenges and opportunities for neurosurgery, especially in effective patient triage.[16,17] Several innovative attempts have been made by Southeast Asian neurosurgeons and collaborators to improve the quality of training, including a recent educational boot camp in Myanmar.[18] There have been several centralized attempts to standardize and expand neurosurgery training in India, proposals to lengthen training times, and incorporate skills laboratories for all trainees.[17] Trainees may also be deployed in locations that can serve their education and improve access to care, which is currently implemented in Indonesia.

Surveys of young neurosurgeons and trainees in Africa highlighted some of the educational limitations that most trainees face, including low exposure to educational conferences, inability to attend national/international research conferences, and low access to cadaver laboratories.[19,20] Major regional training centers are organized by the West African College of Surgeons and the College of Surgeons of East, Central, and Southern Africa (COSECSA), so supporting and working with these organizations may help build more training opportunities.[21] There is a growing movement promoting global neurosurgery among medical students in African countries, so capitalizing on this motivation by increasing training opportunities for these students is paramount to fulfilling and sustaining the global neurosurgery workforce needs.[22,23] Regional multi-institutional efforts to understand the stopgaps in the training pipeline serve as an example to other LMIC contexts with low trainee densities.[7,24,25]

The WHO European and Americas regions have the highest trainee densities. There is a need in these regions to expand neurosurgery education to include topics in global neurosurgery, particularly for HIC trainees, to improve the confidence of trainees in global neurosurgery and in broader public health advocacy.[13,24,26,27]

Solutions to the Trainee Shortage

Several solutions to the global trainee shortage have been posited, ranging from regional training conferences, "twinning" programs between departments and societies,[15,27–30] virtual education,[31–33] novel technologies that facilitate real-time remote collaboration and teaching,[31] and collaborative training opportunities, among others.[34–36] Neurosurgery trainees also report that insufficient funding or the need to pay for their own education are considerable barriers to training.[37] Regional educational centers of excellence such as CURE Uganda may help reduce costs associated with subspecialty training, which is often located in HICs.[38]

Regional and national neurosurgery societies are encouraged to develop formal accreditation processes for training programs in all countries. These processes should have a minimum set of standards and contain additional training requirements depending on each country's disease burden.

In particular, the quality of training is diverse and variable across the African region. This situation is complex due to the region's historical colonial legacy, resulting in Anglophone/Francophone programs across the region. Suggestions to harmonize such programs are now regularly promoted; one such approach would be to promote the development of an Anglophone African Board of Neurological Surgery encompassing the Anglophone training programs in the East, Central, and Southern Africa Region (e.g., COSECSA), the West African College, the South African College of Neurosurgeons, and the Egyptian training programs; and a separate Francophone African Board of Neurological Surgery encompassing the diverse Francophone programs in North and West Africa. In due course, the two lingual groups would consider developing a unified African Board of Neurological Surgery.

Cadaveric dissection laboratories are a gold standard for trainees to practice complex approaches outside the operating room, and expanding access to these laboratories can improve trainee confidence.[39] Several efforts to develop regional dissection laboratories have benefitted dozens to hundreds of trainees and consultants.[40] A variety of novel digital/virtual/augmented reality tools and simulation models may be effective tools to supplement education when cadaver laboratories are unavailable, particularly as endovascular treatment modalities have reduced trainee exposure to skull base approaches in open vascular cases.[13,24,33,41] Neurosurgery education is not limited to trainees; longitudinal outreach programs (including "twinning" programs) and courses educate consultant neurosurgeons and trainees in complex neurosurgery with the goal of creating self-sustaining training programs.[28,42–44]

There are several challenges in building a system to provide neurosurgical care that are related to building the trainee workforce. Neurosurgery training should be based on the needs and resources of each population, including HIC-led education courses for LMIC trainees. Trainees also depend on sufficient resources and the presence of allied professionals (nurses, first responders, neuromonitoring technicians) to focus on learning neurosurgery.

Setting Targets for 2030

The authors posit the need for a central, organized effort to estimate the neurosurgery trainee workforce and resources available to trainees in 2030. Targets for 2030 should be set after multilateral discussions with representatives from national and regional neurosurgery societies present and should establish goals for the neurosurgery trainee density in countries in different WHO regions and WB income levels. They should set goals for how training should be different according to specific national needs, and how centers of excellence in each WHO region can be used to support trainees in nations with poor opportunities. The de-identified data from this study and future efforts should be centrally stored to allow for trend analysis.

