Global Neurosurgery

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Global Neurosurgery

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General Introduction

Adapted from:

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Journal of Neurosurgery. 2018;130(4):1107-1126.

The impact of the COVID-19 pandemic on neurosurgery worldwide.
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The Role of Policy in Global Neurosurgery.
Robertson FC, Park KB, Johnson WD.
Neurosurgery Clinics of North America on Global Neurosurgery. 2024 Oct;35(4):401-410. doi: 10.1016/j.nec.2024.05.002. Epub 2024 Jul 2. PMID: 39244312

The general introduction to this thesis includes an introduction to the field of global neurosurgery, an introduction to the current barriers to care delivery, and a brief outline of the thesis contents.

GLOBAL BURDEN OF SURGICAL DISEASE

Historically, the global health agenda has focused on mitigating the burden of communicable diseases such as HIV/AIDS, malaria and tuberculosis,[1,2] while the burden of non-communicable disease, which often requires surgery for treatment, has received little priority in global health discussions and interventions.[2,3] Paul Farmer and Jim Kim famously underscored this issue by publishing an article coining surgery as "*the neglected stepchild of global health.*"[4] Though public health attention to infectious disease is critical, the burden of diseases that require surgical treatment now outnumbers the burden of HIV/AIDS, malaria and tuberculosis combined.[1,2,4] Importantly, with the projected increase in the incidence of non-communicable diseases in developing nations (e.g. cancer, road traffic injuries, cardiovascular disease and metabolic disorders), the need for surgical capacity in low resource settings will continue to escalate between now and 2030.[1] Furthermore, recent efforts to elucidate the effectiveness of global health interventions emphasize that surgery is an essential component of a properly functioning health system.[5-8] The 2015 Lancet Commission on Global Surgery reported that over five billion people worldwide lack timely access to safe and affordable surgical care, and 30-percent of disability-adjusted life years lost are due to surgical conditions.[1] This unmet need predominantly affects low- and middle-income countries (LMICs) where it amounts to an annual requirement of 143 million essential procedures that go unperformed. Addressing this disparity can prevent an estimated 1.5 million annual deaths. Consequently, mitigating surgical morbidity and mortality by improving timely access to safe and affordable surgery has become a common goal for health systems.[9,10]

The Lancet Commission established a target for countries to be able to deliver 5000 operations per 100,000 population by the year 2030, and denoted that the workforce density of surgeons, anaesthesiologists and obstetricians should be at or above 20 per 100,000 population.[1] It is estimated to cost $420 billion US dollars to scale up surgical care in LMICs by 2030. While this would be a major capital investment, a failure to scale up will continue to drive losses in economic productivity and is estimated to cost $12.3 trillion.[6] Therefore, devoting resources to the infrastructure and workforce for surgical services in LMICs is both a financially and morally sound investment that will save millions of lives. Consequently, the 2015 World Health Assembly Resolution 68.15 designated that strengthening emergency and essential surgery is a necessary part of universal health coverage.[11] On September 25, 2015 the United Nations issued 17 Sustainable Development Goals for 2030.[12] Of these 17, 14 require building surgical capacity and have direct or indirect relevance to

neurosurgeons and neurosurgical care delivery.[13] Global surgery is now gaining momentum on the global political agenda, and neurosurgery is integral to surgical system strengthening.

GLOBAL BURDEN OF NEUROSURGICAL DISEASE

Global neurosurgery as a field is defined as the clinical and public health practice of neurosurgery with the primary purpose of ensuring timely, safe, and affordable neurosurgical care to all who need it.[14, 15] It includes the practice, study, and advocacy of neurosurgery on a global scale, including efforts to address access to neurosurgical care and resources across different regions and countries.

Neurosurgery is an important division within health system strengthening given both the disease burden and cost-effectiveness.[14,15] Each year, approximately 5 million essential neurosurgical cases go untreated, and over 23,000 more neurosurgeons are needed in low- and middle-income countries (LMICs) to address this treatment gap (**Figure 1**).[16] The majority of neurologic conditions arise from non-communicable diseases such as traumatic brain injury (TBI), stroke, hydrocephalus, tumors, epilepsy, but communicable disease or infection also plays a significant role.

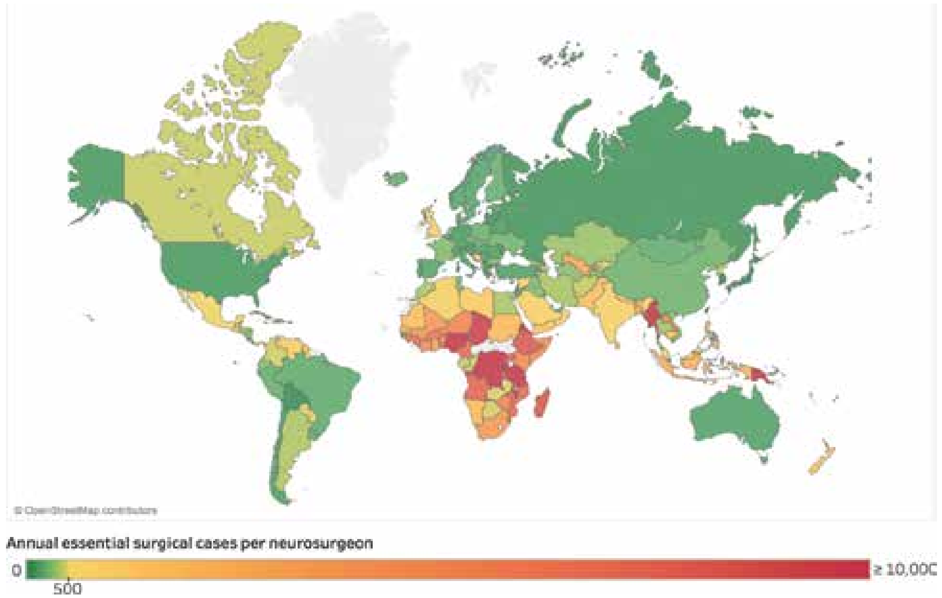

Figure 1. The global deficit of neurosurgical care: operations. ©OpenStreetMap contributors (http://www.openstreetmap.org/copyright). Figure is available in color online only.[15]

Emergent Neurosurgical Pathologies

The ability to perform emergency surgical procedures for TBI, stroke, spinal cord injury, or acute infection is especially important, as rapid action is integral to patient survival. Regarding trauma, 69 million individuals suffer from all-cause TBI annually, particularly in the regions of Southeast Asia and the Western Pacific.[16] The primary cause of the increasing levels of TBI in these countries is secondary to road traffic accidents involving young males, of which motorcycles are the primary vehicle involved.[16-18] The diagnosis in many road traffic accidents are epidural or subdural hematomas. An epidural hematoma is a rapidly expanding collection of blood between the inner table of the skull and the dura mater that increases intracranial pressure and can cause the patient to rapidly decompensate, herniate, and die.[16] Subdural hematomas are also space occupying, and can cause various degrees of brain shift, leading to herniation as well. Importantly, hematoma evacuations require relatively basic skills (burr holes, mini-craniotomy, or hemicraniectomy) but this is an extremely time-sensitive surgery. If the intracranial pressure can be addressed and the clot evacuated expediently, patients have a greater likelihood of a good clinical outcome.[19] This epidemiology of disease in LMICs contrasts the epidemiology in HICs, where falls in the elderly that cause chronic subdural hematomas are a larger problem.[20]

Another pathology that is prevalent in the global context is acute ischemic stroke. Stroke is the second leading cause of both disability and death worldwide, with the highest burden of the disease shared by low- and middle-income countries.[21] In a study by Dasenbrock and Robertson et al, a United States database was used to assess the impact of timing on patient outcomes after decompressive hemicraniectomy for stroke.[22] When evaluated dichotomously, the odds of discharge to institutional care and of a poor outcome did not differ at 48 hours after hospital admission, but increased when surgery was pursued after 72 hours. Subgroup analyses found no association of surgical timing with outcomes among patients who had not sustained herniation. Overall, early decompressive craniectomy associated with superior outcomes. However, performing decompression prior to herniation may be the most important temporal consideration. Thus, the ability to access timely neurosurgical care in is vital, and that remains a major challenge in many low resource settings across the globe.

Regarding CNS infections, a systematic review by Robertson et al. illustrated the extent to which the global burden of CNS infection adds to the demand for neurosurgeons, particularly in LMIC settings (**Figure 2).**[15,16,23-25] CNS infections continue to cause significant morbidity and mortality worldwide, despite the advent of antibiotics, vaccines, and other medical therapies. The causative organisms — bacteria, viruses, parasites, fungi, and prions — can lead to meningitis, encephalitis, spinal and cranial abscesses, discitis, epilepsy, and other severe complications. In fact, neurocysticercosis infection is the leading cause of preventable epilepsy in the developing world,[26,27] and is on the rise in developing nations.[28,29] Spread of

other CNS infections remains a concern in light of increased migration and tourism travel,[30,31] drug-resistant organisms, and immunosuppressed individuals.[32-35] While medical treatment is necessary for most CNS infections, neurosurgical involvement may be required for biopsy, debridement, decompression, or reconstruction.

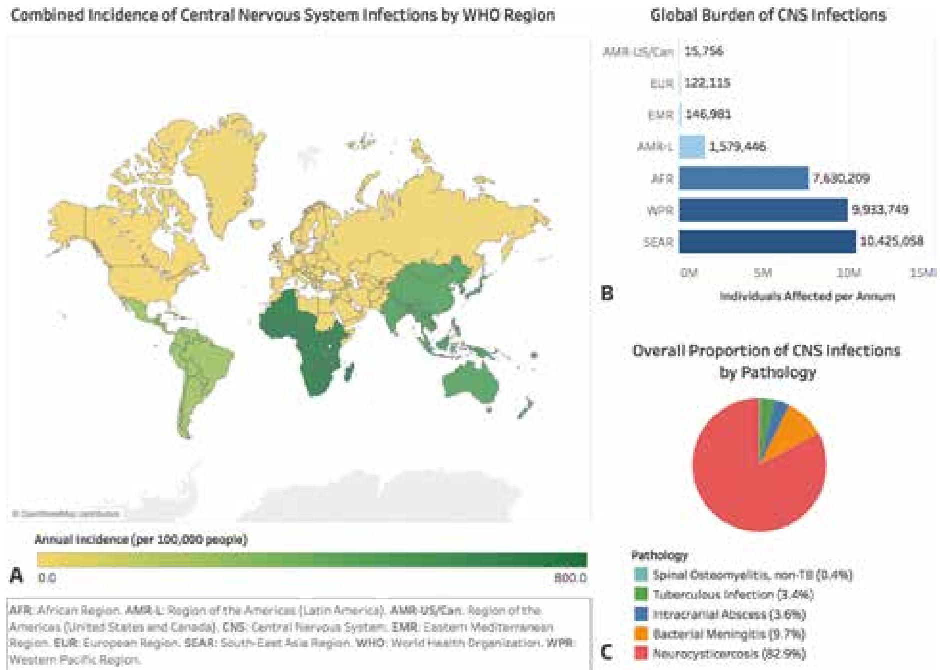

Figure 2. The Global Incidence and Burden of CNS Infection. For the five CNS Infection types studied, the combined incidence (A) and global burden (B) of CNS Infection are depicted, along with (C) proportions of infection by pathology. Publications on cerebral malaria, cryptococcal meningitis, unspecified CNS infections, and human immunodeficiency virus related CNS infections were not included, as those are primarily medically managed disease entities with less relevance for neuro-surgical intervention.

Urgent Neurosurgical Pathologies

The inability to address non-emergent neurosurgical cases also carry a significant burden on the healthcare system and local economies. Primary central nervous system (CNS) cancers had a global incidence of 330,000 and overall mortality of 230,000 respectively in 2016.[39] This reflects a 20% increase in incidence since 1990. Disease burden related to CNS cancer is disproportional to the overall incidence given the very high morbidity and mortality associated with these cancers.[40,41] In a study published in 2022 assessing the macroeconomic burden of this problem, the mortality-to-incidence ratio of CNS cancer in 2019 was 0.60 in high income regions compared to 0.82 in sub-Saharan Africa and 0.87 in Central Europe, Eastern

Europe, and Central Asia.[42] Welfare losses varied across both high- and low-income countries. Welfare losses attributable to CNS cancer in Japan represented 0.07% of GDP compared to 0.23% in Germany. In low- and middle-income countries, Iraq reported welfare losses of 0.20% compared to 0.04% in Angola. Globally, the DALY rate in 2019 was the same for CNS cancer as for prostate cancer at 112 per 100,000 person-years, despite a 75% lower incidence rate, equating to CNS cancer welfare losses of 182 billion USD.

Consequently, the most recent Disease Control Priorities report released a section on *Essential Surgery*, which indicated that first level district hospitals should be able to perform burr holes for hematomas and elevated intracranial pressure and shunts for hydrocephalus, while tertiary care hospitals should have the capacity to perform craniotomies and craniectomies.[5] However, current resource limitations and neurosurgical workforce deficits continue to be significant barriers to such care provision.[15] In many Southeast Asian and Sub-Saharan African countries, the neurosurgical capacity is only 1-10% of the minimum expected neurosurgeon ratio per population, that is 0.01 to 0.1 neurosurgeons per 100,000 population when the expected ratio is at least 1/100,000 to address the complete range of neurosurgical conditions,[36,37] and 0.5/100,000 people if only performing surgery for neurotrauma cases.[43] To this end, there is an imminent need to increase the neurosurgical workforce.

THESIS OUTLINE

The primary objective of this thesis is to underscore the unmet global need for neurosurgeons to meet the ongoing burden of neurosurgical disease, particularly for low- and middle-income countries, and discuss current challenges facing the existing workforce, as well as potential solutions to workforce shortages.

In **Part I, Chapter 2**, the focus is on defining the barriers for young neurosurgeons globally through an international survey. **Part 2** focuses on possible workforce solutions termed task-shifting and task-sharing. **Chapters 3 and 4** review two global surveys describe perspectives on these approaches and help elucidate the prevalence of this practice. A cohort study in the Philippines examines an existing task-sharing model for emergency neurosurgery (**Chapter 5**). **Chapters 6 and 7** describes the changes that occurred during the COVID-19 pandemic, which strained multiple hospital systems and shifted the need for task-sharing into high-income countries. **Part 3** outlines the path forward. New technologies that may aid in workforce expansion for bedside procedures will be presented in **Chapter 8,** specifically, leveraging simulation and new digital technologies for training. As policy is an important factor in steering best practices and safety, the role of policy will be discussed in **Chapter 9**. **Chapter 10** will outline gaps that remain and future directions. **Chapter 11** includes a summary of Chapters 2-10, and **Chapter 12** will synthesize the learnings regarding workforce challenges and solutions in global

neurosurgery. Limitations of existing approaches will be discussed and aspirational goals will be highlighted. Finally, guidelines and best practices will be suggested for futures studies.

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PART

Defining the Problem

CHAPTER 2

Barriers to Professional Development and Service Delivery in Neurosurgery

Adapted from:

The WFNS Young Neurosurgeons Survey (Part II): Barriers to Professional Development and Service Delivery in Neurosurgery.

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World Neurosurgery: X. 2020:100084.

ABSTRACT

Background: Strengthening health systems requires attention to workforce, training needs, and barriers to service delivery. The World Federation of Neurosurgical Societies Young Neurosurgeons Committee survey sought to identify challenges for residents, fellows, and consultants within 10 years of training.

Methods: An online survey was distributed to various neurosurgical societies, personal contacts, and social media platforms (April–November 2018). Responses were grouped by World Bank income classification into high-income countries (HICs), upper middle-income countries (UMICs), low-middle-income countries (LMICs), and low-income countries (LICs). Descriptive statistical analysis was performed.

Results: In total, 953 individuals completed the survey. For service delivery, 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 ($P < 0.0001$). The most reported personal challenge was the lack of opportunities for research (HICs, 34.6%; UMICs, 57.5%; LMICs, 61.6%; and LICs, 61.5%; $P = 0.03$). Other differences by income class included limited access to advice from experienced/senior colleagues ($P < 0.001$), neurosurgical journals ($P < 0.0001$), and textbooks ($P = 0.02$). Assessing how the World Federation of Neurosurgical Societies could best help young neurosurgeons, the most frequent requests ($n = 1673$;953 requests) were research ($n = 384$), education ($n = 296$), and subspecialty/fellowship training ($n = 232$). Skills courses and access to cadaver dissection laboratories were also heavily requested.

Conclusions: Young neurosurgeons perceived that additional neurosurgeons are needed globally, especially in LICs and LMICs, and primarily requested additional resources for research and subspecialty training.

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 [$p=0.136$]).

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.

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).

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 organized 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.

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.

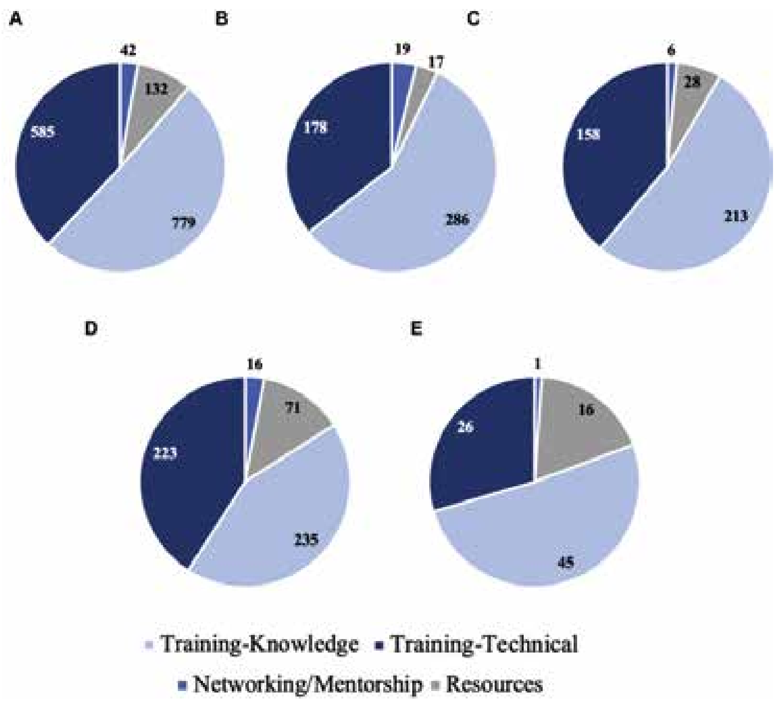

Figure 1. Categorization of respondent requests into categories of knowledge-based training, technical training, networking/mentorship, and resources. (A) Overall respondents and (BeE) by World Bank income classification: (B) high-income countries, (C) upper middle-income countries, (D) low-middle-income countries, and (E) low-income countries.

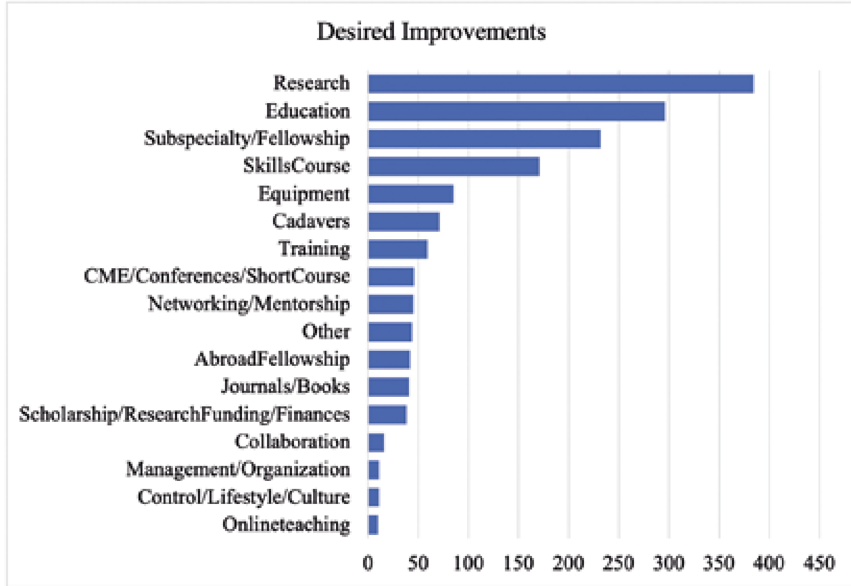

Figure 2. Detailed categorization of respondents' requests for improvement in their current neurosurgical system. Of the 1673 individual requests for system improvement, the most frequent request was for research (384 individuals), followed by additional education (296 individuals), and additional subspecialty or fellowship training requests (232 respondents). The subspecialties of interest are shown below. Twenty-five percent of fellowship requests came from high-income countries, 26.3% from upper-middle-income countries, 44.0% from low-middle-income countries, and 4.74% from low-income countries. CME, continuing medical education.

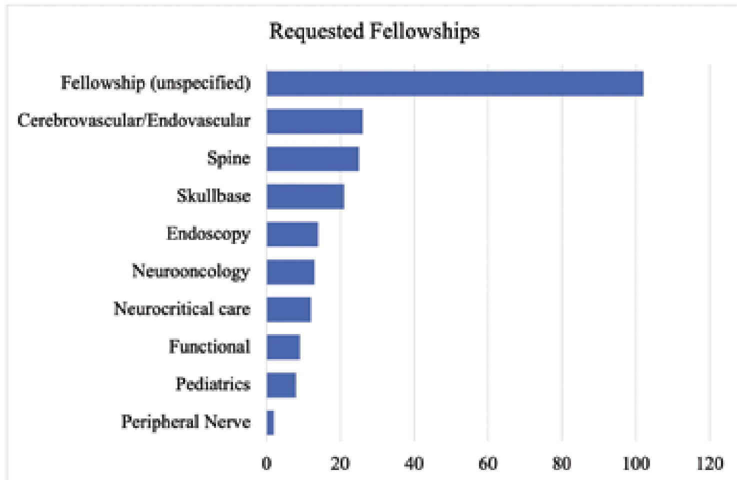

Figure 3. Requested fellowships from young neurosurgery respondents. A total of 232 individuals expressed interest in additional fellowship training. Of the specified fields (102 unspecified), most respondents requested training in cerebrovascular (n = 26), spine (n = 25) and skull base (n = 21).

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 organizes 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 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, organizing 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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PART II

Task-Shifting and Task-Sharing

PART 2 OVERVIEW:

Neurosurgical task-shifting and task-sharing (TS/S), delegating clinical care to non-neurosurgeons, is ongoing in many hospital systems where neurosurgeons are scarce. While TS/S can increase access to treatment, it remains highly controversial. The first paper involves a global survey that investigated current perceptions of neurosurgical TS/S to elucidate whether it is a permissible, temporary solution to the global workforce deficit. The second paper utilized a global survey aimed to provide a cross-sectional understanding of the prevalence and structure of current neurosurgical TS/S practices in low- and middle-income countries (LMICs). The survey yielded 127 responses from 46 LMICs and showed that TS/S is ongoing in many LMICs without substantial structure or oversight, which is concerning for patient safety. The third paper is a retrospective review evaluating an ongoing task-sharing model in the Philippines where neurosurgical workforce deficits are compounded with a large neurotrauma burden. Of 214 emergency neurosurgery operations, task-sharing providers performed 95, neurosurgeons, 119. No significant differences were observed for GCS improvement between admission and discharge or in-hospital GCS improvement, including or excluding inpatient deaths. Task-sharing providers' patients had shorter lengths of stay and were more likely to undergo tracheostomy. The Filipino model of task-sharing is outlined, and it is compared to an optimal theoretical model. This study, one of the first to examine outcomes of neurosurgical task-sharing, demonstrated that a strategic task-sharing model for emergency neurosurgery produced comparable outcomes to the local neurosurgeons. These data invite future clinical outcomes studies to assess effectiveness, and discussions on policy recommendations such as standardized curricula, certification protocols, specialist oversight, and referral networks to elevate the level of TS/S care while continuing to increase the specialist workforce.

CHAPTER 3

Global perspectives on task-shifting and task-sharing in neurosurgery

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ABSTRACT

Background: Neurosurgical task-shifting and task-sharing (TS/S), delegating clinical care to non-neurosurgeons, is ongoing in many hospital systems where neurosurgeons are scarce. While TS/S can increase access to treatment, it remains highly controversial. This survey investigated current perceptions of neurosurgical TS/S to elucidate whether it is a permissible, temporary solution to the global workforce deficit.

Methods: The survey was distributed to a convenience sample of individuals providing neurosurgical care. A digital survey link was distributed through electronic mailing lists of continental neurosurgical societies and various collectives, conference announcements, and social media platforms (July 2018 – January 2019). Data were analyzed by descriptive statistics and univariate regression of Likert-scale scores.

Results: Survey respondents represented 105 of 194 WHO member countries (54.1%; 391 respondents, 162 from high-income countries [HICs], 229 from low- and middle-income countries [LMICs]). The most agreed-upon statement was that task-sharing is preferred to task-shifting. There was broad consensus that both task-shifting and -sharing should require competency-based evaluation, standardized training endorsed by governing organizations, and maintenance of certification. When perspectives were stratified by income class, LMICs were significantly more likely to agree that task-shifting is professionally disruptive to traditional training, task-sharing should be a priority where human resources are scarce, and to call for additional TS/S regulation, such as certification and formal consultation with a neurosurgeon (in-person or electronic/telemedicine).

Conclusion: Both LMIC and HICs agreed that task-sharing should be prioritized over task-shifting and that additional recommendations and regulations could enhance care. These data invite future discussions on policy and training programs.

INTRODUCTION

The United Nations Sustainable Development Goals for 2030 require concerted efforts for building surgical capacity to increase timely access to safe and affordable care.[9,10,12,13] A major focus in low- and middle-income countries (LMICs) is the ability to deliver trauma care, and as 69 million individuals suffer from all-cause TBI annually, neurosurgery is a critical component of this workforce expansion.[14-16] However, in many LMICs the neurosurgical capacity is only 1-10% of the minimum expected neurosurgeon ratio per population, that is 0.01 to 0.1 neurosurgeons per 100,000 population; the expected ratio is at least 1/100,000 to address the complete range of neurosurgical conditions,[36,37] and 0.5/100,000 people if only addressing neurotrauma.[43]

Despite multifaceted approaches to increase neurosurgical capacity – increasing the number of residency training programs, short-term missions, training camps, twinning, encore careers – the workforce deficit remains substantial.[44-47] Consequently, there is a growing interest in the employment of neurosurgical task-shifting and task-sharing (TS/S): delegating certain neurosurgical tasks to non-neurosurgeon specialists, such as general surgeons, general practitioners, or non-physician clinicians.[47,48] While task-shifting is redistribution of both duties and clinical autonomy from neurosurgeons to those with shorter training and fewer qualifications, task-sharing involves a team-based approach with collective input and shared responsibility for patient care.[49] TS/S is a workforce strategy that is more rapid and economical than traditional training, however, it is highly controversial because of safety, ethical, financial, legal, and professional implications.[47] On one hand, having a necessary operation via TS/S may be superior to no care, and TS/S may offer acute stabilization of emergency patients to enable safer transfer to tertiary care facilities.[45,46,50-52] Conversely, TS/S theoretically raises concerns for lower quality care and disrupting professional roles if less-skilled workers substitute for higher skilled staff. As we come together as a global neurosurgical community to strategize for meeting the Sustainable Development Goals of 2030, it is vital to understand the current perspectives within the field before we decide how TS/S will play a role in workforce expansion.

The objectives of this survey were to gain a thorough understanding of current practices and perceptions of TS/S. The results are intended to inform future discussions on policy and training programs and elucidate whether TS/S is a permissible, temporary solution to the workforce deficit, or if efforts should only focus on full training programs.

MATERIAL AND METHODS

Survey Design

A modified Delphi method was used to construct, pilot, and refine the questionnaire.[53] The consulting panel of experts involved neurosurgeons from 20 countries, a majority with experience living or working in a country striving to expand the neurosurgical workforce. Questions were framed to elucidate perspectives on various components of TS/S, particularly as they related to a theoretical task-sharing model outlined by the Lancet Commission on Global Surgery.[1] The surveys were available in English, French, and Spanish (**Appendix 1**), and were approved by the Institutional Review Board at Harvard University (IRB18-0158). The target audience included neurosurgery providers, defined as any health worker providing operative neurosurgical care. Neurosurgery providers were characterized into four groups: **[NS]** Specialist Neurosurgeons: Dedicated neurosurgery consultants/attendings; **[GS]** General Surgeons: General surgery consultants/attendings who have not completed a formal residency/registrar/fellowship training in neurosurgery; **[GP]** General Practitioners: Those with a medical license but without dedicated surgical training; **[NPP]** Non-physician providers: Those who are from a nursing background or from some other, non-physician background.

Survey Dispersal

The surveys were available through an anonymous online link to the Qualtrics platform (Provo, Utah), and were distributed via electronic mailing lists of continental societies and various other neurosurgical groups, email to personal contacts, QR codes, and social media platforms (Facebook, Twitter, WhatsApp). Participation in the survey was voluntary and without remuneration. Given the method of dissemination, a response rate calculation was not able to be obtained. The survey remained open from July 2018 to January 2019. At the end of the survey, individuals were invited to list their name in a separate form to receive collaborator status.

Data Analysis

All survey data were exported for analysis on January 18, 2019 from Qualtrics into an excel file and analyzed using Stata 14.0 (College Station Texas). Data were grouped according to WHO regions: African Region (AFR), Region of the Americas-US and Canada (AMR-USC), Region of the Americas-Latin America (AMR-LA) South-East Asia Region (SEAR), European Region (EUR), Eastern Mediterranean Region (EMR), and Western Pacific Region (WPR), and then reported at the level of individual countries. Data were grouped and analyzed according to 2018 World Bank Income Data: High Income Countries (HICs), versus Low- and Middle-Income Countries (LMICs).[54] Perspectives on task-shifting and task-sharing were elicited using Likert scale scores: a score of 1 represents Strongly Agree; 2, Agree; 3 Neutral; 4, Disagree; and 5, Strongly Disagree. Data were analyzed by descriptive statistics and univariate regression of Likert-scale scores and arranged from the most agreeable statements to least agreeable statements. Probability values less than 0.05 were considered significant. Respondent free text comments were used to represent general themes.

RESULTS

3

We obtained returns from 105 of 194 WHO member countries (54.1%). In addition, we obtained information for 1 nonmember country (Taiwan), with a total of 391 respondents (162 individuals from HICs and 229 from LMICs; **Figure 1, Table 1**). The AFR WHO Region had 70 respondents (17.9%), 5.9% of replies were from the America US/Canada Region, 39.4% were from the EUR, 9.0% from EMR, 8.7% from the Latin American Region, and 0.8% from WPR (**Figure 2**). These countries included (participant count in parentheses):

> *Afghanistan (1), Albania (1), Algeria (8), Argentina (7), Armenia (1), Australia (2), Austria (3), Bangladesh (4), Belgium (3), Benin (1), Bolivia (1), Bosnia and Herzegovina (1), Brazil (6), Bulgaria (2), Burkina Faso (1), Burundi (1), Cameroon (2), Canada (2), Chad (1), Chile (1), China (2), Colombia (6), Congo, Dem. Rep. (4), Cyprus (1), Czech Republic (3), Egypt (17), Ethiopia (7), Finland (5), France (3), Georgia (1), Germany (10), Greece (9), Guatemala (1), Guinea (1), Honduras (2), India (28), Indonesia (5), Iran (1), Iraq (4), Israel and the Occupied Territories (5), Italy (28), Jordan (3), Kazakhstan (1), Kenya (2), Libya (4), Northern Macedonia(1), Malawi (2), Malaysia (10), Maldives (1), Mali (1), Mexico (5), Moldova (1), Morocco (5), Myanmar (1), Namibia (1), Nepal (3), Netherlands (3), Nicaragua (2), Nigeria (14), Norway (1), Pakistan (11), Peru (4), Philippines (7), Poland (1), Portugal (8), Puerto Rico (1), Romania (5), Rwanda (2), Saudi Arabia (3), Serbia (5), Singapore (2), Somalia (1), South Africa (1), Spain (10), Sri Lanka (1), St. Vincent and the Grenadines (1), Sudan (2), Swaziland (2), Sweden (1), Switzerland (1), Syrian Arab Republic (3), Taiwan (1), Tanzania (1), Thailand (1), Tunisia (1), Turkey (16), Ukraine (2), United Kingdom (UK) (22), United States of America (USA) (14), Venezuela, RB (1), Vietnam (2), West Bank and Gaza (3), Yemen, Rep. (1), and Zambia (1).*

Figure 1 Cartographic depiction of survey respondents' country of reporting. A total of 391 individuals from 106 countries completed the survey. Created with mapchart.net.

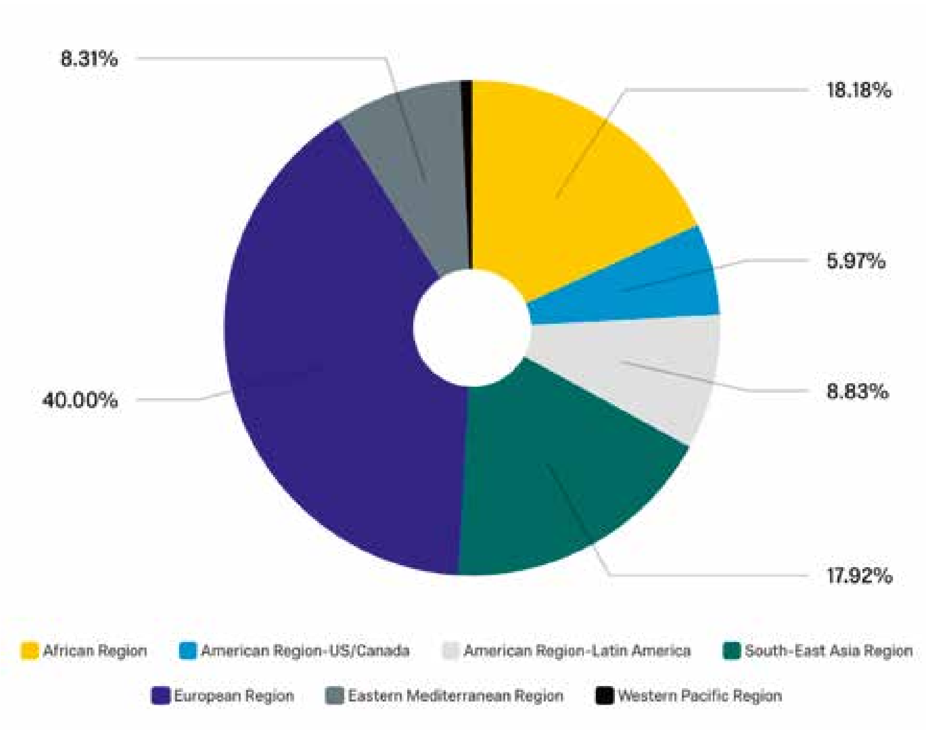

Figure 2. WHO Regions of survey respondents.

Table 1. Demographics of Respondents

Variable Number of Responses (%)	
Age (Category)	**N=391**
<29	66 (16.9)
30-39	181(46.3)
40-49	81 (20.7)
50-59	38 (9.7)
60-69	23 (5.9)
70+	2 (0.5)
Gender	
Man	321 (82.1)
Woman	69 (17.7)
Other	1 (0.3)
Region	
African Region	70 (17.9)
American Region-US/Canada	23 (5.9)
American Region-Latin America	34 (8.7)
Eastern Mediterranean Region	35 (9.0)
European Region	154 (39.4)
South-East Asia Region	72 (18.4)
Western Pacific Region	3 (0.77)
Training Level	
Consultant Neurosurgeon	235 (60.1)
Neurosurgery Trainee	120 (30.7)
Consultant General Surgeon	2 (0.5)
General Surgery Trainee	4 (1.0)
General Practitioner	9 (2.3)
Other (Clinical Officer, Non-Physician Provider)	21 (5.4)
Years of Practice	
Still in training	94 (24.0)
0-5	107 (27.4)
6-10	90 (23.2)
11-20	52 (13.3)
21-30	29 (7.4)
>30	19 (4.9)
Neurosurgical Society Member	
American Association of Neurological Surgeons	99 (30.2)
Asian Australasian Society of Neurological Surgeons	13 (4.0)
Continental Association of African Neurosurgical Societies	31 (9.5)
European Association of Neurosurgical Societies	170 (51.8)
Latin American Federation of Neurosurgical Societies	15 (4.6)
Neurosurgical Subspecialty *(multiple selection)*	
General	285 (21.6)
Pediatric	109 (8.3)
Tumor	244 (18.5)

Table 1. Continued

Variable	Number of Responses (%)
Vascular	140 (10.6)
Functional	70 (5.3)
Spine	190 (14.4)
Trauma	204 (15.5)
Intensive/Neurocritical Care	75 (5.7)
Place of Practice *(multiple selection)*	
Public/governmental sector	218 (32.1)
Private	122 (18.0)
University Teaching Hospital	308 (45.4)
Charitable/Not-for-profit	18 (2.7)
Religious Hospital	13 (1.9)
Setting	
Urban	370 (94.9)
Rural	20 (5.1)
Hospital Level	
Level 1: Small hospital or Health Center, a small number of beds and a sparsely equipped OR for minor procedures	17 (4.4)
Level 2: District or Provincial Hospital, 100–300 beds and adequately equipped major and minor ORs	58 (15.0)
Level 3: Referral Hospital, 300–1000 or more beds with basic intensive care facilities	311 (80.6)

Most respondents were fully trained neurosurgery consultants/attendings (60.1%), followed by neurosurgery trainees (30.7%); other providers of neurosurgical care also completed the survey. Regarding years of clinical experience, survey participants were equally distributed between having 10 or more years of consultant-level experience, 5-10 years of experience, 0-5 years of experience, and currently being in a training program. The majority (94.9%) were working in an urban setting, and over 80% were working in a Level 3 Referral Hospital (300–1000 or more beds with basic intensive care facilities). Hospital type was chiefly University Teaching Hospitals (45.4%), followed by Public/Governmental Sector hospitals (32.1%), and Private Practice (18.0%). There was a broad distribution of neurosurgical subspecialties, and membership in international neurosurgical societies, particularly the European Association of Neurosurgical Societies.

Overall Perspectives

The most agreed upon statement was that task-sharing is preferred to task-shifting **(Figure 3)**. Respondents also reported that task-sharing would result in similar patient outcomes (compared to care delivered by a neurosurgeon), whereas task-shifting would not result in comparable care. There was broad consensus that both task-shifting and -sharing should require competency-based evaluation, standardized training endorsed by governing organizations, and maintenance of certification. The largest differences between perspectives on task-shifting versus -sharing were: will result in similar patient outcomes; can improve healthcare coverage by making more efficient use of the human resources already available; has major safety concerns; and is necessary in my country.

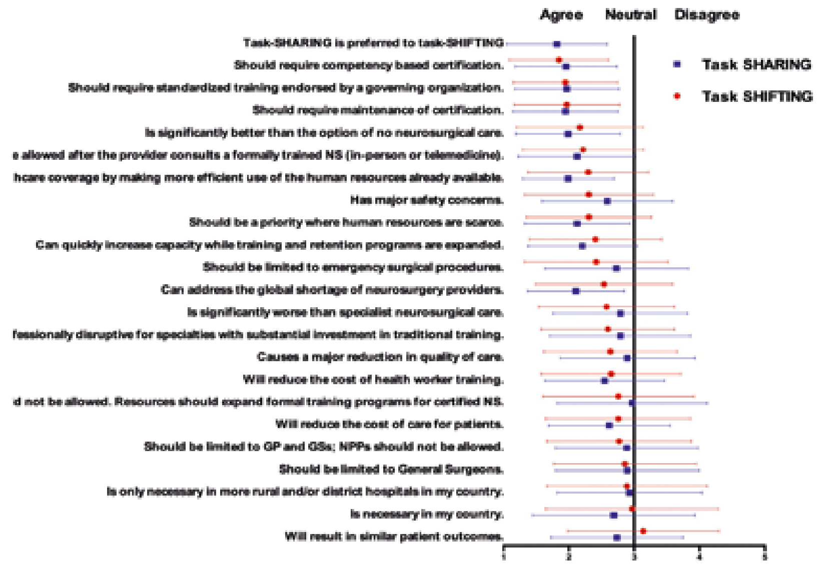

Figure 3. Overall perspectives on Task-shifting (red) and Task-sharing (blue) practices. Data are arranged from most agreeable statements to most disagreeable according to task shifting.

Perspectives by Country Income Status

As task-shifting and -sharing are more often practiced in LMICs than HICs, and subjective opinions may vary accordingly, the perspectives these respective practices were analyzed by World Bank Country Income Status. Univariate regression of Likert scale scores comparing LMICs and HICs are displayed for task-shifting in **Table 2**, and task-sharing in **Table 3.** Results are arranged from the most agreeable statements to least agreeable.

Table 2. Perspectives on Task-Shifting by World Bank Income Classification

Task-SHIFTING	Total	LMIC (Mean, SD)	HIC (Mean, SD)	B-Coefficient	SE	95% CI		P-value
Should require competency-based certification.	1.85 (0.76)	1.79 (0.70)	1.93 (0.83)	-0.06	0.04	-0.14	0.02	0.15
Should require standardized training endorsed by a governing organization.	**1.95 (0.81)**	**1.86 (0.75)**	**2.06 (0.87)**	**-0.08**	**0.04**	**-0.15**	**0.00**	**0.04**
Should require maintenance of certification.	**1.97 (082)**	**1.87 (0.76)**	**2.10 (0.87)**	**-0.08**	**0.04**	**-0.16**	**-0.01**	**0.03**
Is significantly better than the option of no neurosurgical care.	2.17 0.97)	2.13 (0.93)	2.23 (1.04)	-0.03	0.03	-0.09	0.04	0.40
Should only be allowed after the provider consults a formally trained neurosurgeon (in-person, or electronic/telemedicine consultation).	**2.22 (0.93)**	**2.07 (0.88)**	**2.43 (0.96)**	**-0.10**	**0.03**	**-0.17**	**-0.04**	**0.001**
Can improve healthcare coverage by making more efficient use of the human resources already available.	2.30 (0.93)	2.29 (0.89)	2.31 (0.95)	0.01	0.03	-0.06	0.73	0.86
Should be a priority where human resources are scarce.	2.31 (0.96)	2.30 (0.95)	2.32 (0.97)	-0.01	0.03	-0.07	0.06	0.86
Has major safety concerns.	2.31 (0.99)	2.27 (1.01)	2.37 (0.95)	-0.02	0.03	-0.09	0.04	0.43
Can quickly increase capacity while training and retention programs are expanded.	**2.41 (1.01)**	**2.28 (1.00)**	**2.58 (1.02)**	**-0.07**	**0.03**	**-0.13**	**-0.01**	**0.02**
Should be limited to emergency surgical procedures.	**2.42 (1.10)**	**2.22 (1.11)**	**2.69 (1.03)**	**-0.10**	**0.03**	**-0.15**	**-0.04**	**<0.001**
Can address the global shortage of neurosurgery providers.	2.54 (1.06)	2.52 (0.99)	2.55 (1.11)	0.01	0.03	-0.05	0.72	0.84
Is significantly worse than specialist neurosurgical care.	2.58 (1.04)	2.62 (1.04)	2.52 (1.05)	0.02	0.03	-0.03	0.08	0.42
Is professionally disruptive, as these new roles will encroach on specialties where professionals invest great time and resources into their training.	**2.60 (1.03)**	**2.47 (1.04)**	**2.76 (0.99)**	**-0.07**	**0.03**	**-0.13**	**-0.01**	**0.02**
Causes a major reduction in quality of care.	2.64 (1.02)	2.61 (1.04)	2.69 (1.00)	-0.02	0.03	-0.08	0.04	0.56
Will reduce the cost of health worker training.	2.65 (1.08)	2.64 (1.12)	2.66 (1.02)	0.00	0.03	-0.06	0.05	0.91
Will reduce the cost of care for patients.	2.76 (1.11)	2.70 (1.16)	2.85 (1.03)	-0.03	0.03	-0.08	0.03	0.29
Should not be allowed. Resources should focus only on expanding the training programs for formal, certified neurosurgical positions.	**2.76 (1.16)**	**2.58 (1.15)**	**2.76 (1.16)**	**-0.08**	**0.03**	**-0.13**	**-0.03**	**0.003**
Should be limited to GP and GSs; Non-physician providers (NPPs) should not be allowed.	2.77 (1.12)	2.68 (1.11)	2.91 (1.11)	-0.05	0.03	-0.10	0.01	0.09

Table 2. Continued

Task-SHIFTING	Total	LMIC (Mean, SD)	HIC (Mean, SD)	B-Coefficient	SE	95% CI		P-value
Should be limited to General Surgeons.	**2.86 (1.09)**	**2.66 (1.09)**	**3.13 (1.02)**	**-0.10**	**0.03**	**-0.15**	**-0.04**	**0.001**
Is only necessary in more rural and/or district hospitals in my country.	**2.89 (1.23)**	**2.61 (1.13)**	**3.27 (1.26)**	**-0.11**	**0.02**	**-0.15**	**-0.06**	**<0.001**
Is necessary in my country.	**2.97 (1.33)**	**2.68 (1.23)**	**3.38 (1.36)**	**-0.10**	**0.02**	**-0.14**	**-0.06**	**<0.001**
Will result in similar patient outcomes.	3.14 (1.17)	3.11 (1.17)	3.17 (1.17)	-0.01	0.03	-0.06	0.04	0.69

Table 3. Perspectives on Task-Sharing by World Bank Income Classification

Task-SHARING	Total	LMIC (Mean, SD)	HIC (Mean, SD)	B-Coefficient	SE	95% CI		P-value
Is preferred to task-SHIFTING, where new groups/cohorts perform procedures with full autonomy.	1.81 (0.78)	1.76 (0.77)	1.90 (0.78)	-0.06	0.04	-0.13	0.02	0.17
Should require maintenance of certification.	**1.95 (0.81)**	**1.83 (0.78)**	**2.10 (0.83)**	**-0.10**	**0.04**	**-0.18**	**-0.03**	**0.01**
Should require competency-based certification.	1.96 (0.79)	1.88 (0.73)	2.07 (0.84)	-0.08	0.04	-0.15	0.00	0.06
Should require standardized training endorsed by a governing organization.	1.97 (0.81)	1.91 (0.79)	2.06 (0.83)	-0.05	0.04	-0.13	0.02	0.16
Can improve healthcare coverage by making more efficient use of the human resources already available.	1.99 (0.70)	1.92 (0.71)	2.08 (0.67)	-0.08	0.04	-0.17	0.00	0.06
Is significantly better than the option of no neurosurgical care.	1.99 (0.80)	1.92 (0.78)	2.09 (0.83)	-0.06	0.04	-0.14	0.02	0.12
Can address the global shortage of neurosurgery providers.	**2.11 (0.74)**	**2.03 (0.73)**	**2.22 (0.76)**	**-0.08**	**0.04**	**-0.17**	**0.00**	**0.05**
Should only be allowed after the provider consults a formally trained neurosurgeon (in-person, or electronic/telemedicine consultation).	**2.12 (0.90)**	**2.00 (0.86)**	**2.29 (0.94)**	**-0.09**	**0.03**	**-0.15**	**-0.02**	**0.01**
Should be a priority where human resources are scarce.	**2.13 (0.81)**	**2.03 (0.79)**	**2.27 (0.82)**	**-0.09**	**0.04**	**-0.17**	**-0.02**	**0.02**
Can quickly increase capacity while training and retention programs are expanded.	**2.21 (0.83)**	**2.11 (0.82)**	**2.34 (0.83)**	**-0.09**	**0.04**	**-0.16**	**-0.01**	**0.02**
Will reduce the cost of health worker training.	2.55 (0.92)	2.46 (0.92)	2.67 (0.92)	-0.06	0.03	-0.13	0.01	0.07
Has major safety concerns.	**2.59 (1.01)**	**2.45 (1.03)**	**2.78 (0.95)**	**-0.08**	**0.03**	**-0.14**	**-0.02**	**0.01**
Will reduce the cost of care for patients.	**2.62 (0.93)**	**2.51 (0.94)**	**2.77 (0.91)**	**-0.07**	**0.03**	**-0.14**	**-0.01**	**0.03**
Is necessary in my country.	**2.69 (1.24)**	**2.27 (1.05)**	**3.26 (1.26)**	**-0.16**	**0.02**	**-0.20**	**-0.11**	**<0.001**
Will result in similar patient outcomes.	2.73 (1.01)	2.64 (1.08)	2.88 (0.91)	-0.06	0.03	-0.12	0.00	0.07
Should be limited to emergency surgical procedures.	**2.73 (1.10)**	**2.57 (1.18)**	**2.95 (0.95)**	**-0.08**	**0.03**	**-0.13**	**-0.02**	**0.01**
Is significantly worse than specialist neurosurgical care.	2.79 (1.04)	2.71 (1.08)	2.89 (0.96)	-0.04	0.03	-0.10	0.02	0.21

Table 3. Continued

Task-SHARING	Total	LMIC (Mean, SD)	HIC (Mean, SD)	B-Coefficient	SE	95% CI		P-value
Is professionally disruptive, as these new roles will encroach on specialties where professionals invest great time and resources into their training.	2.79 (1.09)	2.71 (1.14)	2.90 (1.00)	-0.04	0.03	-0.10	0.02	0.15
Should be limited to GP and GSs; Non-physician providers (NPPs) should not be allowed.	**2.88 (1.09)**	**2.74 (1.14)**	**3.09 (0.99)**	**-0.07**	**0.03**	**-0.13**	**-0.02**	**0.01**
Causes a major reduction in quality of care.	2.90 (1.03)	2.80 (1.08)	3.02 (0.95)	-0.05	0.03	-0.11	0.01	0.09
Should be limited to General Surgeons.	**2.90 (1.10)**	**2.65 (1.14)**	**3.24 (0.94)**	**-0.12**	**0.03**	**-0.17**	**-0.06**	**<0.001**
Is only necessary in more rural and/or district hospitals in my country.	**2.93 (1.11)**	**2.74 (1.06)**	**3.18 (1.13)**	**-0.09**	**0.03**	**-0.14**	**-0.03**	**0.002**
Should not be allowed. Resources should focus only on expanding the training programs for formal, certified neurosurgical positions.	**2.97 (1.15)**	**2.83 (1.21)**	**3.16 (1.03)**	**-0.06**	**0.03**	**-0.11**	**-0.01**	**0.03**

On task-shifting, there were statistically significant differences between LMICs and HICs on 10 of 22 statements. Respondents from LMICs were more in agreement with requiring standardized training endorsed by a governing organization, requiring maintenance of certification, and only allowing task-shifting after the provider consults a formally trained neurosurgeon (in-person, or electronic/telemedicine consultation), and limiting task-shifting to emergency surgical procedures. They also were more in agreement that task-shifting can quickly increase capacity while training and retention programs are expanded and were more likely to acknowledge that task-shifting is professionally disruptive, as these new roles will encroach on specialties where professionals invest great time and resources into their training. In the statements that were bordering agreeable/neutral stances, more respondents from LMICs noted that task-shifting should not be allowed, as resources should focus only on expanding the training programs for formal, certified neurosurgical positions. There were three statements in which LMICs agreed with while HICs disagreed: (1) task-shifting should be limited to general surgeons; (2) is necessary in their country; and (3) is only necessary in more rural and/or district hospitals in their country.

On task-sharing, there were statistically significant differences between LMICs and HICs on 12 of 23 statements. Respondents from LMICs were more in agreement with requiring maintenance of certification, and only allowing task-sharing after the provider consults a formally trained neurosurgeon (in-person, or electronic/telemedicine consultation), and that task-sharing can address the global shortage of neurosurgery providers. They also were more in agreement that task-sharing should be a priority where human resources are scarce, can quickly increase capacity while training and retention programs are expanded. In the statements that were bordering agreeable/neutral stances, more individuals from LMICs expressed that task-sharing has major safety concerns, will reduce the cost of care for patients, and should be limited to emergency surgical procedures. There were four statements in which LMICs agreed with while HICs disagreed: (1) task-sharing should be limited to GP and GSs (Non-physician providers should not be allowed), (2) should be limited to general surgeons; (3) is only necessary in more rural and/or district hospitals in their country; and (4) should not be allowed, as resources should focus only on expanding the training programs for formal, certified neurosurgical positions.

DISCUSSION

This survey is the first study to investigate the global perspectives on task-shifting and task-sharing care provision in neurosurgery. As the recent survey on TS/S prevalence demonstrated that TS/S is ongoing in many LMICs (*Robertson et al. also currently submitted to World Neurosurgery*), a clear understanding of how HICs and LMICs view TS/S will facilitate consensus-based approaches for health system strengthening and enhance buy-in for policy adoption. As demonstrated in previous global health initiatives, generation of political priority and success of an intervention is highly contingent upon cohesion between the actors involved and consensus surrounding the definition of, cause of, and solutions to the problem.[3,10]

Overall, the most agreed upon statement was that task-sharing is preferred to task-shifting. Respondents also believed that task-sharing could result in similar patient outcomes (compared to care delivered by a neurosurgeon), whereas task-shifting would not result in comparable care and was believed to have major safety concerns. The premise behind this result is that a more extensively trained neurosurgeon would be regularly involved in overseeing or having iterative input on care delivery, and echoes opinions held in the general surgery realm.[55] The broad consensus that both task-shifting and -sharing should require competency-based evaluation, standardized training endorsed by governing organizations, and maintenance of certification is encouraging as it affirms consensus regarding the severity of the problem and potential effective solutions.

When perspectives were stratified by Income Class, LMICs were more agreeable than HICs to additional TS/S regulation. For both task-shifting and task-sharing, LMICs were significantly more in favor of standardized training endorsed by a governing organization, requiring maintenance of certification, and only allowing task-shifting after the provider consults a formally trained neurosurgeon (in-person, or electronic/telemedicine consultation). They were also more likely to acknowledge that task-shifting is professionally disruptive and were more optimistic that task-sharing can address the global shortage of neurosurgery providers, agreeing that task-sharing should be a priority where human resources are scarce, and that it can quickly increase capacity while training and retention programs are expanded.

Seeing the LMIC countries who expressed that task-shifting and task-sharing is needed in their country simultaneously call for additional regulation is a powerful finding that supports why the current time is ripe for the generation of political priority for initiatives to address TS/S in neurosurgery. Since the publication of the Lancet Commission on Global Surgery in 2015, there has been a campaign for developing National Surgical Anesthesia and Obstetric Plans (NSOAPs) in LMICs. In NSOAP, the LMIC's Ministries of Health works with global consultants, such as the Program of Global Surgery and Social Change at Harvard Medical School, to strategize and create action steps to meet the Sustainable Development Goals of 2030.[56] The first country to create a National Surgical Plan was Ethiopia in 2016 (entitled *Saving Lives through Safe Surgery*, *SaLTS*), and many other countries have initiated their own NSOAP since.[57] The process of making an NSOAP is a shared-decision-making approach that emphasized the needs and desires of the LMIC within the recommendations put forth by consultants based on available data and previous experience. In this process, it is key for policy makers from HICs – given that more HIC members have seats at the table of global policy making organizations and meetings – do not impose unfounded ideas on the LMIC. However, when the group planning a health system strengthening agenda has ownership over ideas and visions for change, then policies, local advances and implementation systems are more effective.[3,10] Thus, having LMICs – where TS/S is most relevant – be the nations most keen to implement structure in TS/S practice suggests that there is a greater likelihood that TS/S associated policies would be accepted and put into practice. As countries are writing their respective NSOAPs, information on TS/S should be included. Recommendations on how TS/S programs could be structured within an NSOAP are now accessible in the "*Comprehensive Policy Recommendations for Head and Spine Injury Care in LMICs*,"[58] which emphasizes task-sharing over task-shifting. Nonetheless, the ethics, health system regulation details, and precautions of TS/S in neurosurgery warrant further discussion.

This perspectives survey allows us to gauge the opinions of the actors, the consensus regarding the ideas (potential solutions) and issue characteristics (severity of the problem and effective solutions). By comparing the HIC perspectives to those from LMICs, we can understand where differing opinions may lie and avoid miscommunication and an act of the "Global North" telling the "Global South" what should and should not be done, in a pseudo-colonialist fashion. For instance, given that some HICs have an overabundance of neurosurgical providers, a lesser burden of neurosurgical pathology that requires emergent intervention, more medicolegal implications, and board certification that is tightly regulated to ensure quality of care, perspectives of neurosurgeons from these areas may differ greatly from those in areas facing a large neurotrauma burden without sufficient neurosurgical care. This is a real issue, as highlighted in a recent perspective piece in Lancet Neurology as a rebuttal to a previously published article on task-shifting and sharing (*Training non-physicians as neurosurgeons in sub-Saharan Africa*):[47]

> *"Views on Africa by European and North American experts are commonly provided with little input from Africans who have the necessary insight… We invite readers of* The Lancet Neurology *to learn about initiatives in Africa, and perhaps consider our views on solutions to our challenges. They might be surprised.*[59]*"*

Hence, these results point to where there is agreement, but also where further discussion may be needed before policy recommendation are made.

3

Future Directions

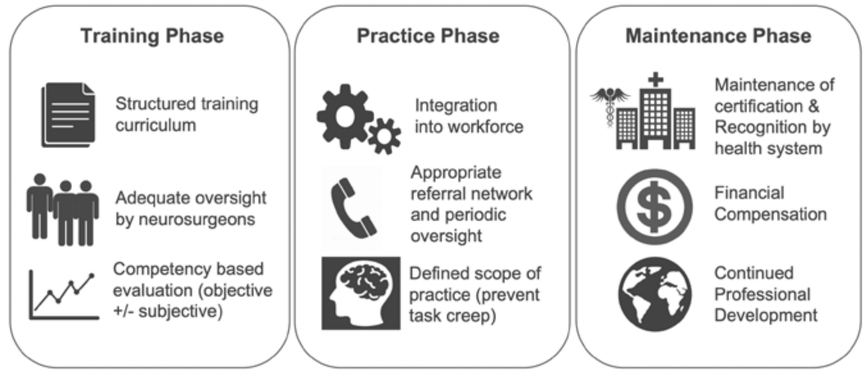

Figure 4. An ideal Task-sharing Model divided into three phases of training, practice, and maintenance of providers. Figure from Robertson et al.51

In summary, surgical workforce deficits compounded by high burdens of surgical disease have led many LMICs to depend on visiting surgeons and task-shifting and -sharing. Though traditional training of neurosurgeons is preferred, task-sharing can be employed to broaden workforce coverage, and task-shifting is the least supported option for workforce expansion. In order to ensure patient safety and mitigate negative consequences of task-sharing, having a robust training and sustaining model is paramount. As mentioned in the Lancet Commission, depicted in **Figure 4**, and crystallized by the survey, task-sharing models should have systematic training and competency-based evaluation prior to allowing task-sharing providers to practice.[1]

Subsequently, local supervision should happen periodically to ensure maintenance of skills and competencies, and proper referral networks should be established for complex cases and complications. The recommended ratios of specialists to task-sharers in the Lancet Commission was 1:4,[1] and recently demonstrated in the Philippines task-sharing study (ratio 2:9) seem to expand access while preserving safety.[51] Task-sharers should be officially recognized and supported by their institutions with a clear definition of their scope of practice, adequate financial remuneration, and clear opportunities for career progression in order to prevent attrition of practitioners and prevent task-creep. Finally, task-sharing should be done in concert with residency strengthening and organized geographic distribution of neurosurgical providers. Ideally, robust residency training programs would provide appropriate specialty knowledge and technical skills to deliver high quality care. Even if a full-time neurosurgical task-sharing model was permanently adopted, countries would still need to develop fully trained and competent neurosurgeon leaders who can champion future teams of task-sharing efforts. Given the upscaling of access to safe, timely and affordable neurosurgery and the consequent reduction in Disability Adjusted Life Years (DALYs), we believe this model would potentiate significant health and economic benefits to the institutions and system. Many of the co-authors on this project have come together to sculpt the "*Comprehensive Policy Recommendations for Head and Spine Injury Care in LMICs.*" This document spans 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. A small component of that involves facilitating safe training, and recommendations for task-sharing models. Neurosurgeons from HICs can partner with LMICs as they formulate their National Surgical Plans and strive to address the burden of neurosurgical disease in their respective countries.

Economics of Task-shifting and -sharing

It is paramount to consider the return on investment for neurosurgical workforce expansion and economic impact of TS/S. In a recent analysis by Rudolfson and colleagues, a value of output model predicted that failing to address the top five neurosurgical conditions in LMICs would amount to annual GDP losses of US$4.4 trillion during 2015-2030.[14] However, workforce expansion requires substantial investment. In the Lancet Commission on Global Surgery Report, it was estimated that the cost of scaling up the surgical, anesthetic and obstetrician workforce to a minimum of 20 providers per 100,000 population would be between US$71-146 billion and would take a median of 34,121 person years.[60] However, if task-sharing were used in a 4:1 associate clinician-to-specialist ratio, the cost and training time would be each reduced by 40%.[1] The *Técnicos de cirurgia* in Mozambique is an example of cost-savings in a task-shifting model;[61] 30-year costs per major obstetric surgery was $38.9 for task-shifting proceduralists and $144.1 for specialist surgeons and obstetrician/gynecologists. Importantly, this was a task-shifting model, not a sharing model, so remuneration within task-sharing may be different as specialists remain involved in consultation. Additional cost-effectiveness and cost-benefit studies should be performed for ongoing TS/S models to help frame discussions with Ministries of Health and Ministries of Finance to develop robust NSOAP plans and health budgets. At the same time, task-sharing should not be seen as a quicker and cheaper option for care provision at the expense of investing in local

residency training programs to develop fully-trained and competent leaders who can champion future teams of task-sharing efforts.

Limitations

The limitations of this study warrant further discussion. While efforts were made to represent a diverse sample of both HICs and LMICs across the seven WHO regions, and we obtained returns from 105 of 194 WHO member countries (54.1%), with a total of 391 respondents (162 individuals from HICs and 229 from LMICs) this is a small sample of total neurosurgeons. Additionally, a large percentage of respondents were from urban settings, and these individuals may have limited information about non-neurosurgeon providers and ongoing practices in rural or remote parts of the country. Consequently, the sample responses may not accurately represent perspectives held by the broader neurosurgeon community. Nonetheless, this study represents one of the first attempts to elucidate global perspectives on task shifting and sharing in neurosurgery and will facilitate further discussion on workforce solutions.

CONCLUSION

Given the global workforce deficit in neurosurgery, there is an increasing interest in the employment of neurosurgical task-shifting and task-sharing. However, TS/S remains highly controversial because of safety, ethical, financial, legal, and professional implications. This perspectives survey aimed to elucidate current perceptions of neurosurgical TS/S to guide the implementation of TS/S as a practical strategy for neurosurgical workforce expansion in LMICs. Both LMIC and HIC countries agreed that task-sharing should be prioritized over task shifting, and that additional recommendations and regulations could elevate the level of care, such as additional governance by professional surgical societies, requiring standardized training, competency-based evaluation, clear role definition, maintenance of certification, adequate oversight, and proper referral networks for complex cases. Importantly, LMICs, where TS/S is more often occurring, were significantly more agreeable to additional structure and regulation for TS/S. These findings represent a call to action for future discussions on policy and training programs surrounding task-sharing for neurosurgery in regions where there is an unmet burden of neurosurgical disease and a dearth of specialist neurosurgeons.

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CHAPTER 4

Task-shifting and task-sharing in neurosurgery: an international survey of current practices in low-and middle-income countries

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ABSTRACT

Background: As nearly 23,000 more neurosurgeons are needed globally to address 5 million essential neurosurgical cases that go untreated each year, there is a growing interest in task-shifting and task-sharing (TS/S), delegating neurosurgical tasks to non-specialists, particularly in low- and middle-income countries (LMICs). This global survey aimed to provide a cross-sectional understanding of the prevalence and structure of current neurosurgical TS/S practices in LMICs.

Methods: The survey was distributed to a convenience sample of individuals providing neurosurgical care in LMICs with a web-based survey link via electronic mailing lists of continental societies and various neurosurgical groups, conference announcements, emailing lists, and social media platforms. Country-level data were analyzed by descriptive statistics.

Results: The survey yielded 127 responses from 46 LMICs; 21 countries (45.7%) reported ongoing TS/S. The majority of TS/S procedures involved emergency interventions; the top three being burr holes, craniotomy for hematoma evacuation, and external ventricular drain. A majority (65.0%) believed that their Ministry of Health does not endorse TS/S (24.0% unsure), and only 11% believed that TS/S training was structured. There were few opportunities for TS/S providers to continue medical education (11.6%), maintenance of certification (9.4%), or receive remuneration (4.2%).

Conclusion: TS/S is ongoing in many LMICs without substantial structure or oversight, which is concerning for patient safety. These data invite future clinical outcomes studies to assess effectiveness, and discussions on policy recommendations such as standardized curricula, certification protocols, specialist oversight, and referral networks to elevate the level of TS/S care while continuing to increase the specialist workforce.

INTRODUCTION

Neurosurgical task-shifting and task-sharing (TS/S) is the process of delegating clinical tasks to non-neurosurgical specialists, such as general surgeons, general practitioners, or non-physician clinicians.[1,2] Task-shifting is the redistribution of these duties and clinical autonomy from highly qualified healthcare workers to those with shorter training and fewer qualifications.[3] In contrast, task-sharing employs collaborative teams that transfer tasks to less qualified cadres, though both a specialist and less qualified provider share clinical responsibility and there is iterative communication and training to preserve high quality outcomes.[4]

TS/S models most often arise out of necessity to meet the medical demands of a patient population with a limited workforce, and many countries are currently employing TS/S for obstetrics, anesthesia and general surgery.[5-7] In neurosurgery, as approximately 5 million essential neurosurgical cases go untreated each year, and over 23,000 more neurosurgeons are needed in low- and middle-income countries (LMICs) to address this treatment gap, we believe that TS/S may already be quite prevalent in neurosurgery.[8] Furthermore, the most recent Disease Control Priorities section on *Essential Surgery* indicated that first level district hospitals should be able to perform burr holes for hematomas and elevated intracranial pressure and shunts for hydrocephalus, while tertiary care centers should have the capacity to perform craniotomies and craniectomies, predominantly for neurotrauma.[9] Though, current neurosurgical workforce deficits continue to be significant barriers to such care provision.[10] At present, few neurosurgical TS/S studies have been reported and details of the respective training structures were not clearly defined. For instance, in a 2014 study of operations performed in a Malawi hospital, 10% of the total 1186 operative cases were neurosurgical (craniotomies of ventriculoperitoneal shunts), and 80% of the neurosurgery cases were done by clinical officers in a task-shifting model.[11] In 2015, an assessment of 1036 surgeries in a Liberian hospital revealed that all 31 (3.0%) neurosurgical cases were performed by general surgeons; neither training protocols nor clinical outcomes were discernable from the published data.[12] Two models of neurosurgical task-sharing have been recently described in the Philippines and Australia, both of which provided much more detail on the training curriculum, competency evaluation, oversight, referral networks, remuneration and clinical outcomes.[13,14] Nonetheless, a more global understanding of the prevalence and diversity of TS/S is lacking.

The goal of this study was to obtain a cross-sectional examination of the prevalence and distribution of neurosurgical TS/S within LMICs, and to better understand the models of training, scopes of practice, and systemic support TS/S providers have. The results are intended to inform future discussions on policy and training programs to facilitate timely access to safe and affordable surgical care

MATERIAL AND METHODS

Survey Design

The survey was designed using a modified Delphi method,[15] piloting and refining the questionnaire with input from neurosurgical experts from 20 countries, a majority with experience living or working in a country striving to expand the neurosurgical workforce. Questions were written to ascertain current practices, particularly as they related to a theoretical task-sharing model outlined by the Lancet Commission on Global Surgery,[4] and depicted by Robertson et al.[13] (**Figure 1**) and were available in English, French, and Spanish (**Appendix 1**). The final survey was reviewed by the Institutional Review Board at Harvard University and granted exemption (IRB18-0158). The target audience included neurosurgery providers, defined as any health worker providing interventional neurosurgical treatments whether supervised or working independently, from LMICs, as defined by the July 1, 2018 World Bank Income classifications.[16] We divided neurosurgery providers into four types: [NS] Specialist Neurosurgeons: dedicated neurosurgery consultants/attendings; [GS] General Surgeons: general surgery consultants/attendings who have not completed a formal residency/registrar/fellowship training in neurosurgery; [GP] General Practitioners: those with a medical license but without dedicated surgical training; [NPP] Non-physician providers: those who are from a nursing background or from some other, non-physician background.