Limitations of the Study

This study has several pertinent limitations. Selection bias is present in the participants selected, given that the majority were found either through already-existing personal connections in global neurosurgery or through bibliometric searches, which is more likely to identify academic neurosurgeons. This bias may result in an overestimation of the trainee workforce given a potential desire of participants to inflate their workforce numbers to improve their reputation. Participants may also be biased to underestimate trainee numbers to encourage external support for their trainees. This study does not include trainees that are not formally neurosurgeons, but do perform some neurosurgery procedures in locations where task-sharing and task-shifting are necessary, so the workforce may be underestimated in some lower-income or developing countries.

Conclusions

There are an estimated 10,546 neurosurgery trainees in 1261 training programs around the world, representing a pooled global density of 0.14 neurosurgery trainees per 100,000 people. The consultant neurosurgeon density was higher in HICs than UpMICs, LoMICs, and LICs, and the trainee density was highest in the WHO European region. Most training programs were in HICs, and programs in HICs were more likely to have accreditation processes. Trainees in LICs had the least access to subspecialty training and cadaver laboratories.

Appendix

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[1]Section of Neurosurgery, Department of Surgery, Aga Khan University Hospital, Nairobi, Kenya; [2]Department of Neurosurgery, Mohammed Vth University, School of Medicine, Hôpital des Spécialités ONO, Rabat, Morocco; [3]Department of Neurosurgery, Northwest School of Medicine, Peshawar, Khyber Pakhtunkhwa, Pakistan; [4]Division of Neurosurgery, Department of Clinical Neurosciences, Addenbrooke's Hospital and University of Cambridge, Cambridgeshire, United Kingdom; [5]Department of Neurosurgery, Royal Infirmary, Edinburgh, Lothian, United Kingdom; [6]Department of Neurosurgery, University Clinical Center of Serbia, Belgrade, Serbia; [7]Department of Neurosurgery, AHEPA University Hospital, Medical School, Aristotle University of Thessaloniki, Greece; [8]Department of Neurosurgery, Mediclinic Parkview Hospital, Dubai, UAE; [9]Department of Neurosurgery, General University Hospital Alicante, Spain; [10]Department of Neurosurgery, Sheffield Teaching Hospital, NHS Foundation Trust, Sheffield, South Yorkshire, United Kingdom; [11]Spine Center, Hospital Del Mar, Barcelona, Catalonia, Spain; [12]Department of Neurosurgery, University Hospital Borgo Trento, Verona, Veneto, Italy; [13]Department of Neurosurgery, University Hospital of Trauma, Tirana, Albania; [14]Department of Neurosurgery, International Neuroscience Institute, Hannover, Lower Saxony, Germany; [15]Department of Neurosurgery, Medical University Innsbruck, Tyrol, Austria; [16]Department of Neurosurgery, University Hospital Sisters of Mercy, Zagreb, Croatia; [17]Federal Neurosurgical Center, Novosibirsk, Novosibirsk Oblast, Russian Federation; [18]Department of Neurosurgery, Leeds General Infirmary, Leeds, West Yorkshire, United Kingdom; [19]Department of Neurosurgery, Sahlgrenska University Hospital, Göteborg, Västra Götaland, Sweden; [20]Institute of Neurosurgery, Catholic University of Rome, Roma Provincia, Italy; and [21]Faculty of Health Sciences, University of Bamenda, Bambili, Cameroon.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Gupta, Gal, Athni, Calderon, Callison, Dada, Lie, Qian, Reddy, Rolle, Chaurasia, Park. Acquisition of data: Gupta, Gal, Athni, Calderon, Callison, Dada, Lie, Qian, Reddy, Rolle, Baticulon, Chaurasia, Dos Santos Rubio, Esquenazi, Golby, Park. Analysis and interpretation of data: Gupta, Baticulon, Chaurasia, Dos Santos Rubio, Esquenazi, Golby, Park. Drafting the article: Gupta, Pirzad. Critically revising the article: Gupta, Gal, Athni, Calderon, Callison, Dada, Lie, Qian, Reddy, Rolle, Baticulon, Chaurasia, Golby, Park. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Gupta. Statistical analysis: Gupta, Gal, Park. Administrative/technical/material support: Pirzad, Park. Study supervision: Chaurasia, Golby, Park.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplementary Fig. 1. https://thejns.org/doi/suppl/10.3171/2023.9.JNS231616.

Companion Papers

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Correspondence

Saksham Gupta: Brigham and Women's Hospital, Boston, MA. sgupta@bwh.harvard.edu.