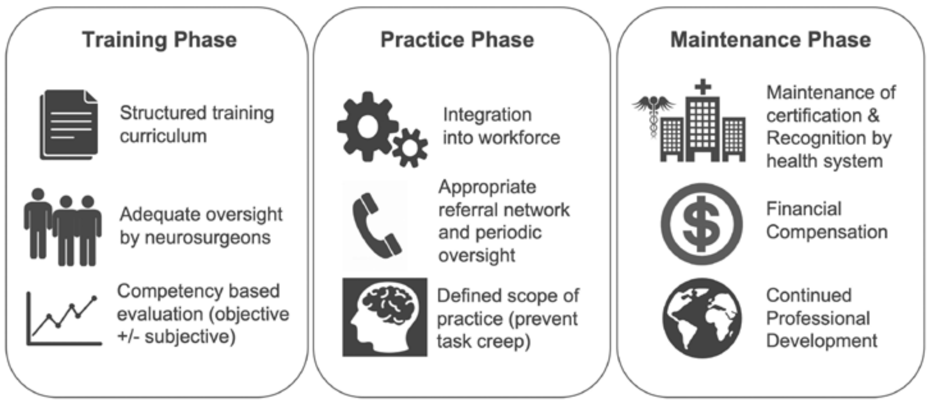

Figure 1. An ideal Task-sharing Model divided into three phases of training, practice, and maintenance of providers. Figure from Robertson et al. 13

Survey Dispersal

The surveys were available online via Qualtrics (Provo, Utah), and accessible via an anonymous weblink, online QR code, and printable PDF that could be collected at various neurosurgical meetings or scanned and emailed to the research team. Participation in the survey was voluntary and without remuneration. The surveys

were distributed by the electronic mailing lists of continental societies and various other neurosurgical groups, email to personal contacts and social media platforms (Facebook, Twitter, WhatsApp). At the end of the survey, individuals were invited to list their name in a separate form to receive collaborator status; this was optional. The wide dissemination of the questionnaire through social media platforms precluded a response rate calculation. The survey remained open from July 2018 to February 2019 and data were exported after survey closure.

Data Analysis

All survey data were exported for analysis on February 28, 2019 from Qualtrics into an excel file and analyzed using Stata 14.0 (College Station Texas). Workforce data were portrayed with descriptive statistics and tables. Data were grouped according to WHO regions: African Region (AFR), Region of the Americas-US and Canada (AMR-USC), Region of the Americas-Latin America (AMR-LA) South-East Asia Region (SEAR), European Region (EUR), Eastern Mediterranean Region (EMR), and Western Pacific Region (WPR), and then reported at the level of individual countries. Respondent free text comments were used to represent general themes.

RESULTS

A total of 127 respondents from 47 LMICs (34.3% of 137 LMIC countries) responded to the survey (**Figure 2, Table 1**). The African WHO Region had 50 participants (39.4.8% of total respondents), while 32.3% of replies were from the South-East Asia Region, 17.3% from the European Region, 5.5% from the Eastern Mediterranean, and 5.5% from the Latin American Region (**Figure 3**). These countries included:

> *Algeria(2), Bangladesh (1), Belarus (1), Bosnia and Herzegovina (1), Brazil (6), Bulgaria(1), Cameroon (1), Cape Verde (1),Chad (1), Democratic Republic of the Congo (DRC; 6), Egypt (3), Ethiopia (6),, Georgia (1), Ghana (3), Guinea (1),Guatemala (1), India (13), Indonesia (4), Iran (1), Iraq (2), Jordan (1), Kenya (1), Libya (1), Malawi (1), Malaysia (5), Morocco(1), Namibia (1),, Nepal (2), Nigeria (11), Pakistan (10), Philippines (3), Romania (2), Russia (1), Rwanda(3),, Senegal (1), Serbia (4), South Africa (1), Sri Lanka (1), Sudan (2), Syria (2), Tanzania (1), Thailand (1), Tunisia (1), Turkey (8), Ukraine (3), Vietnam (2), and Zimbabwe (1).*

Figure 2. Cartographic depiction of where LMIC survey respondents were located. Created with mapchart.net.

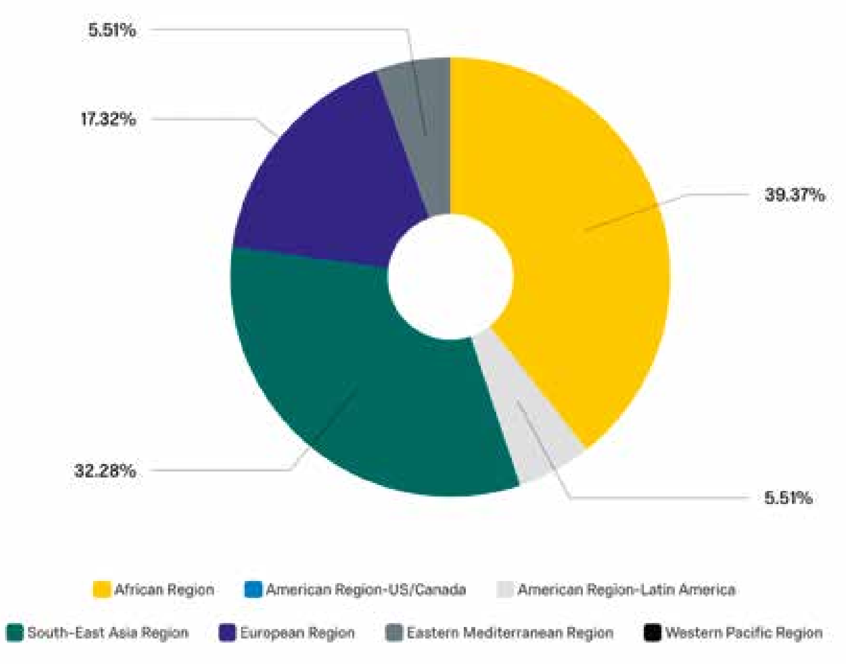

Figure 3. WHO Regions of survey respondents.

Table 1. Survey Respondent Demographics

Variable	Number of Responses (%)
Region	*n=126*
African Region	40 (31.8)
South-East Asia Region	40 (31.8)
European Region	25 (19.8)
Eastern Mediterranean Region	13(10.3)
American Region-Latin America	8 (6.35)
Training Level	*n=126*
Consultant Neurosurgeon	84 (66.7)
Neurosurgery Trainee	32 (25.4)
Consultant General Surgeon	1 (0.8)
General Surgery Trainee	1 (0.8)
General Practitioner	4 (3.2)
Other	4 (3.2)
Neurosurgical Society Member	*n=103*
European Association of Neurosurgical Societies	39 (37.9)
American Association of Neurological Surgeons	32 (31.1)
Continental Association of African Neurosurgical Societies	23 (22.3)
Asian Australasian Society of Neurological Surgeons	6 (5.8)
Latin American Federation of Neurosurgical Societies	3 (2.9)
In-Country Neurosurgery Training Availability	*n=101*
Yes	88 (87.1)
Place of Practice *(All responded with percentages, mean, SD)*	*n=126*
Public	67.9 (39.9)
Private	30.1 (38.5)
Faith-based Hospital	2.0 (10.0)
Setting	*n=126*
Urban	116 (92.1)
Rural	10 (7.9)

4

Of the 127 respondents, 101 identified as being a member of one of the five large neurosurgical societies, with the majority being members of the European (n=36), American (n=29) and African (n=28) Associations. Two-thirds of respondents were of the level of a consultant/attending neurosurgeon (66.1%), 27.6% were neurosurgery trainees, and a small number of general surgeons, general practitioners, or other providers of neurosurgery participated. When asked if neurosurgical training was available in their country, 16.2% indicated that it was not. Regarding place of practice, the majority of the neurosurgical care was provided in the public hospital setting (67.6%), though 30.5% of time was in the private sector, and 2.9% in faith-based hospitals; 92.9% of participants were practicing in urban settings.

The level of reported neurosurgical providers by country is depicted in **Figure 4A and 4B**. **Figure 4A** depicts who performs neurosurgery at the country level, and

Figure 4B demonstrates the reported complexity of surgeries performed according to provider level.

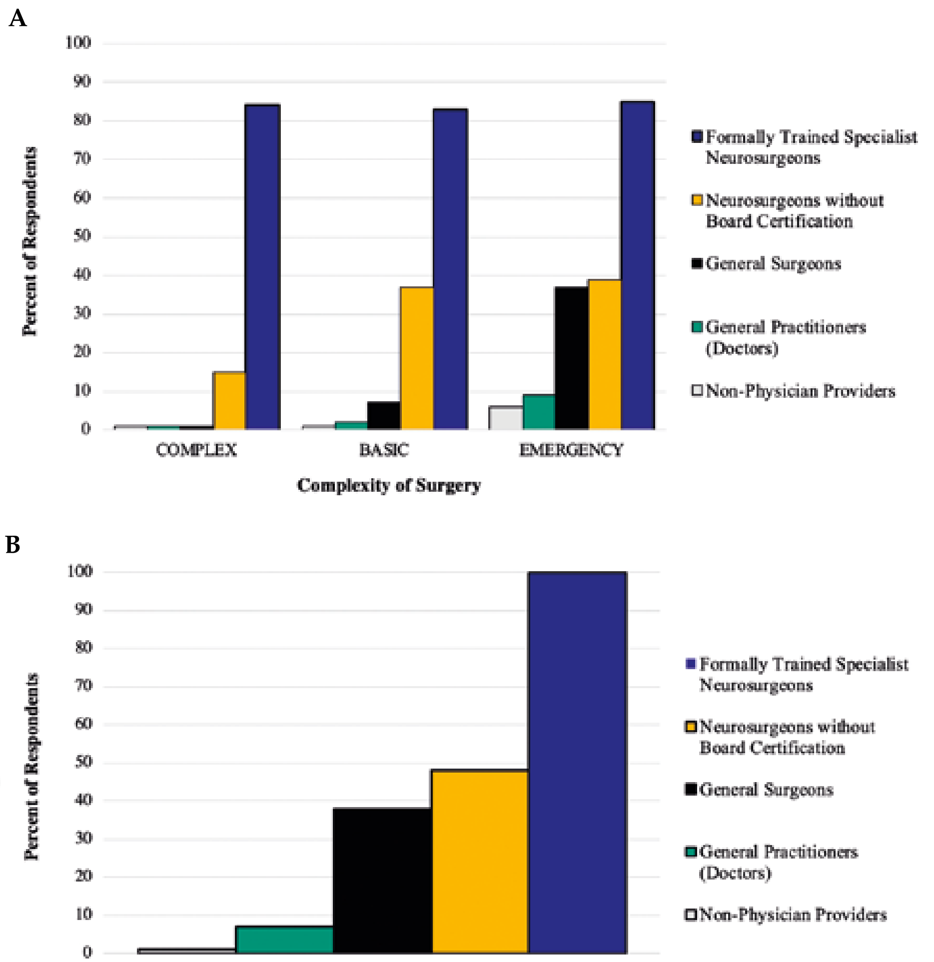

Figure 4A, 4B. Complexity of procedures done by Neurosurgeons and TS/S providers. 4A depicts who performs neurosurgery at the country level. 4B demonstrates the reported complexity of surgeries performed according to provider level. The x-axis reflects the number of responses.

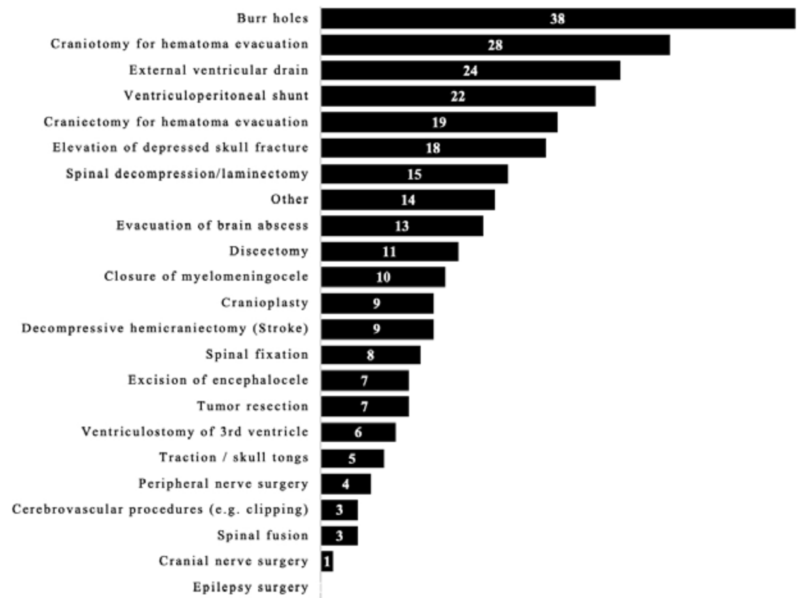

Figure 5. Types of procedures done by TS/S providers.

Overall, 95.1% (n=103) of respondents reported that they had formally trained Specialist Neurosurgeons in their country (one individual from the countries of Bangladesh, DRC, Egypt, Kenya, and Turkey responded "no"; this will be discussed in the limitations section). A total of 21 of the 47 responding countries (44.7%) indicated that TS/S was ongoing in their respective countries. When asked about individuals who completed a neurosurgical training program who are *not* board-certified consultants/attendings but *are* practicing as a neurosurgeon, 44 of 102 respondents from 18 countries affirmed (Brazil, DRC, Egypt, India, Kenya, Malaysia, Morocco, Namibia, Nepal, Nigeria, Pakistan, Philippines, Sudan, Syria, Thailand, Turkey, Ukraine, Vietnam). Thirty-nine of 103 respondents stated that general surgeons were performing neurosurgery in their respective country (Belarus, Cameroon, DRC, Ethiopia, India, Indonesia, Kenya, Malaysia, Morocco, Namibia, Nigeria, Pakistan, Philippines, Sudan, Tanzania, Thailand, and Zimbabwe; 17 countries). Six of 104 respondents stated that general practitioners were performing neurosurgery in their respective country (Malawi, Morocco, Namibia, Nigeria, Sudan, and Tanzania; six countries). Malawi and Morocco reported that non-physician providers also perform neurosurgical procedures. The complexity and types of procedures that TS/S providers perform is depicted in **Figure 5**.

Details from the 21 described TS/S programs are outlines in **Table 2.** When asked if the current Ministry of Health endorses TS/S, 99 individuals responded; 63.6% replied no, 11.1% replied yes (Cameroon, DRC, Egypt, Ethiopia, Indonesia, Malawi, Malaysia, Nigeria, Sri Lanka, and Turkey), and 25.3% were unsure. Of note, some countries with multiple respondents had both yes and no answers from their respective country, denoting a potential misunderstanding or uncertainty of the MOH's endorsement of TS/S. The actual statement by the respective MOH in each country was not verified during this study. Of these 99 respondents, 8.0% stated there was a standardized training program for TS/S providers in neurosurgery. When asked about the typical duration of training in years for uncertified neurosurgery providers, quantitative answers ranged from no training beyond a general surgery residency, to 1 month (Ethiopia, Indonesia), 3 months (Malaysia, Morocco, Nigeria, Thailand, Philippines), 6 months (Sri Lanka), and 2-3 years (Pakistan).

A subset of respondents elaborated in free text response, which can be viewed in the far-right column in **Table 2**. General themes involved permitting TS/S in neurosurgery in the setting of an emergency, such as an epidural hematoma evacuation, when a fully trained neurosurgeon was not available. One Ethiopian respondent noted: "*They [General Surgeons] do the surgeries where there are no neurosurgeons, and patients are unable to be referred due to financial reasons or because the patient is deteriorating fast*." Another Ethiopian affirmed this: "*They [General Surgeons] practice in district hospitals where virtually no neurosurgeons are available.*" In Egypt, India, Indonesia, Israel, Malaysia, Nigeria, the Philippines, and Sudan, respondents echoed that the general surgeons in remote areas will occasionally perform emergency neurosurgery. In Indonesia: "*General surgeons have autonomy to perform emergency neurosurgery such as burr hole evacuation of EDH [epidural hematoma] in remote areas where referral to neurosurgeons is time consuming or impossible*." A Sudanese individual noted that TS/S is *"not allowed, apart [from a] burr hole in [a] remote area for life saving."* In Cape Verde, there was no report on ongoing TS/S, but one respondent noted *"[We have] only one neurosurgeon from Cuba cooperation since 2015. Before that, general surgeons performed emergency neurosurgery and complex cases were sent to Portugal."*

When remuneration for TS/S providers was discussed, 40.9% replied that TS/S providers received no financial payment for neurosurgical procedures, 55.2% were unsure (or not applicable), and 3.2 percent replied in the affirmative (n=93; countries recognizing remuneration for TS/S were Indonesia, Kenya, and Turkey). The ability for TS/S providers to continue medical education or maintenance of certification throughout their training was recognized by 9.8% (n=92; 41.3%, no; 48.9% unsure/NA). Continued professional development opportunities for TS/S providers was reported by 8.6% (n=93; 40.9%, no; 50.5% unsure).

Table 2. Details of TS/S training programs where respondents noted that neurosurgical TS/S was occurring in their respective countries.

Country	TS/S Provider Type	MOH Endorsed (Subjective)	Standardized Training	Length of Training Required	Location of Training	Method of Training	Who leads training	Comments
Belarus	GS	Unsure	No	–	–	–	–	–
Cameroon	GS	Yes	No	–	–	–	–	–
DRC	GS	No	No	Not Standardized	Not Standardized	Not Standardized	NS	*They have to seek permission from consultants for every operation*
Egypt	NA	Yes	No	2-3 years	Referral Hospitals	Clinical Experience		*Minimal cases/emergencies can be done by uncertified NS*
Ethiopia	GS	Yes	No	1 month; 3 months	Teaching Hospital	Clinical Experience; Assist Emergency Surgery	NS	*They do the surgeries in district hospitals and/or where NS are unavailable, and when patients are unable to be referred due to financial reasons or rapid deterioration*
India	GS	No/Unsure	No	Unstructured not allowed	–	–	–	*TS/S is variable, practiced in very few institutions or in rural practice. Not regulated. It depends on the senior neurosurgical consultant covering the region*
Indonesia	GS	Yes	Yes	1-2 months	NS Unit, All Centers	Part of General Surgery Training	NS	*General surgeons have autonomy to perform emergency neurosurgery such as burr hole evacuation of EDH in remote areas where referral to neurosurgeons is time consuming or impossible.*
Israel	GS, GP	No	No	3-4 years	Abroad	Clinical Experience	NS	*In emergency cases only*
Kenya	GS	No	No	–	–	–	–	–
Malawi	GP, NPP	Yes	No	–	–	–	–	*A neurosurgeon is not always available to supervise them but they are encouraged to consult if any case they are in doubt or is beyond their scope of training or experience. all complicated cases within their scope must be referred. All cases outside their scope must be referred.*
Malaysia	GS	Yes	Yes	3 months	NS Center	Part of General Surgery Training	NS	*No formal training program available, GS must obtain endorsement by the head of department in each hospital (for hospitals without NS)*
Morocco	GS, GP, NPP	No	No	3 months	France	Observation; Clinical Experience	NS	–

Table 2. Continued

Country	TS/S Provider Type	MOH Endorsed (Subjective)	Standardized Training	Length of Training Required	Location of Training	Method of Training	Who leads training	Comments
Namibia	GS, GP	Unsure	No	–	–	–	–	*Thy perform burr hole and ventriculoperitoneal shunts. Mostly alone (without supervision).*
Nigeria	GS, GP	Yes	Yes	3 months; Trauma surgery training only	NS Unit; Trauma Surgery	Observation/ Hands-on for highly motivated; Part of GS Training	NS; Trauma Surgeons	*No task shifting, but task sharing practiced & encouraged, mostly in rural areas with no NS supervision. Only resuscitate, then refer to NS. Such providers do personally refer patients they are unable to handle or with resultant complications from their procedures to trained NS.*
Pakistan	GS	No	No	2 years	Post graduate medical institute	Local Curriculum Authorities	–	*TS/S is practiced in teaching hospitals with cover and in private practice groups. I know of those who have almost completed their training but unfortunately couldn't clear their exit exams [but still perform NS]*
Philippines	GS	No	No	3 months	Gov. Teaching Hospital	Direct supervision on rotation	NS	*Basic emergency trauma procedures which are life saving for exigency purposes.*
Sri Lanka	GS	Yes	No	6 months	Same hospital as GS training	Clinical Experience	NS	–
Sudan	GS, GP	No	Yes (only for board certified NS)	TS/S training unclear	–	–	–	*Traditionally refer to advance NS trauma center. TS/S not allowed apart of burr hole in remote area for life saving surgery. We have a specialized local board [for clinical approval].*
Tanzania	GS, GP	Unsure	No	Not specified	Local Hospital	Assist in Surgery	–	*Training of uncertified neurosurgeons happens accidentally/not planned. When one meets an interested trainee, it occurs briefly and unsupervised. No one is sure whether the actual neurosurgery practice continues after the training.*
Thailand	GS	Unsure	Yes	3 months	University Hospital	–	NS	–
Zimbabwe	GS	No	No	–	–	–	–	–

Abbreviations: GP: General Practitioner; GS: General Surgeon; NPP: Non-physician Provider; NS: Neurosurgeon.

DISCUSSION

This survey is the first cross-sectional examination of the global practice of task-shifting and task-sharing care provision in neurosurgery. Its illumination of the prevalence of neurosurgical TS/S is an important step in describing the global neurosurgical workforce and discussing practical approaches to meet the United Nations Sustainable Development Goals for 2030 to mitigate the global burden of neurosurgical disease.[17]

Overall, 21 LMICs (44.6% of LMICs that responded) indicated that TS/S was ongoing in their country, which underscores the magnitude of the neurosurgeon workforce deficit and that many countries are seeking alternative methods for care provision. While the majority of TS/S models described were employing general surgeons, there were also reports of general practitioners and non-physician providers performing neurosurgery. Perhaps more important was the lack of structure, oversight and regulation for these TS/S models. Only eight of the 21 countries believed that this practice was endorsed by their government's Ministry of Health (this data was not verified with the respective MOH offices), and four countries stated there was a standardized TS/S training program. Most individuals reported that the training was led by a neurosurgeon, but it was unclear who was conducting the teaching in many settings. There was tremendous variability in the length of time TS/S providers would train – from one month to years – and there were no concrete examples of competency-based evaluation. Regarding the scope of TS/S provider practice, it appeared predominantly limited to emergency interventions in a rural or district setting, and the most common procedures were burr holes, craniotomy for hematoma evacuation, external ventricular drain, and shunts for hydrocephalus. However, more complex surgeries such as spinal fusion and tumor resection were also mentioned. By not having a governing body for regulation, or a defined scope of practice, there is a serious risk of task-creep: practicing beyond the scope of one's training.[4] The ability for TS/S providers to continue medical education throughout their training was only recognized by 9.8%, and remuneration, only 3.2%.

Importantly, the survey illustrates the current landscape of neurosurgical TS/S and highlights opportune areas for system improvement. As long as there remains a gap between the demand for emergency neurosurgical care and provider capacity, TS/S is likely to arise. Ethically, TS/S presents many challenges. On one hand, having a necessary operation via TS/S may be superior to no care at all; TS/S may allow acute stabilization of emergency patients to enable safer transfer to tertiary care facilities, thereby improving geographic and temporal access to more affordable, lifesaving therapies.[13,14] Conversely, TS/S raises concerns for lower quality care, ambiguous informed consent since unprecedented surgical intervention models may include unknown risk, and disrupting professional roles if less-skilled workers displace higher skilled staff, as has been discussed in the setting of nurse anesthetists and anesthesiologists.[18] The core ethical principles of beneficence, respect for persons, and justice should remain central to the goal of care delivery, as it is our responsibility to maintain moral standards as we strive to meet workforce goals.[19] However, these data call us to recognize that this process is ongoing, and we can take steps to improve safety.

To begin, task-sharing should be emphasized over task-shifting since shared clinical responsibility with expert involvement is presumed to be a safer option.[4] Building from the theoretical model discussed in the Lancet Commission on Global Surgery and depicted in **Figure 1**, it would first be recommended that the TS/S trainee would have obtained a degree in medicine and currently be in or have completed a surgical training program prior to beginning neurosurgical TS/S training. This is to ensure adequate understanding of both medical and operative management and experience in clinical decision making. From the data, it appears that the majority of country models were already adhering to this practice, as 19 of the 21 countries identified general surgeons as TS/S providers; the seven countries that reported general practitioner or non-physician TS/S providers could adapt alternative training programs to ensure that only general surgeons were certified to do such work. Regarding the training protocol, there would not have to be a one-size-fits-all model, but local and tertiary care hospitals could work with their national neurosurgical society and Ministry of Health to agree upon defining the details of their training programs. We saw that countries who recognized specific lengths of neurosurgical TS/S training included ranges from 1 month, 3 months, 6 months, to multiple years, and there was variation between observation and operative exposure. In order for individuals to be competent and confident in technical and non-technical skills, observation is unlikely to be sufficient, and the length of training should correlate with a set number of supervised operative experiences. Furthermore, the programs should involve competency-based evaluation prior to allowing TS/S providers to practice. This concept of progression in surgical competence along the learning curve being directly associated with caseload experience, graduated autonomy, and time has been shown extensively in surgical education literature.[20-23] Local supervision should follow the completion of formal training to ensure maintenance of skills and competencies. Subsequently, local supervision should happen periodically to ensure maintenance of skills and competencies, and proper referral networks should be established for complex cases and complications to allow for tele-consultation and physical transfer of patients when necessary.[24]

Finally, the governance and financing of TS/S regulation and maintenance is critical. Again, only seven of the 21 countries believed that this practice was endorsed by their government's Ministry of Health. The importance of governmental support can be illustrated with the Mozambique model of *Tecnicos de cirurgia*. In 1984, the Mozambican health system introduced *Tecnicos de cirurgia* as a new professional cadre to deliver basic comprehensive services, mainly in rural areas.[25] Initially, this effort was met with resistance from medical doctors and nurses. However, by having a

governance structure, the health system was able to regulate training, define a scope of practice, collect data for ongoing evaluation and safety improvement, and provide financial compensation that facilitated workforce retention.[26] If neurosurgical TS/S providers were officially recognized and supported by their MOH and institutions with a clear definition of their scope of practice adequate financial remuneration, and clear opportunities for career progression, it could prevent task-creep to protect both the patients and the providers; clear role definition empowers the TS/S provider to defer operations that he or she may be pressured to do electively and protect patients from being taken advantage of by individuals seeking to expand their skillset unsafely for financial or professional gains.[4] It also mitigates worry from other professional roles about job security and encroachment upon their specialty. These data show that clear role definition is needed, since it would be more advisable that complex procedures such as spinal fusion and tumor resection remain under the practice of fully trained neurosurgeons.

Limitations

The limitations of this study warrant further discussion. The absolute prevalence of TS/S practice should be interpreted with caution, as we used neurosurgical member societies as our primary source of survey dispersal, and the individuals who received the survey though neurosurgical society email lists were a majority of practicing neurosurgeons in urban settings. These individuals may have limited information about non-neurosurgeon providers and ongoing practices in rural or remote parts of the country, or there may be political reasons or bias that lead to underreporting. Though, that would likely underestimate the true prevalence of TS/S, making this a conservative estimate. Regarding survey structure, questions may have been misinterpreted or the individual who completed the survey may not have had accurate information. An example of this was potential misinterpretation of the number of "formally trained" Specialist Neurosurgeons in one's country, as four individuals from Bangladesh, DRC, Egypt, Kenya and Turkey reported zero, however, we know from the 2016 WFNS survey that these countries have approximately 138, 4, 400, 22, and 981 neurosurgeons, respectively.[27] Nonetheless, this study represents one of the first attempts to elucidate global perspectives on task shifting and sharing in neurosurgery and will facilitate further discussion on workforce solutions.

CONCLUSION

In summary, the combination of neurosurgical workforce deficits and a high and growing burden of neurological trauma and disease amplifies the demand for scaling up neurosurgical care in low resource settings. This survey illustrated that TS/S is ongoing in many LMICs without substantial structure or oversight, which is concerning for patient safety. Overall, this represents a call to action for future discussions on policy and training programs. Additional recommendations and regulations could elevate the level of care, such as additional governance, requiring standardized training, competency-based evaluation, clear role definition, maintenance of certification, adequate oversight, and proper referral networks for complex cases. Moreover, continued collaboration between HICs and LMICs will be needed to optimize residency and task-sharing training programs, ensure proper governance and financing of task-sharing models, and encourage an iterative reflection and improvement process as we strive to mitigate the global burden of neurosurgical disease by 2030.

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CHAPTER 5

Task-sharing for Emergency Neurosurgery: A Cohort Study in the Philippines

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ABSTRACT

Objective: The safety and effectiveness of task-sharing (TS) in neurosurgery, delegating clinical roles to non-neurosurgeons, is not well understood. This study evaluated an ongoing TS model in the Philippines where neurosurgical workforce deficits are compounded with a large neurotrauma burden.

Methods: Medical records from emergency neurosurgical admissions to two hospitals were reviewed (January 2015-June 2018): Bicol Medical Center (BMC), a government hospital where emergency neurosurgery is chiefly performed by general surgery residents (TS providers), and Mother Seton Hospital (MS), an adjacent private hospital where neurosurgery consultants are the primary surgeons. Univariable and multivariable linear and logistic regression compared provider-associated outcomes.

Results: Of 214 emergency neurosurgery operations, TS providers performed 95, neurosurgeons, 119. TS patients were more often male (88.4% vs 73.1%, p=0.007), younger (mean age 27.6 vs 50.5, p<0.001), and resulting from road traffic accidents (69.1% vs 31.4%, <0.001). There were no significant differences between Glasgow Coma Scale (GCS) scores upon admission. Provider type was not associated with mortality (neurosurgeons 20.2%, TS 17.9%, p=0.68), reoperation, or pneumonia. No significant differences were observed for GCS improvement between admission and discharge or in-hospital GCS improvement, including or excluding inpatient deaths. TS patients had shorter lengths of stay (17.3 days vs 24.4 days, OR: -6.67, 95% CI -13.01--0.34, p<0.05), and were more likely to undergo tracheostomy (OR 3.1, 95% CI 1.30-7.40, p=0.01).

Conclusion: This study, one of the first to examine outcomes of neurosurgical task-sharing, demonstrated that a strategic task-sharing model for emergency neurosurgery produced comparable outcomes to the local neurosurgeons.

INTRODUCTION

Each year, approximately 5 million essential neurosurgical cases go untreated, and over 23,000 more neurosurgeons are needed in low- and middle-income countries (LMICs) to address this treatment gap.[1] The majority of these conditions arise from traumatic brain injury (TBI), stroke, hydrocephalus, tumors, epilepsy and infection.[1-5] The ability to perform emergency surgical procedures for TBI is especially important, as 69 million individuals suffer from all-cause TBI annually, particularly in Southeast Asia and the Western Pacific Region.[1] The most recent Disease Control Priorities report indicated that district hospitals should be able to perform burr holes for hematomas and elevated intracranial pressure and shunts for hydrocephalus, while tertiary care centers should have the capacity to perform craniotomies and craniectomies, predominantly for neurotrauma.[6] However, current resource limitations and neurosurgical workforce deficits continue to be significant barriers to care provision.[2]

In many Southeast Asian and Sub-Saharan African countries the neurosurgical capacity is only 0.01 to 0.1 neurosurgeons per 100,000 population when the expected ratio is at least 1/100,000.[7,8] To this end, there is an imminent need to increase the neurosurgical workforce, particularly in countries with the greatest burden of disease. While there have been efforts to increase the number of residency training programs, short-term missions, training camps, and twinning,[9-11] the workforce deficit remains substantial, and there is a growing interest in the employment of neurosurgical task-shifting and task-sharing (TS/S): delegating certain neurosurgical tasks to non-specialists, such as general surgeons, general practitioners, or non-physician clinicians.[11,12] Task-shifting is the rational redistribution of tasks and clinical autonomy from highly qualified healthcare workers to those with shorter training and fewer qualification.[13] In contrast, task-sharing is when duties are transferred to less qualified cadres, but both a specialist and less qualified provider share clinical responsibility.[14] The latter method incorporates workplace strategies that build upon the collective input of the health team so there is shared responsibility over patient care to achieve a high-quality outcome. Therefore, task-sharing is not intended to replace specialists, but to create collaborative teams that enable specialists to expand their reach via training and continued consultation. Both task-shifting and task-sharing in neurosurgery are highly controversial because of safety, ethical, financial, legal, and professional implications.[15] On one hand, having a necessary operation via TS/S may be superior to no care at all, and TS/S may offer acute stabilization of emergency patients to enable safer transfer to tertiary care facilities. Conversely, TS/S raises concerns for lower quality care and disrupting professional roles if less-skilled workers displace higher-skilled staff.

While many countries are currently employing TS/S for obstetrics, anesthesia and general surgery,[9,10,16] the efficacy of this practice in neurosurgery is not well understood, particularly for task-sharing, which is believed to be the more favorable and safer approach of the two.[14] Regarding task-shifting in neurosurgery, the few studies reported were neither sufficiently structured nor powered to assess clinical implications. In a recent Malawi study, 10% of 1186 total operations were neurosurgical, of which, a non-physician clinical officer performed the majority.[17] An assessment of 1036 surgeries in Liberia revealed that all 31 neurosurgical cases were performed by general surgeons.[18] Clinical practitioners seem to be more supportive of TS/S involving general surgeons rather than clinical officers,[8,11] but there remains concern that these providers may not obtain sufficient exposure to trauma surgery or neurosurgery during their training and may therefore be ill-equipped to appropriately manage patients.[19] To the authors' knowledge, only one task-sharing model in neurosurgery with clinical outcomes has been reported: a retrospective review in the rural Royal Darwin Hospital in Perth, Australia where general surgeons regularly performed emergency neurosurgery.[20] Luck et al. concluded that surgical outcomes were comparable to Congress of Neurological Surgeons guidelines and mortality rates in other high-income countries (HICs) such as Canada and Sweden.[20] Importantly, that model was set in a HIC with relatively robust infrastructure and resources, and is not directly comparable to a LMIC setting. Furthermore, neurosurgeon specialists have since been recruited to the aforementioned site, and the task-sharing model is no longer active.[21] Overall, more data is needed to better understand ongoing and prospective models of TS/S in neurosurgery.

The goal of this research was to conduct a retrospective cohort study of a task-sharing (herein referred to as TS) model in neurosurgery in the Philippines to compare neurosurgical patient outcomes between a hospital with fully trained neurosurgeons delivering care, versus a government hospital employing a TS model where general surgery trainees conduct emergency neurosurgery under the intermittent supervision of a neurosurgeon. A thorough understanding of current practices will help inform future discussions on policy and training programs and elucidate whether TS is a permissible, temporary solution to the workforce deficit, or if efforts should only focus on full training programs.

MATERIAL AND METHODS

Study Setting

The Philippines exemplifies a region experiencing a multidimensional neurosurgical burden. It is an archipelago of over 7000 islands home to over 100 million people, half of whom are under 23 years of age.[22] The complex geography poses significant limitations for access to timely emergency surgical care. Concomitantly, the current neurosurgical workforce is 0.108 neurosurgeons/100,000 population, only 10% of the proposed capacity and most are concentrated in the metropolitan capital, Manila.[23] These limitations are of major concern given that road traffic injuries are a leading cause of death in individuals under 24 years of age, and TBI is frequently the primary

clinical cause of road traffic accident mortality.[24,25] Moreover, recent urbanization has correlated with a 45% increase in road traffic deaths in less than 10 years.[24] Hence, the Philippines is faced with both workforce and geographic challenges to delivering timely neurosurgical care in the setting of a growing burden of severe TBI.

The Bicol Region is one of 17 Philippines regions and is home to nearly six million people.[26] There is only one full-time board-certified neurosurgeon who is recognized as a fellow of the Academy of Filipino Neurosurgeons and is primarily based at the 500-bed, national referral hospital for the region, Bicol Medical Center (BMC), where nearly all patients in need of emergency neurosurgery are either initially taken or transferred to once a provincial hospital anticipates a need for neurosurgical intervention. In addition to the primary neurosurgeon at BMC, there is a visiting neurosurgeon in the Bicol region whose availability and location fluctuate; both neurosurgeons are listed as staff at 5-10 hospitals. Consequently, TS has been increasingly practiced at BMC during the past five years in an attempt to increase the provision of emergency neurosurgical care when neurosurgeons are unavailable.

Task-sharing Model

In this TS model, the two consultant neurosurgeons train general surgery residents to perform emergency procedures. The focus of the training primarily involves craniotomies or craniectomies for evacuation of post-traumatic hematomas including epidural and subdural hemorrhages, as well as decompressive craniectomies for uncontrolled cerebral swelling (example of a Filipino craniotomy kit, **Figure 1**, and an emergency epidural hematoma evacuation, **Figure 2**). The patients legally remain under the care of consultant neurosurgeon throughout. The resident training program is based at BMC, the government hospital where emergency neurosurgery is chiefly performed by general surgery residents (TS providers). Residents also rotate at Mother Seton Hospital (MS), an adjacent private hospital 800 meters from BMC where neurosurgery consultants must be the attending on record during any neurosurgical case. There are infrastructural differences between the two hospitals, including computed tomography (CT) and mechanical ventilation availability. General surgery residents complete a 3-month rotation at both BMC and MS hospitals during their second year of the 5-year residency under the two consultant neurosurgeons. The neurosurgical rotator is responsible for mastering a set curriculum in emergency neurosurgery, seeing all neurosurgical admissions, medically managing these patients on the floor or in the intensive care unit (ICU), and attending neurosurgical operations. All medical and surgical plans are discussed with the consultant neurosurgeons via phone call and/or text message in a neurosurgery-specific message thread that includes the rotator, consultants, and all residents who previously completed the rotation. The initial medical management for TBI is empirically started and includes hyperosmolar therapy (mannitol), antibiotics (cefazolin), a proton pump inhibitor (omeprazole), pain medication (paracetamol) and an anti-epileptic (valproic acid). If surgery is required, the consultants and residents collectively decide between transferring care to MS, having the consultant come to operate at BMC, or having a general surgery resident who has completed the neurosurgery rotation operate themselves at BMC. Consultant surgeons also conduct rounds every few days with the rotator to discuss plans in person. Furthermore, patient care is discussed with the entire BMC surgery department during three weekly conferences: Intensive Care Unit discussion, Morbidity and Mortality conference, and Weekly Census. A more comprehensive outline of the training program can be found in **Appendix 1**.

Figure 1. Craniotomy Kit at Bicol Medical Center. A hand-crank Hudson-Brace is used with a Gigli saw (not pictured) to make burr holes complete the craniotomy in many low- and middle-income countries, compared to a power drill in high-income countries.

Figure 2. Emergency Craniotomy for an Emergency Epidural Hematoma Evacuation. A general surgery resident uses a Gigli saw to complete the craniotomy after consulting with the local neurosurgeon who was concurrently resecting a brain tumor.

Study design

Retrospective patient data on emergency neurosurgical admissions were extracted from medical records at the two hospitals, BMC and MS (January 2015–June 2018). The year 2015 was used as a start date since the operative census was first recorded in a traceable, computer form that year. The computer census was used to identify the medical record numbers for patients, and the respective paper charts were pulled from hospital archives. Patients were included if they met specified inclusion criteria: 1) were admitted to the neurosurgical service at BMC or MS for an emergent cranial condition; and 2) had a primary diagnosis of traumatic brain injury, intraparenchymal hemorrhage, contusion, subdural hematoma, epidural hematoma, hydrocephalus, or elevated intracranial pressure. Patients were excluded if the hospital admission was for: an elective, non-emergent surgery; spinal condition; or surgery for other specifications such as suturing of a head laceration, aspiration of subgaleal hematoma, skin debridement, or tracheostomy.

Variables collected included patient age, sex, time of injury, mechanism of injury, duration from condition onset to admission at a facility with neurosurgical care, hospital transfer information, Glasgow Coma Scale (GCS) score upon arrival,[27] date of CT imaging, official results of the scan (original images were not reviewed), perioperative resuscitation including hyperosmolar therapy and intubation, need for surgery, in-hospital time to procedure, type of procedure performed, and person performing procedure. TBI severity was defined as mild (GCS 13-15), moderate (GCS 9-12), or severe (GCS 3-8). The primary outcome was in-hospital mortality. Secondary outcomes included length of stay, GCS upon discharge, improvement in GCS from admission to discharge, change between lowest in-hospital GCS to GCS at discharge, reoperation, receipt of mechanical ventilation if indicated (versus not available and/or bag-valve mask ventilation), pneumonia, and 30-day readmission. Unfortunately, measures of functional status such as Glasgow Outcome Score or modified Rankin Scale score could not be consistently elucidated from the paper medical records.

Ethical approval was obtained from King's College London, Harvard Medical School, and the National Intuitional Review Board of the Philippines via the Bicol Regional Teaching and Training Hospital.

Statistical Analysis

Statistical analyses were performed using STATA 14.0 (StataCorp, College Station, Texas). Univariable analysis was used to compare categorical variables and screen for potential confounders. A Bonferroni correction was used (calculated as α/k, 0.05/15=0.0033) and significant variables were corrected for in the multivariable regression analysis. Multivariable logistic and linear regression models evaluated the association of provider type with the six outcomes. Regressions were run to control for the following potential confounders without overfitting the model: mortality: patient age, GCS score upon arrival, mechanism of injury, and radiographic diagnosis; GCS at discharge/GCS from admission to discharge/GCS from lowest in-hospital score to discharge: patient age, year, time from injury to hospital, GCS score upon arrival, mechanism of injury, and radiographic diagnosis; length of stay: patient age, year, time from injury to hospital, GCS score upon arrival, mechanism of injury, and radiographic diagnosis; Inpatient pneumonia: patient age, GCS score upon arrival, and radiographic diagnosis; Reoperation: patient age, GCS score upon arrival, and radiographic diagnosis; Tracheostomy: patient age, GCS score upon arrival, and radiographic diagnosis. Concordance (C) statistics and R-squared adjusted scores

assessed the discriminatory capacity of the regression models. Probability values less than 0.05 were considered significant.

RESULTS

A total of 3241 cases were examined during the study period: 2233 at BMC and 1008 at MS. The overall mortality rate for all emergency neurological admissions was 20.9% (n=466) at BMC and 18.7% at MS (n=167 of 893 with available mortality data). Surgery was performed in 214 patients (6.6% of admissions, 4.3% at BMC and 11.3% at MS;). TS providers performed 95 emergency neurosurgical operations, while neurosurgeons performed 119 (**Table 1**). Nearly all emergency surgeries performed by TS providers were at BMC (96.8%, n=92); the three TS cases at MS were performed by a general surgery resident who transferred into a neurosurgery program and performed a case at MS during rare emergencies. Neurosurgeons performed 9.2% (n=11) of the emergency neurosurgeries at BMC. TS patients were more often male (88.4% vs 73.1%, p=0.007), younger (mean age 27.6 vs 50.5, p<0.001), and resulting from road traffic accidents (69.1% vs 31.4%, <0.001).The majority of road traffic accident admissions to TS providers were from motorcycle crashes (70.3% of road traffic accidents for TS, 15.4% for neurosurgeons, OR 13.0, 95% CI 4.90-34.5, p<0.001). Patients under the care of neurosurgeons were more likely to have a CT upon admission, and other material supply differences were apparent, for example ten TS patients requiring ventilator support were ventilated via a bag-valve mask ventilator rather than a mechanical ventilator.. Additional variables can be viewed in **Table 1.**

In multivariable regression for mortality (**Table 2**) – after correcting for patient age, GCS score upon arrival, mechanism of injury, and radiographic diagnosis in the statistical model – there was no significant difference in surgical mortality rates between groups (overall 19.1%, neurosurgeons 20.2%, TS 17.9%; OR 0.84, 95% CI 0.36-1.96, p=0.68). There were also no significant differences between reoperation or pneumonia. For all or surviving-only patients, no significant differences were observed for GCS at discharge, change in GCS from admission to discharge or in-hospital GCS improvement. TS patients had shorter lengths of stay (17.3 days vs 24.4 days, coefficient -6.67, OR -13—1--0.34 p<0.05) and were more likely to undergo tracheostomy (OR 3.1, 95% CI 1.30-7.40, p=0.01).

Table 1. Univariable analysis of patient and hospital characteristics. Results are stratified by provider training level (Neurosurgeon versus TS/S). A Bonferroni correction was used (calculated as α/k, 0.05/15=0.0033). Statistically significant differences with univariable linear and logistic regression are bolded.

Variable	Total Population (*N*=214) n (%)	Neurosurgeon (*N*=119) n (%)	TS/S (*N*=95) n (%)	Odds Ratio	95% CI	*p*-value
Patient Characteristics						
Age (years, mean, SD)	**44.7 (19.7)**	**50.5 (19.8)**	**27.6 (17.3)**	**-12.7**	**-17.8- -7.65**	**<0.001**
Sex (Female)	43 (20.1)	32 (26.9)	11 (11.6)	0.35	0.17-0.75	0.007
Hospital Characteristics						
Government/Public (BMC)	103 (48.1)	11 (9.2)	92 (96.8)	*Ref*	*Ref*	
Private (Mother Seton)	**111 (51.9)**	**108 (90.8)**	**3 (3.2)**	**0.003**	**0.00-0.01**	**<0.001**
Time from Injury to Hospital *(med, IQR in hours)*	0.82 (0.22-3.06)	0.47 (0.15-3.03)	0.89 (0.22-3.15)	*Coef.* .0005	*-0.00-0.001*	0.23
Mechanism of Injury						
Road Traffic Accident	102 (47.9)	37 (31.4)	65 (69.1)	*Ref*	*Ref*	
Motorcycle	66 (64.7)	11 (29.7)	55 (84.6)	*Ref*	*Ref*	
Other (3-4+ Wheeled)	**36 (35.5)**	**26 (70.3)**	**10 (15.4)**	**13.0**	**4.90-34.54**	**<0.001**
Fall	39 (18.4)	22 (18.5)	17 (18.1)	0.44	0.21-0.93	0.032
Assault/Violence	10 (4.7)	3 (2.5)	7 (7.5)	1.33	0.32-5.45	0.69
Spontaneous Hemorrhage	**49 (23.1)**	**45 (38.1)**	**4 (4.26)**	**0.05**	**0.02-0.15**	**<0.001**
Other (Tumor, Infection)	9 (4.3)	9 (7.76)	0 (0.0)	1	*colinear*	*colinear*
Radiographic Findings						
Acute Subdural Hematoma	70 (32.7)	37 (31.1)	33 (37.4)	*Ref*	*Ref*	
Epidural Hematoma	65 (30.4)	27 (22.7)	38 (40.0)	3.56	1.12-11.29	0.03
Chronic Subdural Hematoma	32 (15.0)	17 (14.2)	15 (15.8)	1.73	0.54-5.60	0.34
Hydrocephalus	28 (13.1)	26 (21.8)	2 (2.1)	0.08	0.01-0.77	0.02
Subarachnoid Hemorrhage	22 (10.3)	10 (8.4)	12 (12.6)	0.93	0.18-4.90	0.93
Contusion	53 (24.8)	20 (16.8)	33 (34.7)	4.39	1.38-13.9	0.01
Skull Fracture	25 (11.7)	11 (9.2)	14 (14.7)	2.41	0.70-8.3	0.16
Herniation	16 (7.5)	11 (9.2)	5 (5.3)	0.84	0.21-3.43	0.81
Severity Indices						
GCS on Admission (mean, SD)	11.2 (3.6)	11.1 (3.8)	11.3 (3.4)	0.17	-0.82-1.16	0.74
GCS on Admission						
Mild TBI	94 (43.9)	55 (46.2)	39 (41.1)	*Ref*	*Ref*	
Moderate TBI	62 (29.0)	28 (23.5)	34 (35.8)	1.71	0.90-3.27	0.10
Severe TBI	58 (27.1)	36 (30.3)	22 (23.2)	0.86	0.44-1.69	0.66
Treatment Variables						
Intubated Pre-Admission if GCS<8 (n=57)	9 (15.8)	3 (8.6)	6 (27.3)	4.0	0.88-18.1	0.07
CT Day of Admission	**185 (92.5)**	**114 (97.4)**	**71 (85.5)**	**0.16**	**0.04-0.57**	**0.005**
Hyperosmolar Therapy	167 (80.7)	11 (12.5)	77 (87.5)	2.26	1.06-4.81	0.04
In-hospital Intubation Pre-Op	77 (36.0)	38 (31.9)	39 (41.1)	1.48	0.84-2.60	0.17
Mechanical Ventilation Received	97 (45.3)	63 (52.9)	34 (35.8)	0.59	0.33-1.04	0.07
Bag-valve mask ventilator	10 (4.7)	0 (0.0)	10 (10.5)	1	*colinear*	*colinear*
ICU Admission	148 (69.2)	91 (76.5)	57 (60.0)	0.46	0.25-0.83	0.01

Abbreviations: CI: confidence interval; Coef.: coefficient; GCS: Glasgow Coma Scale; ICU: intensive care unit; Ref: reference.

Table 2. Multivariable analyses. The association of the provider type with outcomes after emergency neurosurgery. Statistically significant differences with multivariable linear and logistic regression are bolded.

Surgical Outcomes	Total (n=214)	Neurosurgeon (n=119)	TS (n=95)	OR/ Coeff.	95% CI	*p*-value	C-stat /Adjusted R2
In-Hospital Mortality (%)	19.2	20.2	17.9	0.84	0.36-1.96	0.68	0.77
GCS at Discharge (***all*** patients)	11.6 (4.8)	11.4 (5.0)	11.8 (4.6)	0.61	-0.74-1.95	0.37	0.26
GCS at Discharge (***alive*** patients)	13.8 (2.3)	13.9 (2.2)	13.7 (2.3)	-0.03	-0.80-0.73	0.92	0.22
ΔGCS Admission: DC (***all*** patients)	+0.42 (4.4)	+0.31 (4.4)	+0.55 (4.4)	0.61	0.95-1.08	0.37	0.07
ΔGCS Admission: DC (*alive* patients)	+1.8 (3.4)	+1.6 (3.5)	+2.0 (3.1)	0.30	-0.60-1.2	0.51	0.49
ΔGCS Lowest: DC (***all*** patients)	+2.9 (3.2)	+2.9 (3.3)	+2.8 (3.1)	0.27	-0.75-1.29	0.61	0.04
ΔGCS Lowest: DC (*alive* patients)	+3.6 (3.4)	+3.7 (3.4)	+3.4 (3.4)	-0.04	-1.16-1.09	0.95	0.23
Length of Stay (Mean, SD)	**21.3 (21.7)**	**24.4 (26.9)**	**17.3 (11.3)**	**-6.67**	**-13.01--0.34**	**0.039**	**0.06**
Inpatient Pneumonia (%)	19.6	16.8	23.2	2.2	0.94-5.13	0.07	0.75
Reoperation (%)	3.3	3.4	3.2	2.2	0.33-14.6	0.41	0.66
Tracheostomy (%)	**15**	**9.2**	**22.1**	**3.1**	**1.30- 7.40**	**0.011**	**0.78**

Abbreviations: C: Concordance statistic; CI: confidence interval; Coeff.: coefficient; GCS: Glasgow Coma Scale; OR: odds ratio; SD: standard deviation.

5

DISCUSSION

This retrospective cohort study is one of the first to thoroughly examine the quality of task-sharing care provision in neurosurgery, and this model demonstrates potential to increase access to neurotrauma care while maintaining acceptable clinical outcomes. The regional demand for neurosurgical care was evident with an average of 650 emergency neurosurgical admissions per year to the regional government referral center. Demographically, the patients mirrored the epidemiologic neurosurgical burden in other LMICs, with a majority of cases arising from road traffic accidents involving young males and motorcycles,[1,28,29] in contrast to the epidemiology in HICs where chronic subdural hematomas from falls in the elderly are a larger problem.[30] Furthermore, given that the operative rate was only 6.6% of admissions (4.3% at BMC and 11.3% at MS), and operation rates for TBI in developed nations ranges between 5-10%,[30] the intervention rate suggests that clinical decision making on patient selection for surgical intervention was appropriate.

Outcomes data demonstrated that the use of task-sharing between general surgery residents and neurosurgeons enabled residents to achieve similar outcomes compared to their neurosurgical mentors. After correcting for patient age, GCS score upon arrival, mechanism of injury, and radiographic diagnosis in the statistical model, the overall mortality rate was 19.2% with no statistically significant difference in surgical mortality between provider groups. The study was powered to detect a 16% difference in mortality rate between groups (3.07% overall mortality difference) but the observed difference was 2.3% (20.2 for neurosurgeons, 17.9 for TS). Thus, the care provided by the TS group appears to be non-inferior to the neurosurgical cohort, acknowledging that TS providers were solely providing basic emergency neurosurgical care. However, each health system will likely have unique perspectives on what is an acceptable *clinically* significant difference between operators. The mortality rate in this Philippines study is expected to be higher than a HIC since mortality rates of patients with TBI in LMICs concurrently reflect inequity in staff, stuff, space and systems.[25,30-33] For instance, in a 46-country study that enrolled nearly 9000 patients, those with severe TBI in LMICs had over two-times the odds of mortality compared to HICs (51% mortality vs. 30%; OR 2.23, 95% CI 1.15-3.30).[28] In addition to mortality, this Philippines model showed no significant difference in complication rates, change in GCS, or reoperation rates. Unfortunately, despite its importance in neurosurgical outcomes,[27] a measure of quality of life beyond a GCS score could not be ascertained. Length of stay was significantly shorter for the TS providers; however, this data is difficult to interpret as many patients in fee-for-service private hospitals, such at Mother Seton, tend to have longer lengths of stay since they are paid for services rendered.[34-36] The significantly higher rates of tracheostomy by TS providers compared to the neurosurgeon group likely reflects the TS providers more protocolized approach to care and the known disparities in care between the two hospitals. In this setting, the TS providers were instructed by

the neurosurgeons to place a tracheostomy if the patient had a GCS less than 9 to facilitate early weaning from a ventilator or bag-valve mask ventilation. Additionally, placing a tracheostomy was believed to ease pulmonary toilette given the dearth of personnel to monitor and suction the endotracheal tubes in both the ICU and on the wards. Importantly, TS providers practiced in a lower resource hospital with limited access to ventilator support, CT scans, and ICU level care, yet they were still able to achieve comparable clinical outcomes.

Evaluation of the TS training model

While examining these outcomes, it is paramount to critically examine the task-sharing training and sustaining model to ensure patient safety and mitigate negative consequences. As mentioned in the Lancet Commission on Global Surgery and illustrated in **Figure 3**, TS models should have systematic training and competency-based evaluation prior to allowing TS providers to practice.[14] First, systematic training programs should occur locally and involve a structured training curriculum, adequate oversight during medical and operative management, and competency-based evaluation at the end of the dedicated training cycle. Subsequently, local supervision should happen periodically to ensure maintenance of skills and competencies, and proper referral networks should be established for complex cases and complications to allow for tele-consultation and physical transfer of patients when necessary. Furthermore, it is critical for task-sharers to be officially recognized and supported by their institutions with a clear definition of their scope of practice, adequate financial remuneration, and clear career progression avenues in order to prevent attrition of practitioners and prevent task-creep: practicing beyond the scope of their training.[14]

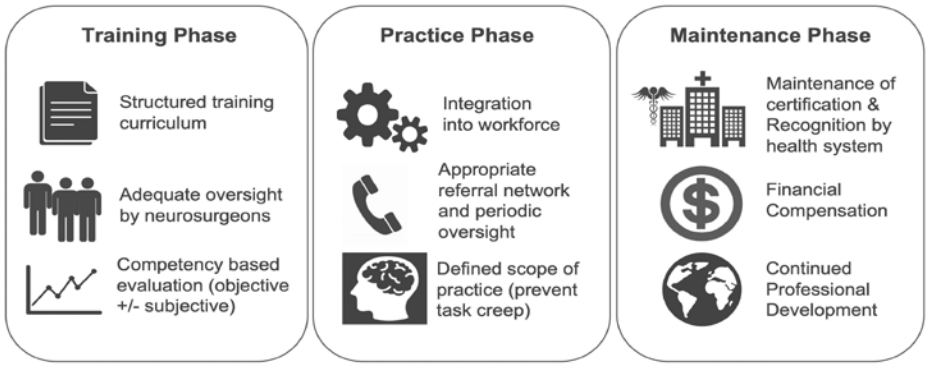

Figure 3. A Theoretical Task-sharing Model. Ideally, task-sharing would involve structure in the three phases of training, practice, and maintenance of providers.

The Philippines model **(Figure 4**) corresponds well to the theoretical model. The structured three-month rotation allows for a dedicated time for the resident to study and practice neurosurgery in both medical management and procedural intervention.

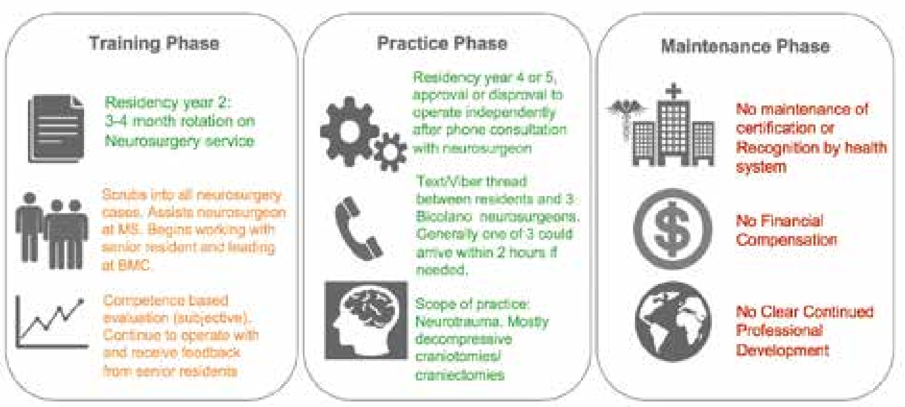

Figure 4. The Bicol Region Task-sharing Model. The program is depicted in the three-phase format of training, practice, and maintenance of providers provided in Figure 1. Green text indicates consistency with an ideal task-sharing model, while yellow text is partially consistent and red is missing or can be improved.

However, the model could move toward standardization by implementing targets for numbers and types of surgeries needed before advancing to operating independently. A competency based written exam on medical management and practical exam on technical skills could also improve the quality of the training program as it would motivate individuals to master the curriculum and provide instructors with information on where remediation may be required. For the practice interval, TS providers staff all cases with the consultant neurosurgeon, so if any referrals or expertise are needed, there is regular interaction between the TS and the neurosurgeon. The scope of practice is limited to trauma and emergencies to prevent task creep. The greatest opportunity for improvement in the Philippines model is maintenance of providers, which typically involves higher level systems managers and a political agenda. Right now, the practice of TS is acknowledged at the local and regional level but is not officially recognized by the Philippine College of Surgeons or Academy of Filipino Neurosurgeons. Maintenance is also inherently absent in this model, as general surgery residents are instructed not to continue practicing neurosurgery once they leave this training program, unless it is an absolute emergency (for which they are invited to call the neurosurgeon) or they transfer to a neurosurgical residency. Instead, the intention is that once the general surgeons go into practice, their neurosurgical experience improves non-surgical neuro-management at outside hospitals as well as timely recognition

of when patients need to be transferred to a hospital with the ability to deliver neurosurgical care. It is conceivable that if there were avenues to maintain certification in emergency neurosurgery management after general surgery residency, and continued communication with specialist neurosurgeons, then graduates from the task-sharing model could continue to provide emergency neurosurgery care as general surgery consultants, analogous to the Australian model at Darwin Hospital.[20] However, the extent of communication and sharing of clinical autonomy would likely be less, and this approach would instead emulate a task-shifting model. This would expand the pool of individuals able to provide neurosurgical care but may risk the clinical safety of the process. Additionally, there is no direct financial compensation for TS residents; the neurosurgical work is part of their curriculum and consultant and resident remuneration is under the umbrella government salary allotted per annum. Additionally, patient payment is either made to the government hospital by PhilHealth, the government insurance plan, or performed as a charity case. Therefore, to respect and retain task-sharers, the governing organizations may consider officially recognizing task-sharing models and practitioners and providing them with a certification for professional development and/or financial remuneration.

Limitations and Strengths

The limitations of this study warrant further discussion. Primarily, the data collection was retrospective and thus dependent upon the quality of hospital census data and the paper medical records. It is likely that cases may be missing, and it was evident that some paper medical records were incomplete. Pre-hospital data such as alcohol involvement, patient status and treatment at an outside hospital were variably recorded and often unfit for analysis. Additionally, in Bicol, the paucity of quality pre-hospital care and time delay in reaching a facility fit to provide adequate intervention may contribute to a smaller population of surgical candidates. While all cases presenting to the hospitals with a neurosurgical emergency were included, it is likely that a contingent of Filipino patients involved in neurotrauma died prior to hospital arrival and therefore the epidemiological assessment of TBI within the area cannot be adequately assessed. In-hospital, the physician and nursing notes were often insufficiently detailed and patient functional status at the time of discharge could not be elucidated. As there was no record of follow-up for these patients, long-term mortality, neurologic status, and functional independence could not be assessed. There were also limitations in comparing the neurosurgeons and TS providers as they operate in two separate hospital environments and are treating different patient populations. In this study, the TS cohort received more trauma admissions, whereas the neurosurgeons treated more patients with spontaneous hemorrhage. While we corrected for GCS score upon arrival, mechanism of injury, radiographic diagnosis, and patient age in the statistical model, the comparison would have been more robust with more similar patient populations. The private hospital setting is often better resourced and treats patients that can afford higher quality care. Overall, this makes the present analysis a more conservative study as the TS providers are at a hospital quality disadvantage. However, there are likely instances in which critical patients who needed surgery were unable to pay for additional care (such as ventilators) at the outside hospital and expired prior to surgery. The generalizability of this study should also be carefully considered. While these data comprise an original report of clinical outcomes related to task-sharing in neurosurgery in an LMIC, it is a single region study. Targeted site data collection may miss geographic variation and limit generalizability, not only outside of the Philippines, but also to different Filipino regions. However, this is a critical starting point for understanding the practice of TS where it is currently ongoing.

Despite these limitations, our study had several strengths. This retrospective cohort study is one of the first to thoroughly examine the quality of task-sharing care provision in neurosurgery within a LMIC where there is a large burden of TBI and both workforce and geographic limitations to neurosurgical care. Furthermore, the interventions closely approximate the theoretical model of safe and effective task-sharing put forth by the Lancet Commission in Global Surgery, which incorporates phases of training, practice, and maintenance of providers with regular oversight. This study serves as a starting point for improving our understanding of how task-sharing can be employed in neurosurgery and informs the need for additional prospective data collection.

Future Directions

An essential part of delivering safe, timely and affordable neurosurgical care in LMICs will be successful disease and population management. For neurosurgical populations, there needs to be a multi-pronged approach to systems improvement of public health prevention, prehospital care, in-hospital care, and rehabilitation. At present, the neurosurgical burden of disease and concomitant workforce deficits in neurosurgery require a concerted effort in workforce expansion in the coming years. This TS model has proven successful due to a systematic education and training of surgically skilled providers, local oversight and teleconsultation for care planning coordination, and a clearly defined scope of practice. Incorporating task-sharing into local, national, and international plans of workforce expansion is not meant to replace specialist providers, but rather to strengthen specialist neurosurgical teams by extending the reach of neurosurgeons' expertise in a fashion that complements their traditional job roles. Furthermore, employment of task-sharing can decrease both the financial and temporal investment needed to increase the surgical workforce. Through additional, prospective data on task-sharing and iterative program evaluation that ensures quality care provision, a task-sharing model has the potential to be expanded to other hospitals within the Philippines and other LMICs to deliver efficient, effective, and safe neurosurgical care.

CONCLUSION

Overall, the combination of neurosurgical workforce deficits and the growing burden of neurological trauma amplify the demand for scaling up neurosurgical care in low-resource settings. This unmet need often leads to the necessary dependence on visiting surgeons and/or task-shifting to medical officers, but task-sharing is likely a much more sustainable and safe option to mitigate the workforce gap. This retrospective cohort study was one of the first to thoroughly examine the quality of task-sharing care provision in neurosurgery within a LMIC. It demonstrated that emergency neurosurgical care could be delivered safely using a carefully designed task-sharing model. Further optimization of the current model is ongoing within the Philippines and we hope this example serves as a reference for hospitals and Ministries of Health facing similar challenges as they strive to increase access to safe, timely, and affordable neurosurgical care.

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APPENDIX 1.

Regarding the acquisition of technical skills, the rotator scrubs (formally participates in the surgery in a sterile fashion) into as many neurosurgery cases at BMC and MS as possible during these three months. At MS, the rotator assists the consultant neurosurgeon, whereas at BMC, he or she assists a senior resident (resident year four or five) or the consultant if the consultant is indeed operating. The rotator's competency in clinical decision making and technical skill are continuously evaluated by the consultants and senior residents; however, there is no clear benchmark for the number of cases the rotator should or will do with a consultant during the three months. Additional autonomy is granted subjectively. After completion of the three-month neurosurgery rotation, the individual continues to train with senior residents and consultants periodically. Occasionally, the consultant neurosurgeons will decide that an individual resident is not competent enough to continue practicing neurosurgery during the latter half of residency; this is communicated to both the individual resident and senior residents.

In the training phase, the post-rotation general surgery residents continue consulting with the neurosurgery consultants via a phone call and/or text message. Their scope of practice is limited to emergency neurosurgery, predominantly for trauma cases. Complex neurosurgical cases such as tumors, and aneurysms are not performed by residents. Residents occasionally place ventriculoperitoneal shunts, and place lumbar drains to decrease ICP; external ventricular drains are rarely placed at BMC due to concern for infectious ventriculitis in the perceived limited hygiene quality in the intensive care unit. By their fifth and final year of residency, most trainees are allowed to operate independently and/or advise junior residents who are in years two through four. These TS individuals are listed as the "Attending on Record" in the medical chart, but the ultimate liability and billing lies with the neurosurgery consultants.

There is no clear maintenance phase at present. General surgery residents are not to continue practicing neurosurgery once they leave this training program. However, the intention is that this training improves non-surgical management at outside hospitals as well as timely recognition of when patients need to be transferred to a hospital with the ability to deliver neurosurgical care. There is no additional financial compensation for these residents, as it is part of their curriculum; all proceeds go to the consultant neurosurgeon, though these are minimal given that the majority are at BMC and are under the umbrella government salary allotted to the consultant neurosurgeon.

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CHAPTER 6

Task-shifting and task-sharing for neurosurgeons amidst the COVID-19 pandemic

Robertson FC, Lippa L, Broekman ML.

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The coronavirus disease (COVID-19) pandemic has swept the globe at an unprecedented rate, flooding hospitals and revealing the vulnerabilities of finite supplies and providers. Neurosurgeons have restricted operations to emergency and essential interventions.[1] Some are being deployed to new intradepartmental roles, others lateralized to provide care for coronavirus patients. The reassignment of staff is a common, often temporary, response to expand coverage in a crisis. However, the coronavirus situation is unique. With the novelty of COVID-19, not even infectious disease and critical care experts are exempt from the learning curve, and individual risk of infection breeds further discomfort. Understandably, these conditions can evoke feelings of fear and powerlessness for patients, families, and providers. In this challenging time, strategic health systems approaches can facilitate timely access to safe and affordable care and transform untoward sentiments into a collective strength.

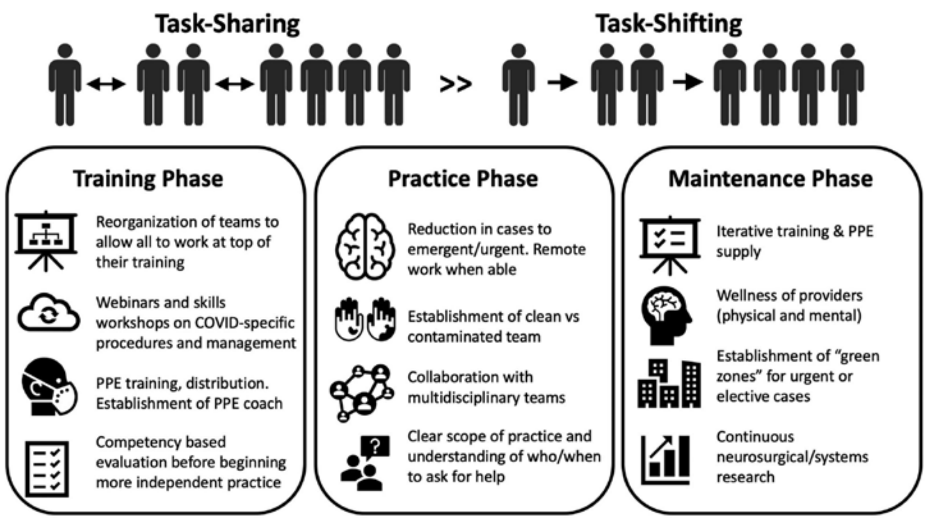

FIG. 1. Task sharing is preferred to task shifting as a method for increasing workforce capacity. An ideal approach involves training, practice, and maintenance phases. Each phase contains its own health system strategies.

Task shifting and task sharing are workforce strategies that involve duty redistribution.[2] Task shifting is transference of clinical autonomy from highly qualified healthcare workers to those with shorter training and fewer qualifications. In contrast, task sharing uses tiered staffing models with collaborative teams of specialists and less-qualified cadres who share clinical responsibility and rely on iterative communication and training to preserve high-quality outcomes. The application of task shifting and task sharing for medical, surgical, and neurosurgical specialties in low-resource settings has shown that task sharing is preferred to task

shifting to maintain safety.[2,3] An ideal task-sharing model can be evaluated in 3 phases: training, practice, and maintenance (**Fig. 1**).[4]

For the first phase—training—the principal step is identifying providers and redistributing in a manner that minimizes "things to be learned" in order to satisfy the "job to be done." One must ensure adequate reserves of those with setting-specific expertise. In the COVID-19 pandemic, the most experienced neurosurgeons are also from the most vulnerable age groups, so their wisdom and skills may be best used via telemedicine encounters, guiding ethical decisions on appropriate neurosurgical interventions, or preserved for neurosurgery-specific cases. Attendings with critical care experience may need to oversee medical ICU care. Residents adept in neurocritical care and placing central lines can undergo intensive skills training to bolster competence and confidence in intubation and ventilator management. Residents staffing neurosurgery services can work remotely when possible to place orders, write notes, call consults, and conduct virtual visits with patients, to provide a buffer in case onsite residents become ill and/or require quarantine. Many centers are assigning "contaminated" and "clean" teams to respective wards. Meanwhile, the reduction in neurosurgical patient censuses permits redeployment of remaining faculty, residents, and advanced-practice providers to support COVID-19–specific care. Hospitals can further benefit from medical student engagement. In the United States, final-year medical students are being issued emergency 90-day limited licenses for early promotion.[5] More junior students can assist with supervision. Comprehensively, many can be mobilized.

The subsequent question is what to teach. Training in technical skills requires shorter time intervals than clinical decision-making capacity, so procedures can be offloaded in a task-sharing model with oversight from experienced persons. Throughout Europe, when the gravity of intensive care demand was realized, hospitals halted elective procedures and implemented skills workshops for non-ICU personnel regarding noninvasive ventilation and advanced monitoring, as well as abbreviated courses on relevant care, such as testing guidelines and pulmonary optimization. Many national and international societies have released open-source webinars and podcasts on high-yield COVID-19–specific management. Departments, neurosurgery included, may benefit from designating personal protective equipment (PPE) "coaches" to oversee proper donning and doffing practices across teams. Concurrent efforts can empower outpatient testing to reduce the burden on hospital centers. Universally, it is essential to ensure adequate governance for standardized curricula, appropriate oversight, and competency-based evaluation before graduating individuals to more independent stages. The escalation of the COVID-19 pandemic means that training phases will be brief, and providers will rapidly advance into the practice phase.

In the practice phase, job scope should be clearly defined to facilitate transitioning into the COVID-19 workforce, seeking consultation for complex cases, and prevention of "task creep," acting beyond permissible guidelines. Within neurosurgical departments, teams can consider dedicating providers for patients at risk for COVID-19 (“contaminated” team). As neurosurgical staff are lateralized to medicine services, we should prepare to humbly engage in working models that involve multidisciplinary teams, supervised in branch models under internal medicine residents and attendings. Again, where to seek help when needed should be clear; preventing task creep protects providers, patients, and the healthcare system. As patient burden exceeds provider capacity, there will be greater pressures to use a task-shifting approach with less oversight, but task sharing is preferred when possible.

The duration of the maintenance phase has yet to be determined. Short-term priorities include ensuring that the newly trained staff thrive for as long as needed, with an adequate supply of PPE and timely dissemination of new information. Addressing the impact of physical, emotional, and moral stress on providers given isolation and care rationing should be incorporated. The longer-term strategy is contingent on multiple factors. If the virus is not seasonal and there is geographic recurrence, control methods may extend into 2022.[6] If so, our community will need to reassess which cases can truly be delayed. We may need to establish “green zones,” as Switzerland neurosurgery is doing, where urgent or elective cases are performed in a separate location, and providers and patients require negative COVID-19 tests and chest radiographs prior to entry. Furthermore, there would be a greater demand for rapid data analysis and iterative systems research to ensure best neurosurgical practices.

While the wrath of coronavirus has caused tremendous disruption in global health already, many cities and countries have yet to experience the virus at its peak. We cannot lie idle, anticipating the storm. In geographic locations currently facing or anticipating the wave of COVID-19 patients, neurosurgeons can begin task sharing to strengthen workforce systems, while continuing to triage operative cases and invest in contingency plans if the pandemic is prolonged. In this arms race between humanity and a virus, we must venture forward with humility, patience, flexibility, and persistence to conquer this challenge together.

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CHAPTER 7

The impact of the COVID-19 pandemic on neurosurgery worldwide

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ABSTRACT

The novel coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory distress syndrome coronavirus 2 (SARS-CoV-2), first appeared in December 2019 and was declared a pandemic by the World Health Organization on March 11, 2020 [1]. By September 9, 2020, 27.7 million cases and 0.9 million deaths were confirmed globally [2]. This disease placed an unprecedented strain on healthcare systems around the world [3], and had a substantial effect on clinical practice across all surgical specialties, with neurosurgery being no exception [5]. Many hospitals implemented no-visitor policies and COVID-19 testing for all inpatients in order to prevent spread and protect patients and healthcare workers [4]. To conserve beds, workforce, and valuable resources such as masks, gowns, and ventilators, surgeons had to restrict operations to emergency and essential interventions. Some neurosurgeons were redeployed to new intradepartmental roles, others lateralized to provide care for coronavirus patients. To limit in person interactions and contagion, there was a surge in telehealth and digital innovation for remote monitoring and management. Research laboratories were closed for prolonged periods. Medical education and residency training were also substantially altered, with cancellation of many in person events and a transformation to online meetings and educational sessions. In this chapter, we discuss the impact of COVID-19 on the global neurosurgery community with respect to clinical care, education, and research. While the pandemic has caused tremendous disruption in global neurosurgery already, there is hope that many of the lessons learned during this time have contributed to our resilience and preparedness for the future, be it a second wave of COVID-19, or a new unexpected challenge.

COVID-19 IMPACT ON CLINICAL NEUROSURGERY

The advent of COVID-19 is dramatically changing how the world practices medicine. An abundance of patients requiring hospitalization for acute respiratory management has strained the healthcare system, forcing all specialties, including neurosurgery, to combat an unprecedented shift in patient prioritization, operative risk management, workforce redistribution, and financial challenges.

Prioritization

At the pandemic's onset, hospitals around the globe mobilized strategic plans to reduce non-COVID related care in order to preserve resources for those with infection, and to flatten the curve by decreasing contagion within the hospital. The surge of COVID-related acute respiratory distress syndrome and consequent need for mechanical ventilation made hospital ventilator capacity a critical resource. Given that operative interventions account for the majority of ventilator use within the hospital, there were concerted efforts to reduce surgical volume. Consequently, the

neurosurgical community strived to establish important principles and guidelines for prioritization of neurosurgical operations [5, 6]. These discussions incorporated ethics, biology, health systems, and lessons learned from previous epidemics like SARS [7]. The foundational question to be answered was if surgery could be deferred without significant neurological deterioration or disease progression [5]. As elective operative time was restricted, hospital committees became responsible for transparent decision-making processes regarding operative urgency, accounting for factors such as disease pathology, patient symptomatology, and the possibility of an equally effective alternative treatment. Under normal circumstances, physician rationale for treatment approach typically follows Kantian or deontological ethical theory, which favors the best possible treatment for the individual patient, regardless of the ramifications to others. However, utilitarianism or consequentialist ethical theory, which centers on treatment of many as opposed to individuals, often dictates medical practice in global health crises like the current pandemic [5, 8].

During 2020, life threatening conditions deemed to be neurosurgical emergencies proceeded as usual across neurosurgical departments [9-11]. This included cerebral hemorrhages (epidural, subdural, subarachnoid, and intraparenchymal), acute hydrocephalus, spinal cord compression with neurological deficit, and cranial and spinal trauma emergencies. The timing of surgical management of other less urgent conditions varied. According to a recent US based survey of leaders of 40 large academic neurosurgical programs, 62% had cancelled all non-urgent cases, 80% of respondents still preferred operating within 1-2 weeks for newly diagnosed high grade gliomas, whereas for presumed low grade gliomas, half of respondents monitored patients with imaging and symptoms [12]. Groups from Italy (Lombardy) [8] and USA (New York and Detroit)[16] attempted to categorize common procedures and pathologies by urgency to facilitate clinical decisions. The Italian group classified oncological procedures in three categories: Class A++ comprised intracranial or spinal tumors that require emergency treatment (severe intracranial hypertension with declining level of consciousness, acute hydrocephalus, spinal cord compression with evolving quadri or paraparesis); Class A+ comprised tumors that need treatment within 1 week (intracranial tumors exerting mass effect with progressive neurological deficit, without declining level of consciousness); Class A comprised conditions needing treatment within a month (tumors with imaging suspicion of malignancy) [11]. An American group prioritized the relative urgency of 86 common neurosurgical scenarios from every subspecialty into six tiers and respective time frames, after a consensus that was achieved among 22 neurosurgeons (14 from the New York and 8 from the Detroit metropolitan areas) using the Delphi method [13]. As more time passed, the European Association of Neurosurgical Societies put forth a unified guideline for triaging, which offered a three-tiered triaging approach, but importantly noted that different countries and regions would be facing conditions that may differ greatly from one another and from day to day. Thus, they advocated for assessments using contemporary knowledge of the evolving local, regional and national conditions, which could result in significant differences in decision-making between regions [14].

As intended, hospital prioritization of COVID management and emergency cases translated to dramatic decreases in neurosurgical case volume. For instance, at the Toronto Western Hospital, neurosurgical cases decreased from 230 in January 2020 to 146 in March and 57 in April 2020; a reduction of 36% and 75% respectively. The subspecialties most affected were Functional and Spine with 80% and 73% reduction respectively, while Oncology and Vascular experienced fewer cancellations; 50% and 40% respectively. Triage schema for University of Toronto are presented in **Figure 1** [16]. Analogous case reduction was described in other large North American and European institutes [6-8]. While non-urgent case cancellation produced an intentional decrease in case volume, there were significant reductions in the number of patients seeking neurosurgical care in the emergency department, noted by University of Toronto as well as Mass General Hospital [11,12]. Furthermore, there have been significant global increases in delayed neurosurgical admissions during lockdowns and quarantine periods, as noted in Morocco [15]. Comparable declines occurred in in-person clinic visits across most neurosurgery departments [7,10]. This is suspected to result from fear of seeking care given risk of inoculation onsite at the hospital. In contrast, telephone consultations and video clinic visits gradually increased in number to cover patient care needs, discussed further below [7]. Overall, prioritization during the pandemic forced neurosurgeons to delay non-urgent and some urgent cases with hopes that it would help optimize care delivery for COVID patients and reduce the risk of contagion in the hospital. After the first wave of the virus passed, it has left a back-log of cases to address, but a newfound appreciation for the possibility and ease of telehealth, which will likely remain a core component of care going forward.

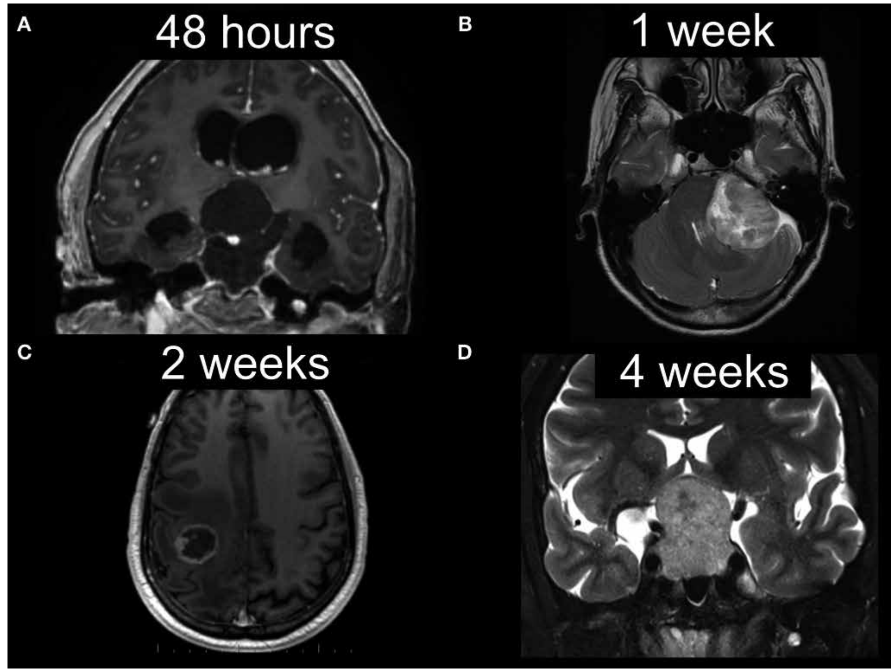

Figure 1: Covid-19 Neurosurgery Case Triage schema at the University of Toronto. Here, classified according to the prioritization scheme published by Thomas et al [13]. (A) Tier 2, Intra-axial tumor with neurological decline; treatment within 48 hours. (B) Tier 3, Cerebellopontine angle tumor with hydro and/or brainstem compression; treatment within 1 week. (C) Tier 4, Intra-axial tumor without shift; treatment within 2 weeks. (D) Tier 5, Transsphenoidal approach for skull base lesion with optic compression; treatment within 4 weeks.

7

Pre-operative measures and transformation of the OR

In addition to intentional decreasing of surgeries, the workflow and perioperative systems also had to transform to apply measures aiming to mitigate the perioperative spread of COVID-19 [16]. Once testing was more readily available, institutional policies began dictating that all patients undergoing surgery had to be tested for COVID-19 preoperatively. However, other institutions suggested that preoperative COVID-19 testing of asymptomatic patients should be examined according to the local epidemiology and availability of testing resources [17]. This was particularly important for low-income countries, however, given that at the time this chapter was written 17.9% of infected individuals were believed to be asymptomatic carriers [18], testing everyone if feasible could potentially decrease the spread.

The use of full personal protective equipment (PPE), such as N95 masks, gowns and gloves, by every health worker involved in neurosurgical operations was deemed mandatory at many institutions, due to the aerosol-generating potential of most neurosurgical operations (e.g. drilling; access to paranasal sinuses). Other groups have suggested that for low-risk patients (tested negative and asymptomatic with no recent travel history or contact with COVID positive patient), surgical masks and droplet precautions should suffice [16]. Having a risk-stratified PPE approach could safeguarding PPE reserve in the context of worldwide shortages and particularly for low-income countries. In some institutions or health systems there were "clean" and "contaminated" patient pathways. In Toronto, specific operating rooms were reserved for confirmed or suspicious COVID-19 patients, ideally with negative pressure ventilation. Additionally, different nursing teams were assigned outside the room for circulating and providing equipment as needed. They believed the number of OR personnel and movement of personnel in and out of the OR should be kept at minimum. Paper charts were kept outside the OR and monitors/machines were covered in plastic wrap. A rigorous decontamination after COVID-19 cases was also essential [16]. At Massachusetts General Hospital, all procedural consents became verbal as opposed to written to avoid cross contamination with pen and paper handling. In Switzerland, Morocco, and other nations, certain buildings were designated as "green zones" to allow for COVID-negative patient and provider care to resume [15]. For each of these approaches, rigorous traffic control and attention to infection status was required.

Intra-operative considerations in Neurosurgery

Modifications of operative practice also took place in order to moderate the effect of high-risk settings encountered in the neurosurgical OR. Local anesthesia or conscious sedation was increasingly preferred to general anesthesia, when feasible, in order to avoid endotracheal intubation and extubation to limit aerosolization. Awake fiberoptic intubation was avoided when possible. All non-essential staff were often asked to exit the room during intubation and extubation [19]. At some institutions, ORs were also closed to entry for 30 minutes after intubation and extubation to allow for aerosolized particles to clear.

Operations implicating the respiratory tract, due to the high viral load [20], carry significant risk of transmission. In neurosurgery, such procedures include endoscopic endonasal, transoral, and translabyrinthine approaches, as well as any craniotomy transgressing the frontal sinuses. Equally effective and safe alternative approaches (e.g. pterional instead of endoscopic endonasal; retrosigmoid instead of translabyrinthine) could be favored or the surgery could be deferred to a later time, when feasible.

A hypothetical and controversial risk in neurosurgery is the airborne transmission of COVID-19 following the use of aerosol-generating instruments such as, drills, monopolar cautery, lasers, and ultrasonic aspirators [17]. However, the infectious potential of aerosolized particles is based on the hypothesis that they include virions. Although, this is proven for the respiratory and digestive tracts [20], this is no longer believed to be the case for cerebrospinal fluid, central nervous system (CNS) tissue, or bone. As such, the recommendation to avoid or restrict the utilization of the aforementioned instruments was deemed unnecessary by many [17].

Redeployment

As the influx of COVID-19 patients rose at each institution, hospital personnel had to adapt to a new reality, and trainees and staff from both medical and surgical specialties worldwide had to be redeployed [9]. The reassignment of staff is a common, often temporary, response to expand coverage in a crisis. With COVID-19, not only was there potential for discomfort from working in a foreign role, but also susceptibility to and fear of infection. In such challenging times, strategic health systems approaches can facilitate timely access to safe and affordable care and provide reassurance that there is an element of control.

Task shifting and task sharing are workforce strategies that involve duty redistribution [21]. Task shifting is transference of clinical autonomy from highly qualified healthcare workers to those with shorter training and fewer qualifications. In contrast, task sharing uses tiered staffing models with collaborative teams of specialists and less qualified groups who share clinical responsibility and rely on iterative communication and training to preserve high quality outcome. Ideally, hospitals requiring redeployment of workers would use a task sharing approach that invokes a three-phase model of training, practice and maintenance (**Figure 2)** [22, 23]. A principle step in task reassignment is strategic identification of providers and redistributing in a manner that minimizes "things to be learned" in order to satisfy the "job to be done." Once assigned, individuals should have a dedicated preparation period and ideally a competency-based evaluation of readiness. Subsequently, the practice phase should involve team-based care with tiered oversight to ensure individuals know who and when to ask for guidance when appropriate. Many neurosurgery residents were redeployed to work in COVID intensive care units, and responsibilities ranged from assisting medical teams as a responding clinician, to facilitating procedures such as central lines and prone positioning. Others filled shifts in testing clinics, and some were redeployed to work on medicine triage floors or in the emergency ward. In institutions with a lower demand for workforce distribution, plans for redeployment were developed, but were not required. Still, many residents took on new roles within their teams. Many hospitals developed systems in which neurosurgical non-COVID-19 patients in the wards and intensive care unit (ICU) were managed with two available teams - one working in hospital and one working from home. Where redeployment plans were not enacted, hospitals have been encouraged to adequately train personnel in case of a second surge of COVID-19.

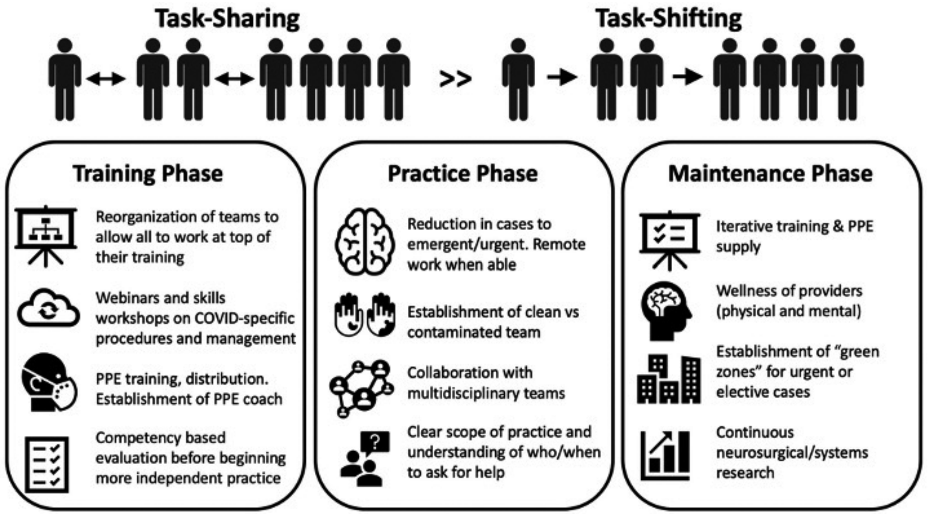

Figure 2: A strategic plan for task sharing during the COVID-19 pandemic. Previously published by Robertson et al, Journal of Neurosurgery [22].

The rise in Telehealth for outpatient assessment and postoperative follow up

While digital or telehealth services existed prior to the pandemic, uptake and integration into regular clinical practice had been slow, predominantly due to learning curves, lower demand, and barriers in financial reimbursement [24]. However, the need to deliver care while reducing the use of PPE and risk of viral transmission with personal contact served as a catalyst for the exponential increase in telehealth. Benefits for the patients include less cost and time of commuting, and no need for missing work, while it can help neurosurgeons optimize their schedules [25]. A recent systematic review of 52 neurosurgical studies (25 prospective and 27 retrospective; 13 US, 39 other countries) with 45,801 patients demonstrated that 99.6% of visits were completed successfully [26]. Of the 0.4% of visits that required subsequent appointments, 81.5% were due to technology failure, and 18.5% required further face-to-face evaluation or treatment. Regarding reimbursement, 94.3% of telemedicine visits were billed using face-to-face procedural codes. Overall, both patients and providers have seemed to enjoy this transition. In a study of 596 neurosurgical patients who had telehealth visits at Michigan State University, patients reported high satisfaction with the experience, providing an average rating of 6.32 ± 1.27 out of 7 [27]. Furthermore, telehealth visits have the potential to be financially advantageous for patients. A study from Mayo Clinic on video telemedicine rather than face-to-face clinic visits for postoperative follow-up showed that patients saved an average of $888 per visit [28]. In-hospital telehealth options are also being explored. In Kuala Lumpur, Malaysia, virtual and physical ward rounds on neurocritical patients were conducted using smart glasses for an individual to

broadcast rounds to the team for 103 neurocritical care patients with high overall inter-rater reliability [29].

More importantly, the potential of digital health for system improvement greatly exceeds video phone calls, and COVID-19 emphasizes the need to invest in this arena. Wearables and digital phenotyping can facilitate both active and passive data collection for remote screening and monitoring of early symptoms to indicate when a patient may need to seek higher levels of care. This technology has already been tested in neurosurgical populations, such as monitoring for physical activity rates and pain control with post-operative spine patients [30]. As such technology becomes more prevalent in home monitoring for COVID symptoms, we as a neurosurgical community should continue exploring remote management of our patients as well, and advocate for appropriate reimbursement for these efforts that account for the value added to patient care.

Future directions – Lessons learned

At the present time, healthcare protocols and national quarantine regulations have enabled countries around the globe to flatten the curve and begin resuming clinical neurosurgery activity. The next steps of health policy will focus on dealing with the backlog of the cancelled neurosurgical cases while maintaining a level of responsiveness in case of a new COVID-19 surge. The strategy should first accomplish the return to "normal" neurosurgical practice with the overarching goal of reaching full capacity. Some possible solutions would be to extend everyday operative hours and running elective ORs during weekends. Resources should be appropriately allocated - additional OR and ICU nurses should be employed, and additional ICU beds should be created. These measures put a financial strain on health systems, especially in low-income countries, however they can help boost surgical capacity as well as create a well-prepared system for a future COVID-19 outbreak. Additionally, widespread application of telemedicine is essential to reduce viral exposure. The achieved improvements in digital health infrastructure and platforms can facilitate more timely and cost-effective outpatient care that enhances value, particularly for the patient. Even if we return to a COVID-free planet, these modes of practice will likely persist.

COVID-19 IMPACT ON NEUROSURGERY EDUCATION AND TRAINING

Similar to other medical and surgical specialties, the consequences of the COVID-19 pandemic on neurosurgery education and training cannot be understated. The experiences of the neurosurgery residents, registrars, and fellows during the acute phase of the pandemic have spurred multiple opinion pieces, letters to the editor, and survey studies conducted around the world [31-35]. Although the structure of the neurosurgery training programs varies significantly among different countries and regions, almost all neurosurgery departments have uniformly reported loss of training opportunities for young neurosurgeons. In a short span of time, adjustments had to be made in order to sustain neurosurgery education while ensuring trainee safety under challenging circumstances.

Loss of training opportunities

The foremost concern was the significant decrease in the operative experiences of neurosurgery trainees. This was primarily due to the cancellation or postponement of elective procedures in most, if not all, neurosurgical centers, as described above. Several other factors contributed to the steep decline in surgeon logs. For instance, in Singapore and the UK, a senior surgeon was assigned to perform procedures that would have ordinarily been given to a junior trainee [36, 37]. Doing so reduced the number of people inside the operating room to limit virus exposure risk, but also minimized operating time and presumably lowered the risk of perioperative complications during a period when hospital resources such as ICU beds and mechanical ventilators were being conserved for COVID-19 services. Thus, it was more challenging for trainees to gain autonomy and practice skills that were at or above their level.

There had also been a reported decline in neurosurgery consults. In the case of neurotrauma, this had been attributed to restricted mobility from mandated lockdowns and quarantines. In developing countries, limited transportation had hampered the ability of patients to reach medical care. Patients had also delayed seeking medical opinion, even for urgent neurosurgical conditions such as aneurysmal subarachnoid hemorrhage. The closure of outpatient clinics and reduction of staff during ward rounds and other patient care activities also meant that opportunities to sharpen clinical skills essential for decision-making had likewise been markedly reduced.

More often than not, trainees had to be withdrawn from their elective and research rotations. Neurosurgery trainees have also been redeployed to areas of need during the peak of the pandemic in their respective countries. Among 192 neurosurgery trainees in Italy, 30% were directly involved in the clinical management of COVID-19 patients [31]. Between 17–54% of trainees in Indonesia, Malaysia, Philippines, Singapore, and Thailand reported working in COVID wards or ICUs, and acute respiratory infection clinics [33].

Because of lack of hands-on experience during this period, a significant proportion of trainees around the world were worried that the pandemic would have a negative impact on their training overall: about one-third of trainees surveyed in North America [34], and as high as 74% of those in Southeast Asia [33]. In a highly technical specialty such as neurosurgery, it is essential that this concern is addressed, and measures are taken to ensure that training programs continue to produce highly skilled and competent neurosurgeons.

Adaptations under fire

In centers where trainees are unable to meet requirements in cases numbers set by their respective neurosurgery boards or councils, the length of the training may have to be extended to compensate for the surgical volume loss. Other strategies included increasing the exposure of the trainees to private cases performed by consultants, and increasing the surgical capacity of designated non-COVID hospitals, and subsequently diverting elective neurosurgical procedures to these centers.

To maintain and develop surgical skills among trainees, neurosurgery departments have developed pandemic curricula, usually consisting of online didactics with practical, hands-on exercises on microsurgery and micronanastomosis using table-top microscopes, or when available, in dedicated simulation laboratories. Plans to develop realistic surgical simulators accelerated (e.g., https://upsurgeon.com), including the utilization of virtual and augmented reality [38][39].Face-to-face departmental teaching activities such as grand rounds, morbidity and mortality conferences, and subspecialty meetings were easily transitioned to the online environment using various meeting software and applications. In fact, many groups have reported an improvement in attendance during these interdisciplinary discussions, likely because of the decrease in clinical workload and ease of joining these activities, even at home. Trainees had to rapidly acquire communication and evaluation skills required for telemedicine, traditionally not taught in most training programs. Although less than ideal for getting a comprehensive clinical evaluation of patients, this replaced the learning experience from outpatient consults and follow ups, for both trainees and medical students aspiring to get into neurosurgery.

While the pandemic introduced an abrupt barrier and negative effect on the ability to train neurosurgeons, especially in LMICs, the increased use of social media and virtual platforms is markedly improving the interactions between institutions for shared learning between neurosurgeons at an international scale. Neurosurgical societies and organizations worldwide regularly conducted online webinars on myriad topics, often focusing on clinical evaluation of neurosurgical diseases and pearls and pitfalls of neurosurgical approaches. Although the advantages of these online learning experiences are many, these must be weighed against "Zoom fatigue," wherein long hours spent in front of a screen may lead to decreased attention span and ultimately, loss of interest in these educational activities.

Other concerns of trainees

Lack of adequate personal protective equipment was a concern for many trainees, especially in areas hardest hit by the pandemic early on [31, 33]. This was crucial, not just for trainees redeployed to COVID-19 units of their hospitals, but also for those who had to perform emergency neurosurgical procedures on confirmed COVID-19 patients. Testing was likewise an issue, especially at the start when RT-PCR was not readily available in most centers and the turnaround time for tests took several days. Because of these issues, many trainees were understandably worried about their personal safety, and that of their families. In a global survey of neurosurgery trainees, 90% said that the pandemic had affected their mental health [32].

A delay in career advancement is looming for many neurosurgical trainees around the world. In the US, the Accreditation Council for Graduate Medical Education (ACGME) published multiple policies to address questions regarding how the pandemic impacted training. Ultimately, the determination of whether or not a resident or fellow can graduate as previously scheduled is the responsibility of the program director with case review by the Clinical Competency Committee [40]. The American Board of Neurological Surgery has postponed both primary and oral examinations. Similarly, in the Philippines, the Philippine Board of Neurological Surgery has decided not to allow final-year residents to sit their exams. Because of travel, work, and visa restrictions, many trainees—especially in low- and middle-income countries—are concerned about international fellowship positions or observership slots that they have previously applied for, or have already secured.

COVID-19'S IMPACT ON NEUROSURGERY RESEARCH

The COVID-19 pandemic has differentially impacted scientists and researchers around the world [41]. When cases began to rise in different countries, it became necessary for academic and research institutions to reduce activity in their physical laboratories to a minimum. By conducting only essential experiments and operations, the risk of COVID-19 transmission among laboratory personnel was mitigated and the need for PPE in these less critical areas similarly reduced. As a direct consequence of the pandemic, health researchers anticipated a decline in patient recruitment for ongoing trials, difficulty in procuring needed equipment and supplies, and subsequent delays in project completion and publication [42]. Studies that had the potential to have an impact on the prevention, diagnosis, and treatment of COVID-19 were prioritized. Others were postponed indefinitely, potentially delaying scientific productivity [38, 43]. Ultimately, those rooted in basic sciences (*e.g.*, biochemistry, biology, chemistry, and chemical engineering) had a greater reduction in research time compared with their colleagues whose work were less dependent on physical laboratories and experiments (*e.g.*, mathematics, statistics, computer science, and economics). In contrast, the reduction in clinical volume provided additional time for research that was able to be conducted remotely, such as outcomes, computational, and health science research. Furthermore, it has sparked an unprecedented rate of transnational collaboration on research. The short and long term implications of this are discussed herein.

In a global survey conducted in March 2020, out of 187 neurosurgeons, 27% reported cessation of research [44]. Women and those with young children were disproportionately affected—likely because of increased responsibilities at home—and the decline in publications authored by women has been documented [45]. Declines in research were more pronounced in low-income countries and those

that had a greater COVID-19 caseload; 36% of respondents said that their research activities had decreased. In India, the researches of academic neurosurgeons were more affected than that of neurosurgeons with non-teaching positions [46]. For many neurosurgical trainees, time away from clinical responsibilities translated to more time for research; they used this period to finish pending manuscripts or revise previously rejected submissions. Out of 192 trainees in Italy, 56% said that their production of scientific manuscripts had increased [31]. In North America, 65% of residents devoted more time to clinical research [34]. These figures are in contrast to Southeast Asia, where 33–60% of residents in Indonesia, Malaysia, Philippines, and Singapore had a decrease in their research activities [33]. Neurosurgery residents in Thailand were least affected, with 54% saying that their research work proceeded on schedule. Furthermore, 20–47% of trainees in the region reported that they would miss a research presentation at a neurosurgical conference due to travel restrictions and cancellation of international meetings. Consequently, during the spring of 2020, academic journals faced a massive surge in COVID-related manuscripts submitted to and published in scientific journals across major disciplines [47, 48]. For instance, from February to June 2020, the *Journal of Neurosurgery* recorded a 55% increase in manuscript submissions compared with the same time period in 2019 [49]. For *Journal of Neurosurgery: Spine* and *Journal of Neurosurgery: Pediatrics*, the increases were 77% and 78%, respectively.

Neurosurgical departments implemented several adaptations to maintain their research activities. Whenever possible, researchers were advised to work on the parts of their projects that could be accomplished at home, such as writing grant applications, literature review, remote data extraction, and data analysis [50]. Academic work that did not require patient contact were encouraged. These included conducting systematic reviews and meta-analyses, writing book chapters, and developing simulation models. Journal clubs were converted to virtual meetings [51]. Often, residents on their research rotation served as backup for those who rendered inpatient care and performed essential neurosurgical operations [52]. When faculty had concomitant research and clinical roles, they were only allowed to perform their research duties if they had no symptoms [53].

Other recommendations included streamlining related projects, dividing researchers into cohorts, limiting people working in the same room, and frequently decontaminating shared resources such as microscopes [50]. Over time, as scientists became more aware of the mechanics of viral transmission, it became necessary to renovate physical facilities to ensure adequate ventilation and social distance between personnel, a complete turnaround from the coworking spaces that were encouraged prior to the pandemic.

To accelerate the gathering of data and generation of recommendations in COVID-related studies, many institutions revised their protocols to expedite research processes, particularly those concerning ethics review by institutional research boards. Collaborative work among departments, organizations, and institutions were encouraged, facilitated by online networks. This was best exemplified by the COVIDSurg study [54, 55]. By rapidly recruiting international collaborators, the investigators were able to analyze the 30-day mortality and pulmonary complication rates of over 1100 patients with COVID-19 from 24 countries, concluding that the threshold for surgery in this group of patients must be raised, especially among the elderly.

To cope with the surge in manuscript submissions, major journals have had to make adaptations in their editorial and peer-review processes [48, 49]. In journals with limited human and technical resources, authors have had to contend with longer turnaround times. While there was a great need to disseminate evidence rapidly, there remained a strong responsibility to critically examine submissions for methodological flaws or scientific misconduct, especially those that had a potential impact on treatment algorithms and public health policies. In JAMA, readers were allowed to leave online comments on COVID-related content to obtain immediate feedback instead of relying on traditional letters to the editor [48]. Social media networks such as Twitter were also instrumental in swift dissemination of study findings and getting real-time peer review from the greater scientific community. More significantly, the majority of scientific journals published their COVID-related articles open access. Among the neurosurgery journals, the *Journal of Neurosurgery* released a special issue that tackled COVID-19 and its impact on all aspects of neurosurgery, while *Neurosurgery*, *World Neurosurgery*, *Acta Neurochurgica* and *British Journal of Neurosurgery* have all expedited the publication of experiences of neurosurgeons, trainees, and neurosurgical departments from around the world, as they grappled and coped with the COVID-19 situation in their respective countries. These articles highlighted strengths and best practices to continue providing essential neurosurgical care in both high-income and developing countries. *Neurosurgical Focus* put out a call for papers on preparedness and guidelines for neurosurgical practice during a pandemic, and the special issue is expected to be published in December 2020.

CONCLUSION

The COVID-19 pandemic rapidly swept the globe in 2020 and placed an unprecedented strain on healthcare systems around the world. At the time this chapter is being written, the full impact of the pandemic on global neurosurgery research remains unknown. However, we do know that it has both caused negative and positive change. COVID adaptations decreased case volume and interrupted training in the short term, but also guided neurosurgeons to reflect on protocols for case prioritization, workforce redistribution, pre and intra-operative safety, telemedicine and more. Regarding research, it interrupted many in-person basic science experiments, but also introduced new mays of carrying out global partnerships for big data collection, such as COVIDSurg. Journals have seen surges

in manuscript submissions during this time, and reformatted their processes to allow for more rapid publication. Education has transformed into more broad access of shared information with online webinars and live operation teaching sessions. Overall, the timespan of the virus as an acute threat for humanity is unclear, but we as a neurosurgical community should continue analyzing the positive changes which have manifested in 2020 as we prepare together for a second wave, another pandemic, or simply negotiating our "new normal."

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PART III

The Path Forward

CHAPTER 8

The Role of Technology. Applying Objective Metrics to Neurosurgical Skill Development with Simulation and Spaced Repetition Learning

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ABSTRACT

Objective: Surgical skills labs augment educational training by deepening one's understanding of anatomy and allowing safe practice of technical skills. Novel, high-fidelity, cadaver-free simulators provide an opportunity to increase access to skills lab training. Furthermore, the neurosurgical field has historically evaluated skill by subjective assessment or outcome measures, as opposed to process measures with objective, quantitative indicators of technical skill and progression. We conducted a pilot training module with spaced repetition learning concepts to evaluate feasibility and impact on proficiency

Methods: The six-week module utilized a simulator of a pterional approach representing skull, dura, brain nerves and arteries (UpSurgeOn Srl). Neurosurgery residents at an academic, tertiary hospital completed a videorecorded baseline exam, performing supraorbital and pterional craniotomies, dural opening, suturing, and anatomical identification under a microscope. Participation in the full six-week module was voluntary, which precluded randomizing by class year. The intervention group participated in four additional faculty-guided trainings. In the 6th week, all residents (intervention and control) repeated the initial exam with videorecording. Videos were evaluated by three external neurosurgery attendings who were blinded to participant grouping and year. Scores were assigned via Global Rating Scales and Task-based Specific Checklists previously built for *Craniotomy (cGRS, cTSC)* and *Microsurgical Exploration (mGRS, mTCS*).

Results: Fifteen residents participated (eight intervention, seven control). The intervention group included a greater number of junior residents (PGY 1-3; 7/8) compared to the control group (1/7). External evaluators had internal consistency within 0.5% (kappa probability>Z 0.0001). The total average time improved by 5:42 minutes (p<0.003; intervention, 6:05, p=0.07; control, 5:15, p=0.001). The intervention group began with lower scores in all categories, and surpassed the comparison group in craniotomy GRS (10.93 to 13.6/16) and TSC (4.0 to 7.4/10). Percent improvements for the intervention group were cGRS 25% (p=0.02), cTSC 84% (p=0.002), mGRS 18% (p=0.003), and mTSC 52% (p=0.037). For controls, improvements were cGRS 4% (p=0.19), cTSC 0.0% (p=1.0), mGRS 6% (p=0.07), and mTSC 31% (p=0.029).

Conclusion: Participants who underwent a 6-week simulation course showed significant objective improvement in technical indicators, particularly those early in their training. Small, non-randomized grouping limits generalizability regarding degree of impact; however, introducing objective performance metrics during spaced repetition simulation would undoubtedly improve training. A larger multi-institutional randomized controlled study will help elucidate the value of this education method.

INTRODUCTION

Surgical education has traditionally been accomplished through a combination of apprenticeship, graduated responsibility, and didactics, supplemented with skill workshops predominantly using cadaveric specimens. There is an abundance of neurosurgical literature that emphasizes the immense time and practice required for ascending the technical skills learning curve, and all underscore the importance of repetition.[1-4] Research on mastery in other technical fields suggests learning occurs in stages: observing, imitating action based on instruction, taking action without assistance, and repetition of actions.[5,6] The repetition stage is integral for the automatization of skill; ultimately leading to the trainee being able to perform a skill without any instruction or assistance.[7] A step further than repetition alone is spaced repetition. Spaced repetition is an educational technique for efficient memorization that uses repeated review of content following a schedule to improve long-term retention.[8]

While surgical trainees will perform many repetitions of a procedure throughout the course of a seven-year training program, there are limitations in relying on intraoperative training for the most efficient knowledge growth and skill acquisition. This is partially given the variability in exposure to cases and approaches within and between residency programs due to differences in rotations, case volume, and resident autonomy. Furthermore, increased pressures on healthcare systems to be more efficient may also contribute to variability in trainee surgical autonomy.[9] Hence, there is a growing interest in integrating new avenues of skills development. As recently emphasized in a perspective article from general surgery, there is a call to action to increase spaced repetition learning within surgical training.[10]

Ideally, a spaced repetition learning approach would not have high cost or resource barriers. While cadaveric skills labs remain instrumental in education, they are limited due to their expense and the logistics around specimen preservation and biohazard safety.[11,12] With the advent of rapidly progressive technologies, surgical simulation with virtual reality, augmented reality, and high-fidelity synthetic models may fill that void. These tools not only have the potential of providing high-frequency repetition for trainees, but their uniformity can potentiate objective evaluation of technical skill improvement. Importantly, the neurosurgical field has historically evaluated skill by subjective assessment or outcome measures, as opposed to process measures with integrated objective and quantitative indicators of technical skill and progression during training. Having a reproducible model enables easier application of quantifiable and trackable metrics.

We developed a surgical training pilot using a simulator of pterional approach with disposable skulls and dura (UpSurgeOn Srl) for a 6-week guided training program to teach and objectively evaluate residents' understanding and improvement of anatomy and surgical skills using predefined metrics. The objective was to evaluate the impact and feasibility of incorporating model simulation into neurosurgical residency to improve knowledge and technical skills.

METHODS

Education and Simulation Model

The study was articulated in 3 phases, a preliminary evaluation, training phase, and final evaluation. For the preliminary evaluation, all participants received a link to a 10-minute introductory video explaining the technical objectives, initial session, and evaluation criteria. Residents were also instructed to download the UpSurgeOn phone application, which included stepwise teaching modules for the pterional craniotomy. The simulation model used was the UpSurgeOn PterionalBox (**Figure 1 A-D**) which consists of a reusable, 3D printed skull, brain, dura and underlying vascular and nerve structures. The skull's design provided a portion of the skull which corresponded to the approach (pterional, supraorbital, etc.) with the accompanying bony features superior temporal line, keyhole, sphenoid wing, and clivus.

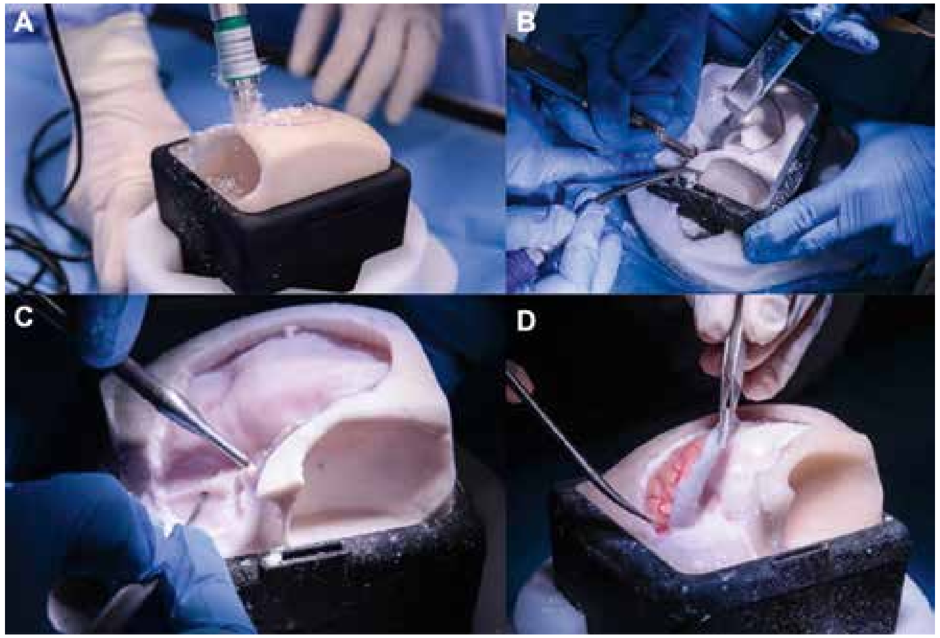

FIGURE 1: Performing craniotomies on the simulator. A-C: participants using various drills to perform a pterional craniotomy. D: example of dural opening.

Trainees were assigned individual skull models and performed craniotomies at surgical stations. They were given printed instructions (**Supplement 1**) of the

approach which began with a supraorbital craniotomy, followed by extension of the craniotomy to include a pterional craniotomy. The residents were instructed to drill the spheroid wing, insert three dural tacking sutures, and open the dura. Participants were asked to do it without instructor help and were timed. The procedure was videorecorded for subsequent evaluation, and the disposable part of the skulls and dura saved for review. Trainees then rotated to a separate station focused on microsurgical identification of anatomy. Using the microscope, a retractor and bayoneted forceps, the resident was asked by the proctor to identify anatomical structures (**Figure 2**, checklist available in **Supplement 2**). Their microscope video feed was visible on a screen and was recorded, and they were asked to identify a standardized list of structures for 3 minutes. At the end of the session, each participant completed a survey evaluating the course, experience, and models (**Supplement 3**).

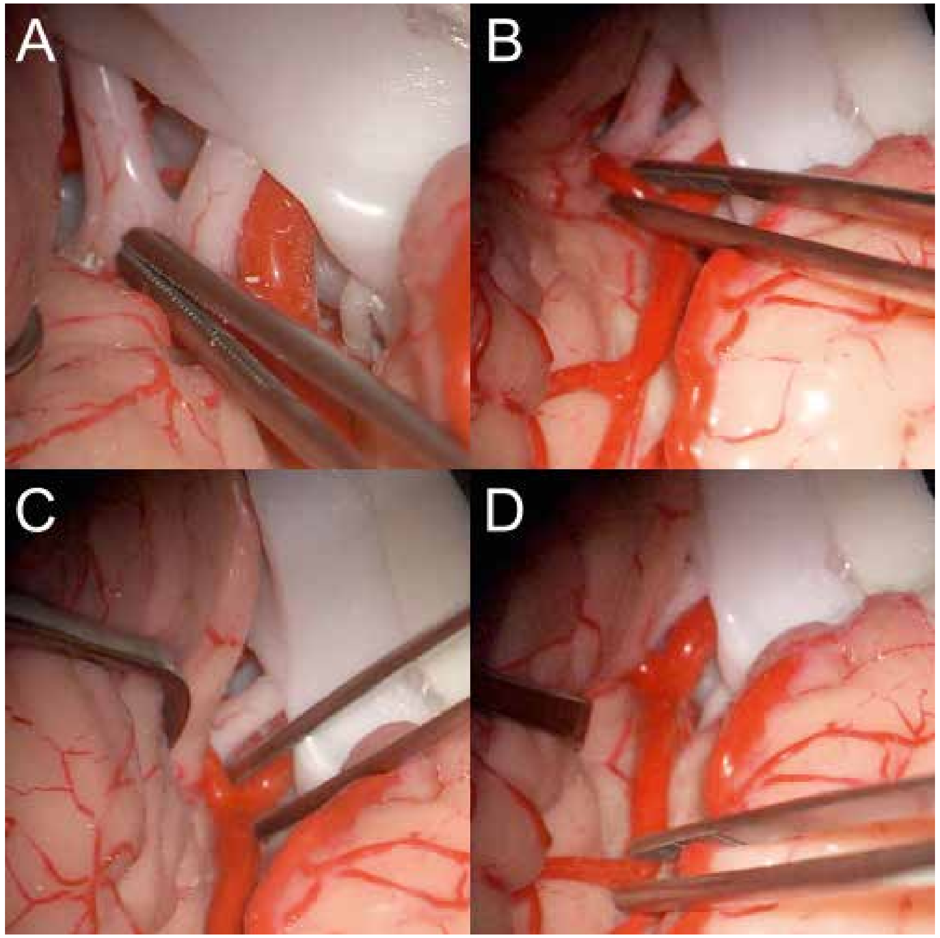

FIGURE 2: Microscope Identification. Examples of anatomy that participants examined during the microscope identification portion as screenshots from the video recording. A: Optic chiasm. B: Anterior cerebral artery. C: Internal carotid artery. D: Middle

For the Training Phase, participants in the intervention group received detailed feedback from their first video completed by an external reviewer. Written feedback was given identifying their technique, approach, and timing. In addition, residents attended a total of four lab sessions with faculty who would provide teaching demonstrations followed by the residents practicing the supraorbital and pterional craniotomy with feedback from faculty. Sessions also included microscope identification of anatomy structures. During the final two sessions, participants were encouraged to time themselves on their procedures to prepare for the final evaluation.

For the final evaluation, all residents (those with and without the focused skills labs) performed the same evaluation from the initial preliminary evaluation including video recordings of the craniotomies and microscope identification. A post-course survey was completed.

Evaluation metrics

Data were analyzed with a pre- and post-test methodology including de-identified video and surveys. Three neurosurgical attendings not affiliated with the institution of study were asked to evaluate the video based upon the criteria established (technique-based checklists, identification of anatomy, and timing). These independent evaluators were blinded to the resident groupings and training levels. Dr. Nicolosi (inventor of the simulator model) was not involved in the evaluation process. Interrater reliability was evaluated with a kappa test. During the course, the tasks of "Craniotomy", "Dural Opening", and "Microsurgical Exploration" were scored using the Objective Structured Assessment of Technical Skills (OSATS)[13] adequately modified to our study. These specific Global Rating Scales and precise Task-based Specific Checklists have been built for *Craniotomy (cGRS, cTSC)* and *Microsurgical Exploration (cTSC, mTCS)* tasks (**Supplement 4**).[14,15] The study design was co-created by FCR, FN and FG. Scores were analyzed with a paired t-test with significance measures at $p<0.05$. Data analysis was performed using Microsoft Excel and Stata software.

8

Setting and Participants

The study was conducted within the neurosurgery residency training program at Massachusetts General Hospital, where there are 21 trainees in the program (though junior residents rotate at an outside hospital, and research residents may be based out of town). The workshops were conducted in the anatomy lab of the Massachusetts Eye and Ear Institute, where there is access to 11 procedure stations. Each station was equipped with high-speed drills, suction, handheld irrigation, a microscope, and pertinent surgical instruments. Residents rotated through the stations so that there would only be one resident at each station during the exam.

Neurosurgical trainees were asked to voluntarily participate in the educational pilot study, with a group of the residents assigned to complete an educational course (an initial evaluation, 4 sessions of simulation across two months, and a final evaluation), while the other group would only complete the initial and final phases, without the focused curriculum. Because of the volunteer and non-mandatory nature, residents were not able to be perfectly randomized by class year. There was a separate consent form to authorize video and photographs during the session, and their use by UpSurgeOn Srl.

RESULTS

Fifteen residents participated (eight, intervention; seven, comparison). Some residents were unable to participate due to rotations at external hospitals. As the trainees were not randomized and were permitted to choose their group, the intervention group included fewer senior residents (Year 1: 3; Year 2: 2; Year 3: 2; Year 6: 1) compared to those who only did the pre-test and final (Year 2: 1; Year 4:1; Year 5: 1; Year 6: 1; Year 7: 3).

The three evaluators had an internal consistency within 0.5%, posting identical scores for approximately 70% of the evaluations. A kappa test for interrater agreement had a kappa of 0.5546, a Z-score of 33.08, and a probability > Z of 0.00001. Therefore, we can confidently reject the hypothesis that they were making their determinations randomly. Average results for the different scales are reported in **Table 1**. All participants improved; however, the intervention group had greater percentages of improvement. Average time for the two openings improved by 5:42 minutes (p<0.003; intervention, 6:05, p=0.07; comparison, 5:15, p=0.001). While the intervention group began with lower scores in all categories, they surpassed the comparison group in craniotomy GRS (10.93 to 13.6/16) and TSC (4.0 to 7.4/10; **Figure 3**). Percent improvements for the intervention group were cGRS 25% (p=0.02), cTSC 84% (p=0.002), mGRS 18% (p=0.003), and mTSC 52% (p=0.037). For controls, improvements were cGRS 4% (p=0.19), cTSC 0.0% (p=1.0), mGRS 6% (p=0.07), and mTSC 31% (p=0.029). Given the control group was comprised mostly of more senior residents, it is notable that final score of the study group exceeded the pre-test scores of the senior residents in three of the four categories.

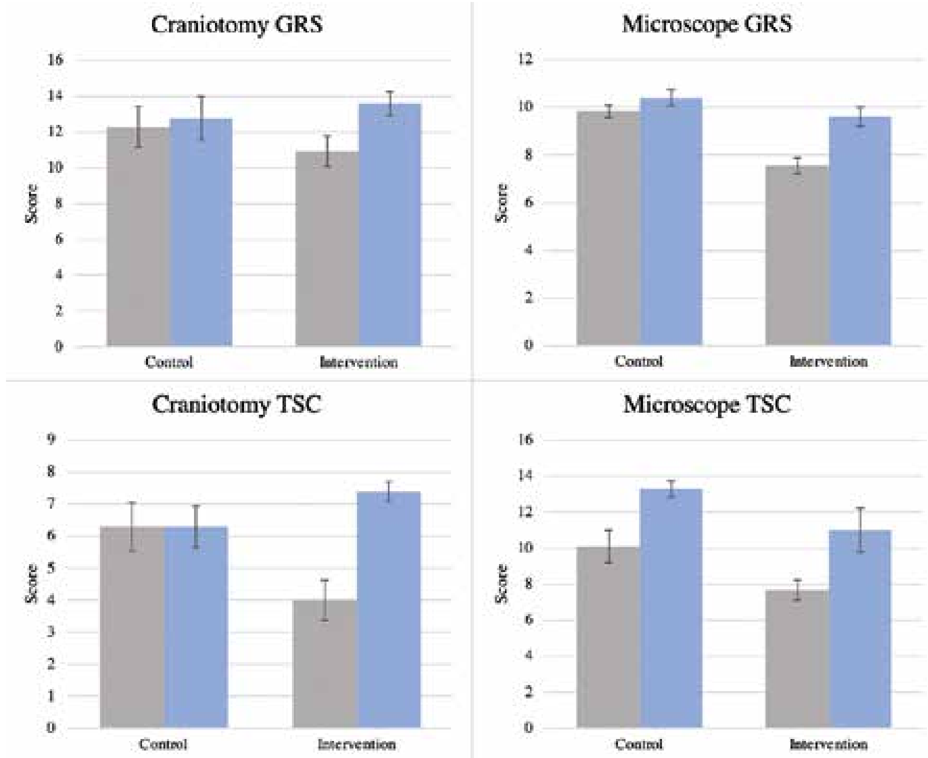

FIGURE 3: Pre- and post-test scores for each assessment. Global Rating Scales and precise Task-based Specific Checklists for Craniotomy (cGRS, cTSC) and Microsurgical Exploration (cTSC, mTCS) tasks.

For the surveys, which were all on a 4-point scale, the study group had an average 0.42 point (10.7%) increase in subjective proficiency of both craniotomy practice and microsurgical dexterity (final average 1.71 and 1.86, respectively. There was also an average 0.42 point (10.7%) increase in subjective confidence in the use of neurosurgical instruments (final average 3.43), and 1 point increase (25%) in confidence with the microscope (final average 2.29). When asked if this method of training should be part of a standard training curriculum, pre- and post-course scores were unchanged with an average of 3.43. For the comparison group, there was a 1-point increase in subjective confidence in the use of neurosurgical instruments, 0.33 increase in confidence with the microscope, and 0.33 increase in favor of including this in the residency curriculum with all members rating a 4 (Strongly agree).

TABLE 1: Participant scores. Average scores are displayed for Specific Global Rating Scales (GRS) and precise Task-based Specific Checklists (TSC) for Craniotomy (cGRS, cTSC) and Microsurgical Exploration (mGRS, mTCS) tasks. Data were compared using a paired t-test, and bolded results are statistically significant (p<0.05).

	Craniotomy GRS					Microsurgical Exploration GRS				
Participant	Pre-test		Post-test			Pre-test		Post-test		
Control	Average	SD	Average	SD	% Improvement	Average	SD	Average	SD	% Improvement
1	14.7	0.6	15.0	1.0	2%	10.0	0.0	11.0	0.0	10%
2	13.3	0.6	14.0	1.0	5%	11.0	0.0	10.7	0.6	-3%
3	7.0	0.0	7.0	0.0	0%	9.3	0.6	10.7	0.6	14%
4	13.3	0.6	15.3	0.6	15%	9.0	0.0	9.0	0.0	0%
5	9.0	0.0	10.0	1.0	11%	9.3	0.6	9.3	0.6	0%
6	16.0	0.0	16.0	0.0	0%	9.7	0.6	11.0	1.0	14%
7	12.7	0.6	12.0	0.0	-5%	10.3	0.6	11.0	0.0	6%
Combined	12.3	3.0	12.8	3.2	4%	9.8	0.7	10.4	0.9	6%
Paired t-test					0.19					0.07
Intervention	Average	SD	Average	SD	% Improvement	Average	SD	Average	SD	% Improvement
1	9.3	0.6	14.0	0.0	50%	8.0	0.0	8.7	0.6	8%
2	7.3	0.6	12.3	0.6	68%	6.0	0.0	8.0	0.0	33%
3	10.0	0.0	14.0	0.0	40%	7.0	0.0	8.7	0.6	24%
4	11.0	0.0	10.0	0.0	-9%	7.7	0.6	8.0	0.0	4%
5	11.3	0.6	14.7	0.6	29%	7.3	0.6	7.7	0.6	5%
6	14.0	0.0	15.7	0.6	12%	8.0	1.0	10.3	0.6	29%
7	15.0	0.0	15.7	0.6	4%	7.7	1.2	9.7	0.6	26%
8	9.3	0.6	12.7	0.6	36%	8.7	0.6	10.3	0.6	19%
Combined	10.9	2.4	13.6	1.9	25%	7.5	0.9	8.9	1.1	18%
Paired t-test					0.02					0.003

	Craniotomy TSC					Microsurgical Exploration TSC				
Participant	Pre-test		Post-test			Pre-test		Post-test		
Control	Average	SD	Average	SD	% Improvement	Average	SD	Average	SD	% Improvement
1	8.0	0.0	8.0	0.0	0%	10.0	0.0	14.0	0.0	40%
2	4.0	0.0	5.0	0.0	25%	14.0	0.0	12.0	0.0	-14%
3	6.0	0.0	6.0	0.0	0%	9.0	0.0	14.0	0.0	56%
4	8.0	0.0	7.0	0.0	-13%	7.0	0.0	14.0	0.0	100%
5	3.0	0.0	3.0	0.0	0%	8.0	0.0	11.0	0.0	38%
6	8.0	0.0	8.0	0.0	0%	10.0	0.0	14.0	0.0	40%
7	7.0	0.0	7.0	0.0	0%	13.0	0.0	14.0	0.0	8%
Combined	6.3	2.0	6.3	1.7	0%	10.1	2.4	13.3	1.2	31%
Paired t-test					1.00					0.029
Intervention	Average	SD	Average	SD	% Improvement	Average	SD	Average	SD	% Improvement
1	4.0	0.0	8.0	0.0	100%	10.0	0.0	9.0	0.0	-10%
2	2.0	0.0	6.0	0.0	200%	6.0	0.0	11.0	0.0	83%
3	3.0	0.0	8.0	0.0	167%	9.0	0.0	14.0	0.0	56%
4	3.0	0.0	8.0	0.0	167%	7.0	0.0	7.0	0.0	0%
5	3.0	0.0	6.0	0.0	100%	8.0	0.0	5.0	0.0	-38%
6	5.0	0.0	8.0	0.0	60%	5.0	0.0	14.0	0.0	180%
7	8.0	0.0	8.0	0.0	0%	6.0	0.0	14.0	0.0	133%
8	4.0	0.0	7.0	0.0	75%	7.0	0.0	14.0	0.0	100%
Combined	4.0	1.8	7.4	0.9	84%	7.3	1.6	11.0	3.5	52%
Paired t-test					0.002					0.037

DISCUSSION

This 6-week pilot aimed to evaluate the impact and feasibility of incorporating model simulation and spaced repetition learning into neurosurgical residency to improve anatomic knowledge and technical skills using objective criteria that could be tracked over time. There appeared to be key significant differences seen for those undergoing iterative training in the study group in scores from the craniotomy and microscope anatomy global rating scales and task-based specific checklists. The study group improved an average of 3 points per evaluation, versus 0.57 in the comparison group. As the sample size was small, there was not enough data to better ascertain which exact skills improved most with the training (e.g., if improvements were more related to use of the craniotome vs drilling the sphenoid ridge). Both cadres had improvements in the time taken to perform the craniotomy tasks, with greater improvements the study group. Though, in both analyses, the higher initial score of the more senior residents makes it more difficult to have a comparable increase, as there is likely a plateau in the learning curve. Nonetheless, this study is unique as it demonstrated that a set curriculum with synthetic models could have benefits to technical skill development through repetition over a relatively short time span. This concept of spaced repetition is clearly defined in the literature for fact or word memorization, such as with the use of flashcards or digital applications.[8] As this understanding becomes more prevalent, there has been a call to action to try to integrate this for surgical technical skills as well.[10] This pilot demonstration is important for three key reasons: high-fidelity simulators with ease of use, objective evaluation, and feasibility to incorporate into formal neurosurgical education.

The search for high-fidelity simulation with increased levels of complexity has been a priority for neurosurgical programs in the past decade, as the field recognizes the benefit of providing a reproducible risk-free practice to further motor acquisition and automate psychomotor skills.[16,17] In a 2013 national survey of U.S. Neurosurgical Program Directors, 45% thought that residents should achieve pre-defined levels of proficiency on simulators before working on patients, and 74% indicated that they would make simulator practice mandatory if available.[18] Only 17% of program directors expressed desire for more use of cadaveric models, while 84% believed physical models and virtual simulation were more advantageous. The Society of Neurologic Surgeons (SNS) has historically orchestrated a national “Intern Bootcamp” to teach first year residents with simulation for basic procedures such as placement of external ventricular drains, lumbar puncture, central lines, and craniotomy and dural suturing.[17] It was instituted in 2009, and by 2011, 100% of US residents in ACGME-accredited neurosurgical training programs participated in the program.[19] While a great success, the skull models were single use, and the underlying anatomy limited, leaving much to be desired for training those beyond entry-level interns.

In recent years, realistic physical and virtual reality (VR) models for surgical training have gained significant popularity as a complement and sometimes an alternative to traditional cadaveric specimens.[20] Also in 2013, the Congress of Neurological Surgeons established a Simulation Committee to explore the use of technology in maximizing neurosurgical education. Their report noted that VR-based models are limited in reproducing the tactile learning of a surgical procedure, leading residents to prefer physical models.[21] Additionally, they noted that VR models have dedicated hardware 10-100 times more expensive than physical models. The Brainbox simulator used in this study has the benefit of a disposable and exchangeable skull cover that is limited to the area of focus to permit repeated use at a much more affordable cost. The underlying brain specimen incorporates a tremendous level of detail; for example, the pterional box includes the cranial nerves (II, III, optic chiasm), arteries of the internal carotid, anterior cerebral, anterior communicating, middle cerebral, posterior communicating, posterior cerebral, ophthalmic, and perforating arteries. Structures also include the pituitary stalk, lamina terminalis, and surrounding brain. This level of detail allows the user to appreciate the view obtained by the craniotomy placement, and more anatomic study and practice navigating deeper structures. Many other physical models have been designed and studied for aneurysms[22-27] including deep anastomoses,[28,29] cerebral[30,31] and thalamic[32] tumor resections, the skull base approach,[33,34] the pre-sigmoid approach,[35] craniofacial deformities [36], craniosynostosis,[37,38] foramen ovale puncture,[39] pediatric lumbar pathology,[40] and endoscopic intracranial,[41-43] and paranasal[31,44] approaches. This study is not stating the surgical simulator used in this case is the one that should be used in all situations, but merely that the model should have a reusable component, be anatomically accurate, and affordable.

Returning to the SNS Intern Boot Camp, effectiveness of the program was measured by participant surveys about subjective knowledge gained, as well as a 6-month follow-up knowledge test.[19] The authors themselves admitted that: “In general, validated assessments are often lacking from surgical simulation models.” For simple procedures like a lumbar puncture or external ventricular drain, residents can be evaluated with a general sense of “hitting the target space,” but the detailed planning, dexterity of tool handling, careful drilling, and other more complex skills are rarely assessed. In this pilot, we employed craniotomy and microscope anatomy global rating scales and task-based specific checklists that could be reviewed in detail by external reviewers. This approach permits the reviewer to attend to finer detail than may occur in the operating room and provide objective feedback. Furthermore, by having an external reviewer, residents may have less discomfort than if one of their known attendings is scrutinizing their technique. Therefore, it creates a safe space for individuals to practice, and be aware of areas they need to improve. While the reports were not shared with institutional faculty in this study, the transparency of the reports with the program directors could be decided on by the respective programs.

Finally, feasibility. Traditionally, skills workshops are single time points in a resident's training. There is one during intern bootcamp, then a few led by industry at his or her institution, then perhaps a one to three hosted by programs or meetings that they will spend a few consecutive days working on the craft. These are all valuable, but the repetition required for mastering a skill requires both frequent and spaced repetition. This pilot did a total of 6 sessions for those in the course. This was held during the weekly education time provided for students, though there were some days that residents were pulled away for clinical duties. Each residency program would have to align an iterative skills curriculum with their education structure and lab availability, but the absence of biologic material, minimal set-up, and fast cleanup required facilitates this process. The 6-week course was also a trial, and more studies will be needed to determine the optimal length of the training, frequency, and ideally a delayed assessment to assess for knowledge and skill retention. Additionally, given more enthusiasm from residents in earlier training periods and the relatively simple skills assessed in this study, the pterional module may be best suited for junior residents. More complex simulations with tumor resection or aneurysm clipping may be better suited for more senior residents, though the junior residents would likely benefit from those as well.

LIMITATIONS

The limitations of this study warrant further discussion. First, this was a pilot study at a single institution, so the small group size limits the power of analysis. While there did appear to be statistically significant improvements with the intervention, the small n limits the granularity of detail of assessment, e.g., we are unable to discern which specific skills improve most with this approach. Additionally, as the pilot was voluntary and not randomized, there was a greater number of senior residents in the control group. This was partially reflective of lower interest by senior residents in practicing more basic technical skills, though on the surveys, they felt this was a useful tool that should become a permanent in the curriculum. Thus, inferences from the data on degree of improvement and overall significance should be interpreted with caution, as those with less experience at baseline are more likely to have larger gains than those already scoring highly on the exam. Future studies, if aiming to isolate the degree of impact more accurately, would likely require mandatory participation within the program and randomization by class year, and standardized, multi-institutional participation.

CONCLUSION

This single-center pilot program demonstrated that a 6-week course using a high-fidelity a cadaver-free simulation model improved speed and objective skill scores among neurosurgical residents. This demonstration of objective measurement is key, as you cannot manage what you do not measure, and our field has historically fallen short in objective and quantitative technical skill measurement. Comparable fields such as aviation and sports are much further ahead in the realm of statistical tracking and improvement, and we believe this paper not only emphasizes the gestalt understanding that practice leads to improvement, but also underscores the need for more measurement. Further understanding of which skill components improve most under these conditions, as well as the appropriate time course for an iterative training program will require a larger, multi-institutional study. Such an effort is being coordinated, as well as expansion to using other models (spine, complex tumor) with hopes to move toward simulation becoming a core part of technical skill development for neurosurgical trainees.

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CHAPTER 9

The Role of Policy in Global Neurosurgery

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ABSTRACT

There have been tremendous strides over the past decade to institute strong policy as means to facilitate alignment on goals and strategies for global neurosurgical systems strengthening. In this chapter, we highlight key historic policy milestones in the global neurosurgery movement. We discuss the role of international organizations in neurosurgery, and the incorporation of neurosurgery into global health agendas. We then delve into specific examples of policies that have been established (such as comprehensive recommendations for neurotrauma, spina bifida, and hydrocephalus), highlight the role of international organizations in shaping neurosurgical policies, emphasize the importance of advocacy, and explore future directions.

INTRODUCTION

The global neurosurgery movement emerged with increasing recognition of the impact of neurological disorders on public health, and of neurosurgery as an integral part of global health systems improvement. Each year, over five million people with neurosurgical conditions do not receive the essential treatment required, with the greatest inequities occurring in low- and middle-income countries (LMICs).[1] This disparity propagates morbidity, mortality, and economic losses.[2] Global neurosurgery as a field is defined as the clinical and public health practice of neurosurgery with the primary purpose of ensuring timely, safe, and affordable neurosurgical care to all who need it. It includes the practice, study, and advocacy of neurosurgery on a global scale, including efforts to address access to neurosurgical care and resources across different regions and countries. A cardinal element in driving sustainable change is engaging in policy dialogue as content experts.

Multinational political commitment, such as the World Health Assembly (WHA) resolutions, facilitates cooperation among nations to align on universal measures and objectives to implement sustainable solutions. Global neurosurgery practitioners can contribute to the process by generating accurate assessment of the burden of neurosurgical disease, identifying areas of improvement, and recommend interventions. Policies that recognize the importance of neurosurgical services within broader health agendas can lead to increased funding, training programs, and infrastructure development which ultimately benefit the population by improving neurosurgical outcomes.

Global efforts to improve surgical care, including neurosurgical care has seen significant policy milestones and landmarks over the past decade, from the Lancet Commission on Global Surgery and the Bogotá Declaration to the development and adoption of National Obstetric, Anesthesia, and Surgical Plans (NSOAPs) that integrate neurosurgery into broader healthcare frameworks and contribute to improved policy development and resource allocation.

In this chapter, we will highlight key historic policy milestones in the global neurosurgery movement. We will discuss the role of international organizations in neurosurgery, and the incorporation of neurosurgery into global health agendas. We will then delve into specific examples of international and national policies that have been established, highlight the role of international organizations in shaping neurosurgical policies, emphasize the importance of advocacy, and explore future directions.

Historical Background

While efforts to enhance the level of neurosurgical care globally have existed for many years, only recently did the field of global neurosurgery become more formalized and aligned at scale. **Figure 1** is not a fully comprehensive timeline, but highlights key moments in that evolution, beginning a rapid succession of events in 2015. First, the Sustainable Development Goals (SDGs) for 2030 set by the United Nations included many more topics relevant to surgical care than the Millennium Development Goals, going from 8 goals with 18 targets, to 17 goals with 169 targets.[3] The 3rd Edition of the Disease Control Priorities (DCP-3) report included Volume 1 on Essential Surgery, which identified 44 surgical procedures as essential on the basis that they address substantial needs, are cost effective, and are feasible to implement.[4] The Lancet Commission on Global Surgery in 2015 further emphasized that surgery is an integral, indivisible component of a properly functioning health system.[2] It leveraged data from multiple foundational papers to support that investing in surgical services in LMICs is affordable, saves lives, and promotes economic growth, and was necessary to achieve the SDGs. Metrics from the Lancet Commission included access to timely essential surgery, specialist workforce density, surgical volume, perioperative mortality, and protection against impoverishing and catastrophic expenditure. Striking results from that assessment included that 143 million additional surgical procedures are needed in LMICs each year to save lives and prevent disability, and only 6% of the procedures at that time were occurring in the poorest countries, where one-third of the world population lived. Additionally, the 2015 WHA Resolution 68.15 was wholly focused on strengthening emergency and essential surgical care and anesthesia as a necessary part of universal health coverage.[5] These four events, which occurred in rapid succession, catapulted global surgical care into the spotlight and served as a call to action to address surgery on the global political agenda.

Figure 1: Key events in policy and global neurosurgery. SDGs: Sustainable Development Goals; DCP3: Disease Control Priorities 3rd Editions; NSOAP: National Surgical, Obstetric and Anesthesia plans; SaLTS: Saving Lives Through Safe Surgery.

To guide development of sustainable surgical systems, the Harvard's Program of Global Surgery and Social Change (PGSSC) partnered with several Ministries of Health to develop National Surgical, Obstetric and Anesthesia Plans (NSOAPs) that are fully embedded within the national health policy, strategy, or plan. The

process of NSOAP development is specific to each country and elucidates current gaps in health care, prioritizes solutions, and provides specific time bound, prioritized implementation plans.[6] It includes: 1) Infrastructure; 2) Workforce; 3) Service delivery; 4) Financing; 5) Information management; and 6) Governance. By working with governments to foster new policies that incorporate these six building blocks, context-specific plans could be made that aligned on universal measures and objectives, garnered appropriate financial and human resource involvement, and laid the groundwork to implement sustainable solutions. Zambia and Ethiopia were two of the first countries to commit to national strategies for improving surgical and anesthesia care in 2015, and will be discussed further in this chapter.

Neurosurgery is an important subspecialty to involve in health system strengthening given the disease burden and cost-effectiveness.[7,8] Each year, an estimated 22.6 million patients suffer from neurological disorders or injuries that warrant a neurosurgical evaluation, and of these, 13.8 million individuals would require surgery. Unfortunately, approximately 5 million essential neurosurgical cases go untreated, and over 23,000 more neurosurgeons are needed in LMICs to address this treatment gap; this number is projected to increase rapidly over the next 2-3 decades.[9] For instance, stroke mortality and daily adjusted life years lost are expected to rise from around 7 million to 10 million, and 45 million to 190 million (respectively) by 2050; as hemorrhagic stroke rates in LMIC are at minimum 34%, this has significant implications for both endovascular and open neurosurgery.[10] Furthermore, of the 17 Sustainable Development Goals for 2030, 14 require building surgical capacity and have direct or indirect relevance to neurosurgeons and neurosurgical care delivery.[11] The DCP-3 Vol 1 Essential Surgery indicated that district hospitals should be able to perform burr holes for hematomas and elevated intracranial pressure and shunts for hydrocephalus, while tertiary care centers should have the capacity to perform craniotomies and craniectomies, predominantly for neurotrauma.[4] However, current resource limitations and neurosurgical workforce deficits continue to be significant barriers to such care provision.[8]

Consequently, in December 2016, leaders of organized neurosurgery met during the International Conference on Recent Advances in Neurotraumatology in Bogotá, Colombia to recognize the tremendous deficit in global neurosurgical care and simultaneously call on our own professional community to unite and play a leading role as agents for change. The 2016 Bogotá Declaration the first document of its kind and was a significant landmark in catalyzing the rise of national and international policies positioned to tackle the global burden of neurosurgical disease.[12]

As you cannot manage what you do not measure, this spurred additional transnational collaborations in research in burden of disease and gaps in access to care. It also sparked the launch of the Global Neurosurgery Initiative at the PGSSC to galvanize additional investigations and coalesce data into policy recommendations. In 2018, the Journal of Neurosurgery released a series of publications from this group that articulated the burden of disease as it related to traumatic brain injury, hydrocephalus, infection, epilepsy, oncology, and more. It also quantified the geographic operative and consultation demands, workforce need, and examined academic collaborations. These findings were incorporated into the "*Comprehensive Policy Recommendations for Head and Spine Injury Care in Low- and Middle-Income Countries*" in 2019, and the and the *Comprehensive Policy Recommendations for the Management of Spina Bifida & Hydrocephalus in Low- and Middle-income Countries* in 2022 (discussed in more detail below).[13 14]

By 2019, five countries had completed an NSOAP and an additional 37 member states had either completed or were in the process of drafting or initiating a National Plan for Surgical Care.[13] Also in 2019, the World Federation of Neurosurgical Societies (WFNS) established the Global Neurosurgery Committee, which greatly complimented an long-standing WHO-WFNS Liaison Committee. The aim of this committee is designing a global action plan with 5 key objectives and over 20 targets. The 5 objectives were 1. Amplify neurosurgical access, 2. Align global neurosurgery activity, 3. Advance relevant research, especially from LMICs, 4. Assimilate global neurosurgery activity within the global surgery framework, and 5. Advocate for neurosurgical care for all.

In 2021, the GNC established its 2.0 plan, with a structure that is decentralized with multiple thematic teams, each with their own strategic plans. The teams are, Workforce, Coordination, Research, Policy, Decolonize, External Relations, Capacity Building, Global Spine Surgery, Nursing, Advocacy, Innovation and Technology, Neurodiagnostics, and Young Neurosurgeons. The 10 teams have developed mini-strategic plans with Specific, Measurable, Attainable, Relevant, and Time-based (SMART) objectives. 2021 also was a landmark year for the launch of the Journal of Global Neurosurgery. This is a free, open access journal that gives preferences to LMIC authors to ensure research in the most affected countries is being empowered and shared.

In 2022, the Spina Bifida and Hydrocephalus Policy Recommendations were released, and a resolution was introduced to the World Health Assembly in May 2022 by WFNS in collaboration with the Global Alliance for Prevention of Spina Bifida.[15] This lead to the 2023 adoption of WHA resolution 76.19 calling for mandatory folic acid food fortification along with other micronutrients to combat preventable micronutrient deficiencies, such as spina bifida and neural tube defects.[16] That year, the WFNS World Congress was held in Bogotá with a theme of Global Neurosurgery. Additionally, Springer published a book *Neurosurgery and Global Health*, edited by Dr. Isabelle Germano and authored by many of the content experts in global neurosurgery.[17] In 2023, there were continued global efforts on the development and implementation of NSOAPs and the WFNS World Congress in Cape Town, South Africa with a full day dedicated to global initiatives.

With that overview of the landscape of progress within global neurosurgery, we will delve further into the policy recommendations for Head and Spine Injury as well for the Management of Spina Bifida & Hydrocephalus in LMICs, and then

highlight case examples of NSOAPs that have integrated these frameworks into their national policy.

Comprehensive Policy Recommendations for Head and Spine Injury

Head and spine injuries were the initial focus because in LMICs global neurotrauma comprises the highest proportion of unmet neurosurgical operative burden, with almost 5 million cases per year. These policy recommendations were intended to be nested within the NSOAP framework of addressing the six domains of a healthcare system (infrastructure, workforce, service delivery, financing, information management, and governance). The neurotrauma policy recommendations added domains adapted from proposals by the American College of Surgeons for improving trauma systems.[18]. This includes: 1) Surveillance; 2) Prevention; 3) Pre-hospital care; 4) Surgical system; and 5) Rehabilitation. Herein, the policy recommendations create a matrix across the six domains of healthcare (**Figure 2**).

	Surveillance	Prevention	Pre-hospital care	Surgical system	Rehabilitation
Infra-structure	-Integration through agile platforms -Leverage international partnerships for surveillance	-Safe roads	-Contextualized pre-hospital system	-80% of population within 4-hours of neurotrauma center -Strengthen pre-existing trauma infrastructure for neurotrauma	-Contextualized allocation of space and stuff for neuro-rehabilitation -Facility stratification for severity
Workforce	-Fit for purpose workforce for data collection, analysis, and interpretation -Align international collaborations to support local workforce capacity - Flexible and strategic use task-shifting and task-sharing to optimize human resources	-Robust workforce for public health education and implementation	-Neurotrauma care training of emergency medical personnel	-1 neurosurgeon per 200,000 people at minimum -Task-sharing of surgical workforce is preferred over task-shifting -Dramatically increase neurosurgical training capacity	-Ensure rehabilitation training capacity is adequate -Ensure competency throughout continuum education
Service delivery	-Minimum data to include demographics, diagnosis, mechanism, severity, and outcome measure -Use existing trauma registry -Use WHO Trauma System Maturity Index to monitor progress	-Strengthen public education -Encourage safety-conscious "Ride hailing" services -Strengthen enforcement of safety laws	-Prevent hypotension and maintain oxygenation -Time from injury to neurotrauma facility should not exceed 4-hours	-Standardization of essential neurotrauma equipment -CT scanner in all neurotrauma facilities -Critical care unit in all neurotrauma facilities -Leverage telemedicine as a tool for increasing coverage - Innovate for low-resource settings	-Sensitive to gender and age sub-groups - Partner with family for delivery of non-technical physical therapy
Financing	-Maximize external funding -Build internal capacity -Use open-source platforms	-Promote health benefits of public investment in safe roads -Partner with external organizations for advocacy	-Cost-effective training models -Utilize low-cost or free digital technology	-Embed neurotrauma within universal health coverage package -International partnerships for neurotrauma capacity building	-Embed neurorehabilitation within universal health coverage package
Information management	-Utilize WHO International Registry for Trauma and Emergency Care (IRTEC)	-Tracking of safety law compliance	-Encourage data collection by emergency medical personnel	-Track neurotrauma workforce and operative mortality	-Collection of neurorehabilitation outcome data
Governance	-Empower ministry of health leadership -Utilize reporting requirements to improve accountability and compliance	-Regulatory framework to strengthen enforcement -Comprehensive helmet laws - Workplace safety regulations	-Inclusion of pre-hospital care in national health plans	-Draw on existing international technical resources to assist with neurotrauma capacity building -Promote neurotrauma as vital to achieving national and international health and development goals	-Rehabilitation is indispensable to a quality health system

Figure 2: Head and Spine Injury Recommendations Matrix. Published by Park, Khan et al, 2019.[13]

Within the document, each frame of the matrix is supported with data and includes principles for guidance for the policy maker. For example, under *Surveillance*, there is guidance on establishing a neurotrauma registry including more granular recommendations on minimum data to include relating to demographics, diagnosis, mechanism, severity, and outcome measures. It discusses how the WHO Trauma System Maturity Index and the WHO International Registry for Trauma and Emergency Care can be leveraged to achieve national surveillance. There are recommendations for sources of funding and collaboration to meet the financial burden associated with establishing these networks, as well as guidance on involving medical associations in legislative and government processes for the development and organization of an effective trauma registry.

Under *Prevention*, the document goes beyond foundational elements of safe roads. It gives evidence for revisiting the national and local laws, such as those on helmets.

The document also highlights logistical and cultural barriers that may be at play in law enforcement. For example, Bachani et al. found the rate of helmet usage among motorbike riders in Cambodia to be as low as 33% three years after the passage of helmet legislation, with misconceptions from riders that that they are unnecessary for short distance or at low speeds.[19] Additionally, the document references a study in Vietnam that found a primary reason for adults not having young children wear helmets was secondary to fear that it increases the risk of neck injury.[20] Thus, it describes how effective injury prevention strategy must include public education and media campaigns to increase compliance.

Overall, this policy document provides both a compass and a roadmap for policy leaders to integrate local laws, campaigns, research, and change efforts into their local health ecosystem.

Comprehensive Policy Recommendations for the Management of Spina Bifida & Hydrocephalus

The subsequent comprehensive policy recommendation effort mirrored that of the neurotrauma recommendations above. It was guided by the PGSSC as well as an international expert advisory group. An international group consisting of neurologists, pediatricians, neurosurgeons, surgeons, anesthesiologists, and nurses, as well as professional societies, patient advocates, researchers, global health practitioners, and policy makers from 18 countries and four continents. The recommendations were divided into the following sections: (1) screening and surveillance, (2) prevention, (3) pre-hospital care, (4) surgical systems, (5) rehabilitation, and (6) transitional and follow-up care (**Figure 3**)[14]. The authors recognize that the data and recommendations are intentioned to serve as a starting point to engage the patients, healthcare providers, public health practitioners, and policymakers in a productive dialogue that will lead to smart policies and tangible outcomes for children with spina bifida and hydrocephalus in LMICs.

	Surveillance	Prevention	Prehospital Care	Surgical Care	Rehabilitation	Transitional Care
Infrastructure	-Head circumference measurements - Common data elements -Improve access to obstetric facilities	-Neonatal sepsis treatment -Microbial diagnostics -Folic acid supplementation	-WHO Emergency Care System -Strengthen multisectoral coordination	-Strengthen Surgical System -80% population coverage -Expand first-level hospitals	-Designated rehabilitation space -Disabled-friendly infrastructure	-National strategy for life-long care -Community-based rehabilitation -People-centered facilities
Workforce	-Use non-physician workforce -Train parents/caregivers - Destigmatize	-Increase prenatal care workforce -Family involvement -Advocacy groups	-Education of care team -Support families	-Increase pediatric providers -Dedicated training centers. -Task shifting/sharing	-Training and education -Task sharing/task shifting	-Patient empowerment -Coordination by nurses and CHW
Service Delivery	-Community-based screening -Public health education -Universal databases	-Parental education -Folic acid fortification -Public education	-Public health campaigns -Coordinate dispatch	-Multidisciplinary teams - Wards for SB/HCP patients - Access to imaging	-Multidisciplinary care teams -Engage family/caregivers in rehabilitation care	-Safe transition to adulthood
Financing	-Government funding - NGO funding -Leverage international partnerships	-Fund infant care -Fund Folic acid supplementation -Funding education	Affordable transportation	-Include SB/HCP care into UHC -Consider international partnerships	Embed into a UHC package	Embed in UHC
Information Management	-National registries -WSeb-based platforms -Standardization	-National registries. -Common data elements	-Optimize referrals -Strengthen data collection	-Track SB/HCP workforce	Rehabilitation data	- Quality of life metrics -Health Passport model
Governance	-Screening & reporting mandate -Support to the Ministry of Health	-Child health legislation -Folic Acid legislation -National Prevention Campaign	-Emergency service teams -Disability rights legislation	Dedicated SB/HCP teams	Establish departments	-Protect rights of SB/HCP patients -Multidisciplinary Transition teams

Figure 3: Comprehensive Policy Recommendations for the Management of Spina Bifida & Hydrocephalus in Low- & Middle-Income Countries. 2021;2(1).

Case Studies of Successful Integration of Neurosurgery into National Health Policies

ETHIOPIA

With the momentum of the 2015 Lancet Commission on Global Surgery, Ethiopia was one of the first countries to pledge intention to develop a systematic national strategy. In 2016, they released the Federal Ministry of Health of Ethiopia National Safe Surgery Strategic PLAN: Saving Lives Through Safe Surgery (SaLTS) with a timeframe of 2016-2020.[21] At the start, the WFNS workforce density map showed Ethiopia with a density of neurosurgeons of 0.025 per 100,000 population to reflect the 25 neurosurgeons for a population of 97 million people, ranking them 150th in the world.[22] Ethiopia was actively working to scale their neurosurgery workforce, as they reflected on the striking statistic of only having two neurosurgeons who cared for the entire population in 2006.[23] In the SaLTS plan, the government set a goal of achieving a workforce of 50 neurosurgeons by 2020, which they indeed achieved with 50 attending neurosurgeons and 80 neurosurgical residents, putting the neurosurgeon

density per 100,000 people at 0.045. The growth rate for the number of neurosurgeons and neurosurgery residents was 20% and 26.3%, respectively, from 2006 to 2020. In a 2021 article by Asfaw et al entitled *Neurosurgery in Ethiopia: A New Chapter and Future Prospects,* the authors reflect on this journal and future directions. To achieve such growth, Ethiopia forged international partnership between Addis Ababa University, University of Bergen, Haukeland University Hospital, and a private hospital in Addis Ababa. Other institutions such as the U.S.-based Foundation for International Education in Neurological Surgery (FIENS) contributed to the success of the partnership by arranging for dedicated volunteer neurosurgeons to stay in Addis Ababa from weeks to months and teach resident physicians. They also placed a tremendous emphasis on developing local research capacity; greater than 77% of the neurosurgical publications pertinent to Ethiopia were published since the first class of residents graduated in 2010.

Importantly, Asfaw et al also frames the tremendous progress in the context of recent policy recommendations. In their reference to the 2019 *Comprehensive Policy Recommendations for Head and Spine Injury,* they underscore that_there should be 0.5 neurosurgeon per 100,000 people, making the 560 the minimum number of required neurosurgeons in Ethiopia. However, they are optimistic that if they can sustain a high retention rate for locally trained neurosurgeons coupled with the gradual increase in state resources devoted to surgical development, Ethiopia could achieve this workforce target. Based on growth rates of the total population and neurosurgical workforce, Ethiopia will have a neurosurgeon density >0.5 per 100,000 people by 2036. Their example of a self-sustained neurosurgery program transforms both the clinical capacity and the academic productivity of local neurosurgeons. Overall, the neurosurgical development in Ethiopia demonstrates the profound effect of leveraging policy to formulate benchmarks and secure funding and establish training programs via international partnerships to improve neurosurgical access.

ZAMBIA

The Republic of Zambia, former Minister of Health Dr. Chitalu Chilufya (term: 2016-2021), and Counsellor-Health, Permanent Mission of Zambia to the UN in Geneva, Dr. Emmanuel Makasa (term: 2012-2018) have been champions in efforts to expand access to surgical care, sponsoring and chairing the diplomatic negotiations that culminated in the development and adoption of WHA68.15 in 2015 and subsequently Decision WHA70(22) in 2017 that requires WHO Director-General to report on their progress of WHA68.15 every 2 years.[24]

Zambia was a leader in establishing an NSOAP that proactively spoke to many of the subspecialties as well. [25,26] With respect to neurosurgery, they listed the number of facilities offering neurosurgical services at a base of 1 in 2017, with a goal of 3 in 2019 and 7 by 2021. For the number of facilities offering spinal surgery services, there was a base of 1 in 2017, and a goal of 2 in 2019 and 2021. On workforce, ideal staffing quota for neurosurgeons was one neurosurgeon per Level 2 Hospital and five neurosurgeons per Level 3 Hospital. They projected this into a framework for evaluation that identified the national need of 70 neurosurgeons, and the dramatic deficit of 68 neurosurgeons at that time. To understand the financial requirements involved for this capacity escalation, the team modeled Human Resources Needs and Costing. For Training over the next 5 years focusing on district hospitals, with a 3-year goal of 5 neurosurgeons and a 5-year goal of 12 additional (17 total), accounting for a 4-year training span, the cost per provider per year would be 325,762.50, and 22,151,850.00 total. This was within the multidisciplinary total workforce training cost of 612,252,925.00 Kwacha ($USD 23,422,966). Having the detailed strategic plan with required resources laid out enables better commitment of funding and prioritization of the efforts. Today, the total number of neurosurgeons in Zambia fluctuates around 90, though not all are Zambian nationals; most are accredited by the College of Surgeons of East, Central, and Southern Africa (COSECSA).

NIGERIA

Nigeria's Federal Ministry of Health developed and implemented their second National Strategic Health Development Plan for 2018-2022, which would integrate their National Surgical, Obstetrics, Anesthesia and Nursing Plan (NSOANP) that they formulated in 2017. They named this subdivision of focus Strategic Priorities for Surgical Care (StraPS), which introduced specific surgical system targets and an implementation roadmap that prioritized monitoring, evaluation, and feedback for central and state governments to follow. StraPS was one of the first to include children's surgery in a surgical plan, which is highly relevant in Nigeria given that 43% of the 200 million population is under 15 years of age.[27] They also incorporated scaling nursing workforce in the plan.

Neurosurgery has been addressed in several contexts in Nigeria's NSOANP. While the World Health Organization's (WHO's) recommendation is an ideal ratio for every population to be 1 neurosurgeon to 100,000 individuals, Nigeria currently has 0.01 neurosurgeons per 100,000 (29 neurosurgeons at the time of the document).[6] A publication by Garba (Harvard Medical School), Alfin (Jos University Teaching Hospital, Katon Rikkos, Nigeria), and Mahmud (National Hospital, Abuja, Nigeria) in *Frontiers in Surgery* is an example of leveraging prior policy recommendations to fuel engagement of the neurosurgical community with health care planners and policy makers. [28]

Garba et al call on some specific strengths and areas for improvement in the plan. The NSOANP does cite neural tube defects as priorities of basic surgical care provision, which aligns with the comprehensive spina bifida and hydrocephalus recommendations. Nigeria committed to building the capacity at district and secondary hospitals to handle diagnosis and stabilization of neurological trauma (e.g., epidural hematoma, includes emergency burr hole if transfer not possible). They also prioritized training anesthesia subspecialties in neuro-anesthesia.

To build their workforce, Garba et all suggest that a two-tiered approach to training can be adopted in order to address the immediate need while working on the long-term strategy to improve the number of trained neurosurgeons in the country. For example, in the spirit of task sharing discussed in the *Comprehensive Policy Recommendations for Head and Spine Injury*, a fast – tracked, competency-based certification of General and Pediatric surgeons who can perform neurotrauma operations and neural tube defect surgeries could be adopted. Secondly, the authors call for an acceleration of neurosurgical training by both the National Post graduate Medical College of Nigeria (NPMCN) and West African College of Surgeon (WACS) that would allow those interested in neurosurgery to fast-track into specialized training without going through a general surgery training. There is also additional emphasis on the need for a formalized neurotrauma registry.

Both the current national plan in Nigeria, as well as the calls to action in the recent publication that are rooted in international policy recommendations are key examples of how policy can provide guidance and a foundation for systems level change.

Role of International Organizations in Shaping Neurosurgical Policies

International organizations play a crucial role in shaping neurosurgical policies globally. Their involvement spans a range of activities, from facilitating research that serves as the foundation for policy development and partnering with governments to craft the NSOAPs, to providing human resources and funding to enable execution of the goals. Key players in the global neurosurgery effort are listed here:

G4 Alliance - The Global Alliance for Surgical, Obstetric, Trauma and Anesthesia Care is a coalition of over 70 member organizations dedicated to advocating globally for the neglected surgical patient. They work to increase awareness, foster political will, shape policy, and mobilize resources. The G4 Alliance Strategic Plan and Theory of Change for 2022-2024 describes their advocacy goals and strategies under three pillars: awareness, policy, and resource mobilization. They played a key role in advancing the policy agenda of WHA Resolution 68.15, and continue aiding in the development of national surgical plans.

World Federation of Neurosurgical Societies (WFNS) – WFNS is a professional, scientific, non-governmental organization comprising of 130 member societies and over 30,000 neurosurgeons worldwide. For many years WFNS has the honored status of a non-State actor in official working relations with WHO. In 2019, WFNS established the Global Neurosurgery Committee. The committee developed a definition of global neurosurgery which has been widely adopted **–** the clinical and public health practice of neurosurgery with the primary purpose of ensuring timely, safe, and affordable neurosurgical care to all who need it. The committee also rolled out the global action plan with the help of the secretariat consisting of medical students and trainees from around the world. The second Global Neurosurgery Committee (2021-2023) created thematic teams to implement mini-strategic plans to achieve their set goals and the results were presented over multiple sessions at the WFNS World Congress in Cape Town in December 2023. The third iteration of the Global Neurosurgery Committee will seek to support on the ground capacity building in those countries with little or no neurosurgical care capacity such as Sierra Leone through strategic partnerships.

Foundation for International Education in Neurological Surgery (FIENS) – FIENS is highly involved in capacity-building initiatives. They have partnered with multiple institutions to develop international curricula for training programs, which can be certified LMICs. They work to find the equipment, supplies, and mentoring to allow the development of such programs until they become self-sustaining, further dedicated to the post-graduate education of these individuals.

Future Directions

As we have seen, there have been tremendous strides over the past decade to institute strong policy as means to facilitate alignment on goals and strategies for global surgical systems strengthening. These international efforts allow the neurosurgery community to engage with policymakers, governments, and other stakeholders to raise awareness about the importance of neurosurgical services and to influence policies that support health system strengthening and service delivery capacity building at the national level. The establishment of the NSOAP framework has fueled multiple nations to implement their own national objectives on improvement of surgical systems within their broader national health plans. Furthermore, the development of comprehensive recommendations for neurotrauma, spina bifida, and hydrocephalus have furthered the detail to which neurosurgical objectives can be instituted to augment care and mitigate the burden of neurosurgical disease worldwide.

Going forward, we as a neurosurgical community must come together to increase efforts in advocacy, further the recommendations for additional neurosurgical subspecialties and associated technologies, as well as partner with neurosurgical leaders across the globe to form national context-specific plans (NSOAPs). Though, the work does not stop there. Policy helps ensure goal alignment and dedication of funds, but much work must go into policy adoption, implementation, and enforcement. Policy formation also calls the global neurosurgical community to action to assist in resource provision and investment in training, building data registries, developing resource-stratified guidelines for specific neurosurgical conditions through expert teams, enabling research in the local context, regularly examining progress, and sharing knowledge. It is only through the unity of policy makers, practitioners, and researchers that we can raise the level of neurosurgical care throughout the world.

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CHAPTER 10

Investing in the future: a call for strategies to empower and expand representation of women in neurosurgery worldwide

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ABSTRACT

As progress is gradually being made toward increased representation and retention of women in neurosurgery, we should elevate effective efforts that may be driving positive change. Here, we describe explicit efforts by the neurosurgery community to empower and expand representation of women in neurosurgery, among which we identified four themes: (I) Formal Mentorship Channels, (II) Scholarships & Awards, (III) Training & Exposure Opportunities, or (IV) Infrastructural Approaches. Ultimately, there is a need for a data-driven approach to improve representation and empowerment of women in neurosurgery to best direct our efforts across the globe.

INTRODUCTION

The neurosurgical community is beginning to recognize the need for greater female representation, and that achieving gender parity in neurosurgery will require personal and institutional accountability. The proportion of females in neurosurgery demonstrates a positive growth trend, expanding from approximately 4.7% in 1980 to approximately 15.5% in 2013 (American Association of Neurological Surgeons (AANS) data).[1,2] Attrition of female neurosurgery residents declined from 25% to 17% comparing the 1990-1999 and 2000-2009 epochs.[1] Nonetheless, significant disparities in female representation continue to impede progress toward equity and parity.[3,4] However, the encouraging increases in representation and retention may indicate that recent efforts are beginning to take effect.

Behind these positively-trending numbers have been numerous explicit efforts by the neurosurgery community to improve gender equity among practicing neurosurgeons, neurosurgery trainees, and even aspiring neurosurgeons. These efforts vary in terms of strategies and goals, and their respective impact on female representation in neurosurgery remains unclear. A better understanding of these strategies and programs may elucidate the most effective mechanisms to achieve gender parity and equity in neurosurgery, and encourage concerted, evidence-based approaches among key stakeholders.

Here, we describe explicit efforts by the neurosurgery community to empower and expand representation of women in neurosurgery.

METHODS

We identified efforts centered around women in neurosurgery through broadly academic and institutional webpages, peer-reviewed literature, web-based search engines, and chain-referral sampling.[5] We defined "exclusive opportunities for women in neurosurgery" as "explicit efforts by members and/or governing bodies of the surgery or neurosurgery community to empower and/or expand representation of women in neurosurgery". We also employed chain-referral sampling to maximize the likelihood of finding programs not identified through literature and internet searches. A qualitative thematic analysis was used to organize the interventions into broader categories.

RESULTS

From our search, we identified eighteen opportunities that satisfied our criteria defined above. To contextualize these opportunities, we constructed four themes: (I) Formal Mentorship Channels, (II) Scholarships & Awards, (III) Training & Exposure Opportunities, or (IV) Infrastructural Approaches. We defined these themes as follows: **Formal Mentorship Channels** are groups with membership exclusive to women currently practicing and/or are interested in practicing neurosurgery typically with the goals of facilitating mentorship for and fostering professional development of their more junior members. **Scholarships & Awards** are formal recognitions with or without a conjunctive monetary prize bestowed upon exclusively female applicants to further their neurosurgical career and/or celebrate their accomplishments. **Training & Exposure Opportunities** are programs delivered at various time points of a surgical career with the goals of enhancing students' interest and understanding prior to entering residency while optimizing training opportunities for neurosurgery applicants and residents. Finally, **Infrastructural Approaches** are concerted systems-level efforts to increase female neurosurgeons' representation in high income countries and/or low- and middle- income countries (LMICs) by promoting diversity and inclusivity at an institutional level.

DISCUSSION

Here we discuss examples of programs, initiatives and/or opportunities specifically geared toward increasing female representation and support in neurosurgery to contextualize each of the four themes (Table 1).

1 Formal Mentorship Channels

Mentorship is widely recognized as a crucial component of surgical training to translate passion to tangible career progression. Many of the leading national and international professional neurosurgery societies have established platforms for mentorship and educational opportunities. For example, the American Association of Neurological Surgeons (AANS) Young Neurosurgeons Committee created channels for practicing neurosurgeons to provide guidance to medical students and incoming residents; the Congress of Neurological Surgeons (CNS) Resident Committee and the Council of State Neurosurgical Societies (CSNS) Young Neurosurgeons Section actively involve residents in educational projects and leadership opportunities. However, the persistent gender gap in neurosurgery suggests women may face additional barriers to accessing and benefitting from these opportunities, inspiring initiatives around the world to specifically address this inequity.[6]

One approach is through the establishment of programs and societies exclusively for women in (or interested in) neurosurgery. As a joint section of the AANS and the CNS, Women in Neurosurgery (WINS) has been conducting programs and initiatives, such as career talks and mentoring programs, to encourage and support aspiring female physicians to pursue neurosurgery for the past 30 years. The WINS is one of the first organizations to create specialized mentoring programs to pair undergraduate students, medical students, and residents with practicing female neurosurgeons, recognizing that early female representation and mentorship is essential to fostering success. Importantly, student membership in WINS is being

offered without a fee and is open to both medical and pre-medical university students.

Mentorship is an invaluable and irreplaceable component of surgical education, regardless of format and geographical location. Women in Surgery Africa (WiSA) is a group which provides support to female surgeons and medical students in 14 countries of the College of Surgeons of East Central and Southern Africa (COSECSA). The WiSA mentorship program has been growing since its establishment from 13 mentorship pairs in 2017 to 24 pairs in 2020. Members are encouraged to access resources donated by The Royal College of Surgeons of Ireland on the portal, and to organize mentoring sessions via Skype, email, and WhatsApp. While this program is not exclusively targeted at neurosurgery enthusiasts, WiSA exemplifies the foundational importance of increasing representation of women in surgery in low resource regions.

2 Scholarships & Awards

Other often intertwined approaches to eliminate barriers in career advancement is to strategically include and reward outstanding women in neurosurgery practice, since the lack of scholarly support and financial resources are known to be deterring factors in the pursuit of academic goals.[7] For example, scientific meetings and conferences offer important yet financially contingent opportunities for education and networking in neurosurgery, which may influence career opportunities.

The WINS offers several travel scholarships and grants help defray the cost of travel and registration fees for outstanding residents with recognized contributions to the field, including the WINS/Greg Wilkins-Barrick Chair Visiting International Surgeon Award (VISA Award), The Sherry Apple Resident Travel Scholarship, and the Louise Eisenhardt Resident Travel Scholarship. These merit-based scholarships help facilitate more equitable career opportunities as well as encourage academic excellence. Non-financial awards are also used to achieve the latter. For example, another prominent award recognizing young female neurosurgeons is the WINS Leadership Development Award, which is given to a WINS member neurosurgeon who has practiced for less than ten years and has demonstrated excellence in scholarship, research, clinical practice, mentorship, and leadership.

WiSA also offers a number of grants and awards to support exceptional female surgeons in the COSECSA region. For example, the WiSA Travel Grant Award and the Shield Maiden Award have both been awarded to neurosurgeons to attend COSECSA conferences.

3 Training & Exposure Opportunities

Neurosurgery education is not limited to residency training. Rather, such education should be delivered at various time points of medical training, and the value of neurosurgery exposure in medical school should not be underestimated. A study by Zuccato et al. reported that early surgical exposure increased medical students' understanding about neurosurgery and encouraged passionate students to plan further neurosurgical clinical experiences.[8] However, only a third of the participants in that study were women, highlighting how inequities in early opportunities may perpetuate future representation imbalance. WINS holds regular named lectureships honoring pioneering female neurosurgeons, and is running the "Speaker's Bureau" to provide neurosurgical exposure to students by offering lectures on neurosurgery careers to medical schools.

As for residency programs, WINS emphasized the goal of having 20% female in each class entering residency by year 2012. Encouragingly, the proportion of women matched to neurosurgery residency positions increased from 10.7% in the 1990s to 15.5% in 2013.[1] It was a huge milestone given that currently only 6.1% of board-certified neurosurgeons are women in the United States.[9] That being said, we still have a long way before we reach equal gender representation in neurosurgery.

4 Infrastructural Approaches

Other organizations have prioritized structural changes to address systematic trends driving disparities. For example, the Diversity in Neurosurgery Task Force under European Association of Neurosurgical Societies was created in 2019 to foster an inclusive environment for neurosurgeons from all genders and backgrounds by tackling the barriers in career advancement. Furthermore, some similar initiatives have explicitly integrated global health and international disparity into gender initiatives, recognizing inherent links between the two. The Gender Equity Initiative in Global Surgery was established as an initiative in association with the PGSSC, to further address gender disparities and enhance inclusivity in surgery, obstetrics, and anesthesia workforce around the world through research, advocacy, and mentorship matching.[10] In addition, headed by renowned female neurosurgeons internationally, the WFNS-WIN Committee was established under the World Federation of Neurosurgical Societies (WFNS) to enhance female professional development and influence in neurosurgical activities around the world.

Limitations

It is important to note that this article represents a proposal, and many of the aforementioned programs have not been validated for efficacy or effectiveness. Our list of programs and opportunities is not exhaustive, and new opportunities continue to rise with greater awareness for gender equity in academia and clinical practice. Moreover, while we chose not to include coed programs in our discussion, we recognize that such opportunities can still be leveraged by women. For example, the FIENS-Bassett Global Neurosurgery Fellowship is an international traveling fellowship offered by the Foundation for International Education in Neurological Surgery (FIENS) for neurosurgeons who are either training in a residency program in a LMIC or who have completed residency training in a LMIC within the past five years. The fellowship covers the expenses for a three-month period at a

neurosurgical unit outside of one's country of residence. Although these programs serve an undeniably important role in expanding neurosurgical access globally, the proportion of women accepted into such coed programs as a whole remains low, much like the "coed" field of neurosurgery itself.

Future Directions

Given the variety of approaches and the unique nature of neurosurgery, there is a need for a data-driven approach to evaluate the effectiveness of each of these programs advancing female career progression in neurosurgery. Doing so will require defining and validating metrics of effectiveness and evaluation methodology for these diverse approaches.

Additionally, attention should be paid to the influence of local context and culture on the relative success of a given approach. Tailoring innovations to local settings should be encouraged, yet proper evaluation of program outcomes is essential to informing resource allocation for the most effective outcomes. It should be noted that many of these programs mentioned are based in high-income, high-resource settings around the globe. Explicit, contextually informed efforts to increase female representation in lower-resource settings through local empowerment are essential to ensuring no country is excluded from this movement in gender equity.

Finally, the neurosurgery field should ensure women neurosurgical trainees or students who are of underrepresented ethnic or other groups in neurosurgery are included in these opportunities for women. Addressing intersectionality is indispensable in efforts to promote women in neurosurgery to avoid perpetuating other systemic biases and disparities.

CONCLUSIONS

This piece reviews numerous strategies to empower and expand representation of women in neurosurgery globally. The four themes we provide help contextualize approaches by leading institutions around the world to address gender disparities in neurosurgery, and provide insight for where additional research and data driven changes are needed. Although much progress is to be made before female representation might be on par with men, we are hopeful that programs like these might continue to inspire progress.

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CHAPTER 11

Summary

The field of global neurosurgery has significantly evolved in the past decade, driven by a growing recognition of the critical role neurosurgery plays in public health, as well as more international alignment on core principles and strategies to address the global neurosurgical burden of disease. This evolution has been marked by key milestones and initiatives aimed at expanding neurosurgical capacity, improving training and education, and establishing policies to enhance neurosurgical services, particularly in LMICs.

Part I: Defining the Problem

In Part I, the global survey of young neurosurgeons highlights differential barriers to delivering care across country income classes. For service delivery, the limited number of trained neurosurgeons was seen as a barrier 69.2% of LMICs and 23.9% of respondents from LICs. The data illustrate a need for initiatives focused on workforce development, training programs, policy formulation, and research aimed at building local capacity, improving education, establishing comprehensive health policies, and fostering research collaborations to ensure sustainable development in neurosurgical services.

Part II: Task Shifting and Sharing

In Part II, Chapters 3 to 5 explore the evolving landscape of task shifting and task sharing in neurosurgery, particularly in response to global health challenges and disparities in access to care. These chapters delve into global perspectives, practices in LMICs, and specific case studies, such as emergency neurosurgery in the Philippines. The Philippines study illustrated a practical implementation of a task-sharing program, compared it to a theoretical ideal, and ultimately demonstrated that task-sharing may be a safe practice to address emergency surgical needs where neurosurgeons are scarce, if the proper protocols are followed.

Chapters 6-7 highlighted the adaptive responses of neurosurgeons during the COVID-19 pandemic. They highlight the critical role of task sharing as an innovative strategy to address the urgent need for skilled human resources, especially in resource-constrained settings. The analysis underscores the necessity for standardized training, competency evaluation, and policy support to ensure these practices enhance neurosurgical care delivery while maintaining safety and quality. The chapters also reflect on the pandemic's profound impact on neurosurgery, emphasizing the need for resilient healthcare systems that can adapt to crises and continue to provide essential surgical services.

Part III: The Path Forward

In Part III, Chapters 8 to 10 collectively emphasize the significance of technology, policy, and gender equity in advancing global neurosurgery. Chapter 8 discusses the utilization of technology and objective metrics, such as simulation and spaced repetition learning, to enhance neurosurgical skill development, suggesting that

high-fidelity simulators and objective evaluation can significantly improve training outcomes. Chapter 9 explores the pivotal role of policy in global neurosurgery, detailing how strategic policy formulation, including National Surgical Obstetric, and Anesthesia Plans, has been crucial in integrating neurosurgery into broader healthcare strategies and improving access to care worldwide. Chapter 10 advocates for targeted strategies to increase the representation and empowerment of women in neurosurgery, highlighting the importance of mentorship, scholarships, and systemic changes to achieve gender parity. Together, these chapters underscore a holistic approach to developing the neurosurgical field through innovative educational techniques, supportive policies, and an inclusive professional culture.

CHAPTER 12

General Discussion

GENERAL DISCUSSION

The purpose of this thesis was to explore the multifaceted challenges impeding neurosurgical care in underserved areas, particularly in low- and middle-income countries, as well as to identify opportunities for improvement. With the culmination of this thesis in 2024, it lies near the midpoint between the December 2016 Bogota Declaration on Global Neurosurgery that recognized the massive deficit in neurosurgical care, and the 2030 U.N. Sustainable Developments goals that include 14 articles pertinent to improved neurosurgical care.[1,2] Midpoints are critical moments to reflect on the path thus far, and analyze what changes need to be incorporated into the strategy to attain the goal. Behavioral Economist Daniel Pink notes that: "Midpoints can have two distinct effects. They can bring us down, or they can fire us up."[3] My hope is that we, the collective global neurosurgery community, come together in this midpoint and get fired up. To optimize the power of this midpoint, and truly get fired up, it is important to review where the field was at the start of this research, where we are now, and where we have to go.

Early Stages of the Global Neurosurgery Movement

The 2015 Lancet Commission of Global Surgery catalyzed a revolutionary movement as it changed the mindsets of many in the global health and global policy communities. [4] It was no longer the neglected stepchild in the global health sector.[5] The catalog of publications from the Commission united data to articulate the scale of the burden of surgical disease, and sounded the alarm that investing in global surgery and the surrounding infrastructure was both urgent and economical. Through the Bogota Declaration and subsequent series of publications in the Journal of Neurosurgery, the global neurosurgery community also gained momentum. The efforts by Dewan et al to combine country registries, third-party modeled data, and meta-analyzed published data to generate incidence and volume figures for 10 common neurosurgical conditions allowed approximation of the global burden of neurosurgical disease.[6] That also clarified the 23,300 additional neurosurgeons who would be needed to address more than 5 million essential neurosurgical cases that go unmet each year. Transforming the global neurosurgery ecosystem required breaking down this massive challenge into smaller, tangible factors. Change would involve addressing the six domains of a healthcare system: infrastructure, workforce, service delivery, financing, information management, and governance. [7]

Getting to the Midpoint

The work of this thesis focused primarily on the workforce category. At the time of the Global Health Research Group on Neurotrauma launch in September 2017 in Cambridge, UK, there was ongoing debate about non-neurosurgeons performing neurosurgery around the world. Some felt that "something was better than nothing" if non-neurosurgeons were helping address the unmet need of neurosurgical care, whereas others remarked that this could be introducing harm, both to patients and to the healthcare system. The discussion was lacking evidence to support either side, and was the inspiration for the core of this thesis.

To evaluate the potential of task shifting and sharing as strategic solutions, we first collected data and perspectives from global surveys that highlight varying levels of acceptance and application across different regions. [8,9] This illustrated that task shifting and sharing was ongoing in many LMICs without substantial structure or oversight, which was concerning for patient safety. These data invited future clinical outcomes studies to assess effectiveness, and discussions on policy recommendations such as standardized curricula, certification protocols, specialist oversight, and referral networks to elevate the level of task shifting and sharing care while continuing to increase the specialist workforce. This allowed generation of a theoretical framework to approach the process. Furthermore, the global survey on perspectives of the challenge showed that both LMIC and HICs agreed that task-sharing should be prioritized over task-shifting and that additional recommendations and regulations could enhance care. These data invited future discussions on policy and training programs.

The case study in the Philippines was one of the first to examine outcomes of neurosurgical task-sharing, demonstrated that a strategic task-sharing model for emergency neurosurgery produced comparable outcomes to the local neurosurgeons. [10] Altogether, these three studies helped frame the need to continue training fully trained neurosurgeons, but also articulate recommendations for task sharing. First, systematic training programs should occur locally and involve a structured training curriculum, adequate oversight during medical and operative management, and competency-based evaluation at the end of the dedicated training cycle. Subsequently, local supervision should happen periodically to ensure maintenance of skills and competencies, and proper referral networks should be established for complex cases and complications to allow for tele-consultation and physical transfer of patients when necessary. Furthermore, it is critical for task-sharers to be officially recognized and supported by their institutions with a clear definition of their scope of practice, adequate financial remuneration, and clear career progression avenues in order to prevent attrition of practitioners and prevent task-creep: practicing beyond the scope of their training.[11]

That framework for task sharing was incorporated into the 2019 Comprehensive Policy Recommendations for Head and Spine Injury Care in LMICs.[12] Task sharing plays a small but important role in the broader context of infrastructure, workforce, service delivery, financing, information management, and governance.

Impact of the Global Pandemic

During this journey toward global surgical development milestones for 2030, the world faced an unprecedented turn of events with a global pandemic. The novel coronavirus disease (COVID-19), caused by the severe acute respiratory distress syndrome coronavirus 2 first appeared in December 2019 and was declared a pandemic by the World Health Organization on March 11, 2020.[13] By September 9, 2020, 27.7 million cases and 0.9 million deaths were confirmed globally.[14] This disease placed an unprecedented strain on healthcare systems around the world,[15] and had a substantial effect on clinical practice across all surgical specialties, with neurosurgery being no exception.

While the pandemic introduced an abrupt barrier and negative effect on the ability to train neurosurgeons, especially in LMICs, the increased use of social media and virtual platforms is markedly improving the interactions between institutions for shared learning between neurosurgeons at an international scale. Neurosurgical societies and organizations worldwide regularly conducted online webinars on myriad topics, often focusing on clinical evaluation of neurosurgical diseases and pearls and pitfalls of neurosurgical approaches.[16] As the vaccine was developed and distributed, and healthcare systems rebounded, the newfound strength in global communication over webinars and other virtual meetings persisted. which is likely a benefit to democratized education and collaboration for the field. [17] There was even the innovation of hybrid workshops that combined virtual teaching with hands-on simulators (e.g. UpSurgeOn) to enable anatomical learning and technical training.[18] At Massachusetts General Hospital, the positive effects of using these simulators for spaced repetition learning was validated.[19,20] This approach can be leveraged to facilitate collaboration between HICs and LMICs despite the geographic distances.[18]

Workforce Today

A study published by Gupta et al in January 2024 re-evaluated the global neurosurgery workforce density compared to the 2016 study.[21] They estimate that the neurosurgeon workforce has grown by 11.9% per year between 2016 and 2022, with the fastest growth in upper-middle income countries (21.3%), and LMICs (26.0%), and the most rapid annual growth was in the Southeast Asia region (33.0%). There were nearly 73,000 estimated neurosurgeons worldwide (0.93 neurosurgeons per 100,000 people; median national density, 0.44/100,000; **Figure 1**). Variables associated with increased neurosurgery workforce growth included the presence of a national neurosurgery society, increasing global development aid, and national gross domestic product. To achieve the goals of 1 neurosurgeon per 100,000 by 2030, more needs to be done.

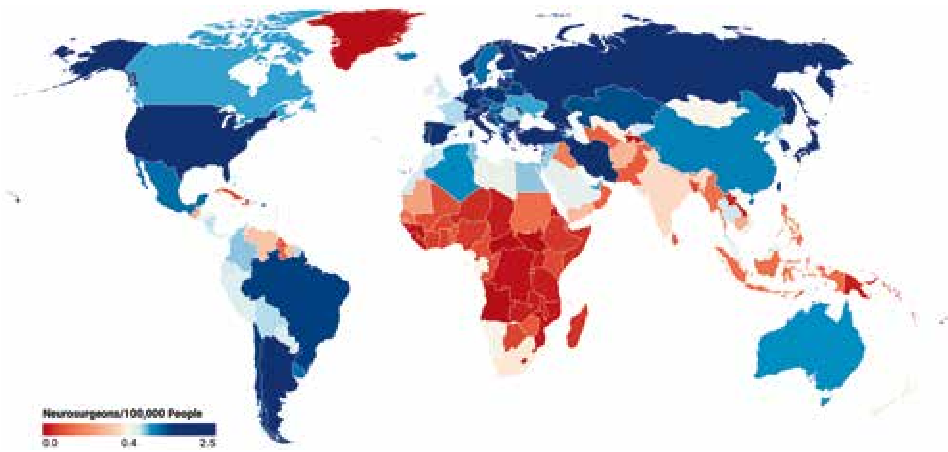

Figure 1: Map demonstrating the global neurosurgeon density. Countries near the average national median density (0.44 neurosurgeons per 100,000 people) are demonstrated in white, those increasingly above the median are demonstrated in increasingly dark blue, and those increasingly below the median are demonstrated in increasingly dark red. This figure was created with Data wrapper (Datawrapper GmbH). [21]

At the Policy Level

There have been tremendous strides since 2015 to institute strong policy as means to facilitate alignment on goals and strategies for global surgical systems strengthening. By 2019, five countries had completed an NSOAP and an additional 37 member states had either completed or were in the process of drafting or initiating a National Plan for Surgical Care.[12] Also in 2019, the WFNS established the Global Neurosurgery Committee, to assist in designing a global action plan with 5 key objectives and over 20 targets. The 5 objectives were 1. Amplify neurosurgical access, 2. Align global neurosurgery activity, 3. Advance relevant research, especially from LMICs, 4. Assimilate global neurosurgery activity within the global surgery framework, and 5. Advocate for neurosurgical care for all. Furthermore, the development of comprehensive recommendations for neurotrauma, spina bifida, and hydrocephalus have furthered the detail to which neurosurgical objectives can be instituted to augment care and mitigate the burden of neurosurgical disease worldwide. In 2021, the Journal of Global Neurosurgery launched as a free, open access journal that gives preferences to LMIC authors to ensure research in the most affected countries is being empowered and shared. In 2023, there were continued global efforts on the development and implementation of NSOAPs and the WFNS World Congress in Cape Town, South Africa with a full day dedicated to global initiatives.

Moving beyond the Midpoint

Overall, tremendous progress has been made in the field of global neurosurgery and there is much enthusiasm as the field nears the 2030 goals. Going forward, we as a neurosurgical community must come together to increase efforts in advocacy, further the recommendations for additional neurosurgical subspecialties and associated technologies, as well as partner with neurosurgical leaders across the globe to form national context-specific plans (NSOAPs). Though, the work does not stop there. Policy helps ensure goal alignment and dedication of funds, but much work must go into policy adoption, implementation, and enforcement. Policy formation also calls the global neurosurgical community to action to assist in resource provision and investment in training, building data registries, developing resource-stratified guidelines for specific neurosurgical conditions through expert teams, enabling research in the local context, regularly examining progress, and sharing knowledge.

From a workforce standpoint, to achieve the goals of 1 neurosurgeon per 100,000 by 2030, there are needs for development of local and regional plans, collaboration between HICs and LMICs to implement robust training systems, collaboration between neurosurgeons and neurologists to build local centers of excellence, and leveraging technologies and low-cost innovation for education and training, to name a few. By leveraging task-sharing strategies alongside of investing in traditional training, embracing technological advancements, and advocating for supportive policies, significant progress can be made towards improving neurosurgical workforce density. Gupta et al. also insightfully call for a central, organized effort to estimate the neurosurgeon workforce and resources available to neurosurgeons in 2030, possibly through a collaborative, multilateral effort through the global neurosurgery committees of national and international neurosurgery societies.[21]

Charting a path forward, we must emphasize collaboration, innovation, and equity in healthcare access. It is only through the unity of policy makers, practitioners, and researchers that we can raise the level of neurosurgical care throughout the world.

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APPENDICES

Nederlandse samenvatting

Acknowledgements

Report of Scholarship

Curriculum Vitae

NEDERLANDSE SAMENVATTING

Het vakgebied van de wereldwijde neurochirurgie is de afgelopen tien jaar aanzienlijk geëvolueerd, gedreven door een groeiende erkenning van de cruciale rol die neurochirurgie speelt in de volksgezondheid en door toenemende cohesie van internationale kernprincipes en strategieën om de neurochirurgische ziektelast aan te pakken. Deze evolutie wordt gekenmerkt door belangrijke mijlpalen en initiatieven gericht op het uitbreiden van de neurochirurgische capaciteit, het verbeteren van training en onderwijs en het vaststellen van beleid om de neurochirurgische diensten te verbeteren, vooral in de lage- en middeninkomenslanden – ook wel de “Low and Middle Income Countries” (LMIC’s).

Deel I: Het definiëren van het probleem

In deel I belicht het internationale onderzoek onder jonge neurochirurgen de verschillende belemmeringen voor het leveren van zorg in landen met verschillende inkomensklasse. Een van de obstakels was het beperkte aantal opgeleide neurochirurgen vanuit de LMIC en LIC: respectievelijk 69,2% en 23,9%. Deze gegevens illustreren de behoefte aan initiatieven gericht op de ontwikkeling van het personeelsbestand, trainingsprogramma’s, beleidsformulering en onderzoek gericht op het opbouwen van lokale capaciteit, het verbeteren van het onderwijs, het opzetten van een alomvattend gezondheidsbeleid en het bevorderen van onderzoekssamenwerkingen om duurzame ontwikkeling in neurochirurgische diensten te garanderen.

Deel II: Taakverschuiving en -deling

In Deel II onderzoeken de hoofdstukken 3 tot en met 5 het evoluerende landschap van taakverschuiving (“task shifting”) en taakverdeling (“task sharing”) in de neurochirurgie, vooral als reactie op wereldwijde gezondheidsuitdagingen en ongelijkheden in de toegang tot zorg. In deze hoofdstukken wordt dieper ingegaan op de internationale perspectieven over hoe het beste tegemoet kan worden gekomen aan het tekort aan arbeidskrachten in de neurochirurgie, evenals op de huidige praktijk van taakverschuiving en taakverdeling in de LMIC’s en specifieke casestudies van taakverschuiving en taakverdeling. Deze casestudies keek onder andere naar noodchirurgie in de Filippijnen. Het onderzoek dook dieper in op het implementeren van een programma voor “task sharing” en vergeleek dit met een theoretisch ideale situatie. Uiteindelijk bleek “task sharing” veilig te zijn in de praktijk indien de juiste protocollen worden gevolgd en biedt het houvast aan neurochirurgen bij spoedeisende chirurgische casussen.

In de hoofdstukken 6 tot en met 7 worden de adaptieve houding en acties van neurochirurgen tijdens de COVID-19-pandemie belicht. Deze hoofdstukken benadrukken de cruciale rol van het delen van taken als een innovatieve strategie in omgevingen met een vraag naar geschoold personeel en beperkte middelen.

De beschreven analyse benadrukt het belang van gestandaardiseerde training, competentie-evaluatie en beleidsondersteuning om de neurochirurgische zorgverlening verbeteren met behoud van de veiligheid en kwaliteit. De hoofdstukken reflecteren ook op de diepgaande impact van de pandemie op de neurochirurgie, waarbij de nadruk wordt gelegd op de behoefte aan veerkrachtige gezondheidszorgsystemen die zich kunnen aanpassen aan crises en essentiële chirurgische diensten kunnen blijven leveren.

Deel III: Het pad voorwaarts

In Deel III benadrukken de hoofdstukken 8 tot en met 10 het belang van technologie, beleid en gendergelijkheid bij het bevorderen van de wereldwijd neurochirurgie. In hoofdstuk 8 wordt het gebruik van technologie en objectieve maatstaven besproken. Dit beschrijft voorbeelden zoals simulatie en leren met gespreide herhaling om de ontwikkeling van neurochirurgische vaardigheden te verbeteren. Gespreide herhaling is een pedagogie waarbij de studenten het memoriseren van de anatomie herhaalden en een deel van een operatie uitvoerden om de kennis te verstevigen. Deze onderzoeken suggereren dat we hulpmiddelen zoals hifi-simulators en curricula die herhaling en objectieve metrische evaluatie met zich meebrengen, kunnen inzetten om de training te verbeteren. We moeten efficiënte en effectieve pedagogiek overwegen om meer neurochirurgen op te leiden in landen met een tekort aan arbeidskrachten.

Hoofdstuk 9 onderzoekt de cruciale rol van beleid in de wereldwijde neurochirurgie. Dit beschrijft hoe neurochirurgie een belangrijke rol speelt in het bredere doel van het ontwikkelen van robuuste chirurgische systemen. Daarom is het, wanneer landen strategisch beleid creëren, zoals nationale chirurgische verloskundige en anesthesieplannen, noodzakelijk om neurochirurgie op te nemen in de bredere gezondheidszorgstrategieën om de toegang tot zorg wereldwijd te verbeteren.

Hoofdstuk 10 pleit voor gerichte strategieën om de vertegenwoordiging en empowerment van vrouwen in de neurochirurgie te vergroten, waarbij het belang wordt benadrukt van mentorschap, beurzen en systemische veranderingen om gendergelijkheid te bereiken. Samen benadrukken deze hoofdstukken een holistische benadering van de ontwikkeling van het neurochirurgische veld door middel van innovatieve onderwijstechnieken, ondersteunend beleid en een inclusieve professionele cultuur.

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REPORT OF SCHOLARSHIP

Peer Reviewed Publications, Research Investigations

1. Menna G, Kolias A, Esene IN, Barthélemy EJ, Hoz S, Laeke T, Veiga Silva AC, Longo-Calderón GM, Baticulon RE, Zabala JP, Hassani FD, El Abbadi N, Khan MM, **Robertson FC**, Thango N, Cheresem B, Ogando-Rivas E, Roumy LG, Karekezi C, Alamri A, Spena G, Cenzato M, Servadei F, Giussani CG, Nicolosi F. Reducing the Gap in Neurosurgical Education in LMICs: A Report of a Non-Profit Educational Program. World Neurosurg. 2024 Feb;182:e792-e797. doi: 10.1016/j.wneu.2023.12.040. Epub 2023 Dec 13. PMID: 38101536
2. Chiurillo I, Sha RM, **Robertson FC**, Liu J, Li J, Le Mau H, et al. High-Accuracy Neuro-Navigation with Computer Vision for Frameless Registration and Real-Time Tracking. *Bioengineering*. 2023;10(12):1401.
3. Dolmans RGF, Nahed BV, **Robertson FC**, Peul WC, Rosenthal ES, Broekman MLD. Practice-Pattern Variation in Sedation of Neurotrauma Patients in the Intensive Care Unit: An International Survey. J Intensive Care Med. 2023 Dec;38(12):1143-1150. doi: 10.1177/08850666231186563. Epub 2023 Jul 7
4. Vooijs M, **Robertson FC**, Rosseau G, Tasiou A, Rodríguez-Hernández A, Mihaylova SI, et al. Ethical challenges of travel for experimental therapy in malignant brain tumor patients. Journal of Neurosurgery. 2023;1(aop):1-5.
5. **Robertson FC,** Stapleton CJ, Coumans J-VC, Nicolosi F, Vooijs M, Blitz S, et al. Applying objective metrics to neurosurgical skill development with simulation and spaced repetition learning. Journal of Neurosurgery. 2023;1(aop):1-9.
6. Poon MT, Piper RJ, Thango N, Fountain DM, Marcus HJ, Lippa L, et al. **(Robertson FC)** Variation in postoperative outcomes of patients with intracranial tumors: insights from a prospective international cohort study during the COVID-19 pandemic. Neuro-oncology. 2023.
7. Javed S, Perez-Chadid D, Yaqoob E, Shlobin NA, Ham EI, Veerappan VR, et al. **(Robertson FC)** Needs, Roles and Challenges of Young Asian Neurosurgeons. World neurosurgery. 2023.
8. Elkaim LM, Levett JJ, Niazi F, Alvi MA, Shlobin NA, Linzey JR, et al. **(Robertson FC)** Cervical Myelopathy and Social Media: Mixed Methods Analysis. Journal of Medical Internet Research. 2023;25:e42097.
9. Dolmans RG, **Robertson FC**, Eijkholt M, van Vliet P, Broekman ML. Palliative care in severe neurotrauma patients in the intensive care unit. Neurocritical Care. 2023:1-8.
10. Dolmans RG, Nahed BV, **Robertson FC**, Peul WC, Rosenthal ES, Broekman ML. Practice-Pattern Variation in Sedation of Neurotrauma Patients in the Intensive Care Unit: An International Survey. Journal of Intensive Care Medicine. 2023:08850666231186563.
11. Sellier A, Russo D, **Robertson F**, Rodriguez-Arribas M-A, Charissoux M, Azria D, et al. A choroid plexus metastasis of a prostatic adenocarcinoma mimicking a choroid plexus carcinoma: a case report. Neurochirurgie. 2022;68(1):113-6.
12. **Robertson FC,** Wu KC, Sha RM, Amich JM, Lal A, Lee BH, et al. Stereotactic Neurosurgical Robotics With Real-Time Patient Tracking: A Cadaveric Study. Operative Neurosurgery. 2022;22(6):425-32.
13. **Robertson FC,** Sha R, Amich J, Lee B, Lal A, Calvachi P, et al. 181 Frameless Neuronavigation With Computer Vision and Real Time Tracking for Bedside External Ventricular Drain Placement: A Cadaveric Study. Neurosurgery. 2022;68(Supplement_1):54.
14. Palmisciano P, Haider AS, Balasubramanian K, Dadario NB, **Robertson FC**, Silverstein JW, et al. Supplementary motor area syndrome after brain tumor surgery: a systematic review. World Neurosurgery. 2022;165:160-71. e2.
15. Ng PR, Zaki MM, Collier CG, **Robertson FC,** Hauser BM, Farren S, et al. Systems analysis of neurosurgical first-case delays identifies opportunities to optimize operating room efficiency. Perioperative Care and Operating Room Management. 2022;28:100262.
16. Gerstl JV, Yearley AG, Kilgallon JL, Lassarén P, **Robertson FC,** Herdell V, et al. A national stratification of the global macroeconomic burden of central nervous system cancer. Journal of Neurosurgery. 2022;1(aop):1-9.
17. **COVID Collaborative**, Adamina M, Ademuyiwa A, Adisa A, Bhangu AA, Bravo AM, et al. The impact of surgical delay on resectability of colorectal cancer: An international prospective cohort study. Colorectal Disease. 2022;24(6):708-26.
18. Clark D, Joannides A, Adeleye AO, Bajamal AH, Bashford T, Biluts H, et al. **(Robertson FC)** Casemix, management, and mortality of patients receiving emergency neurosurgery for traumatic brain injury in the Global Neurotrauma Outcomes Study: a prospective observational cohort study. The Lancet Neurology. 2022;21(5):438-49.
19. Thango NS, Baticulon RE, Ogando E, **Robertson FC,** Lippa L, Kolias A, et al. The Role of Young Neurosurgeons in Global Surgery: A Unified Voice for Health Care Equity. JOURNAL OF GLOBAL NEUROSURGERY. 2021;1(1):64-7.
20. Sadler SJ, Ip HKY, Kim E, Karekezi C, **Robertson FC.** Investing in the future: a call for strategies to empower and expand representation of women in neurosurgery worldwide. Neurosurgical Focus. 2021;50(3):E8.
21. **Robertson FC,** Raahil MS, Amich JM, Essayed WI, Lal A, Lee BH, et al. Frameless neuronavigation with computer vision and real-time tracking for bedside external ventricular drain placement: a cadaveric study. Journal of Neurosurgery. 2021;136(5):1475-84.
22. **Robertson FC,** Linzey JR, Alotaibi NM, Regenhardt RW, Harker P, Vranic J, et al. # RadialFirst and# RadialForNeuro: A descriptive analysis of Twitter conversations regarding transradial access. The Neuroradiology Journal. 2021;34(5):494-500.

23. Palmisciano P, El Ahmadieh TY, Haider AS, Bin Alamer O, **Robertson FC,** Plitt AR, et al. Thalamic gliomas in adults: a systematic review of clinical characteristics, treatment strategies, and survival outcomes. Journal of neuro-oncology. 2021;155:215-24.
24. Mohan M, Layard Horsfall H, Solla DJF, **Robertson FC,** Adeleye AO, Teklemariam TL, et al. Decompressive craniotomy: an international survey of practice. Acta Neurochirurgica. 2021;163:1415-22.
25. Kanmounye US, Zolo Y, **Robertson FC,** Bankole NDA, Kabulo KDM, Ntalaja JM, et al. Prevalence of spine surgery navigation techniques and availability in Africa: A cross-sectional study. Annals of Medicine and Surgery. 2021;68:102637.
26. Kanmounye US, **Robertson FC,** Thango NS, Doe AN, Bankole NDA, Ginette PA, et al. Needs of young African neurosurgeons and residents: a cross-sectional study. Frontiers in surgery. 2021;8:647279.
27. Kanmounye US, **Robertson FC,** Sebopelo LA, Senyuy WP, Sichimba D, Keke C, et al. Bibliometric analysis of the 200 most cited articles in World Neurosurgery. World Neurosurgery. 2021;149:226-31. e3.
28. Harker P, Regenhardt RW, Alotaibi NM, Vranic J, **Robertson FC**, Dmytriw AA, et al. The Woven EndoBridge device for ruptured intracranial aneurysms: international multicenter experience and updated meta-analysis. Neuroradiology. 2021;63(11):1891-9.
29. Glasbey JC, Nepogodiev D, Simoes JF, Omar O, Li E, Venn ML, et al. **(Robertson FC)** Elective cancer surgery in COVID-19–free surgical pathways during the SARS-CoV-2 pandemic: an international, multicenter, comparative cohort study. Journal of Clinical Oncology. 2021;39(1):66.
30. Glasbey J, Ademuyiwa A, Adisa A, AlAmeer E, Arnaud AP, Ayasra F, et al. **(Robertson FC)** Effect of COVID-19 pandemic lockdowns on planned cancer surgery for 15 tumour types in 61 countries: an international, prospective, cohort study. The Lancet Oncology. 2021;22(11):1507-17.
31. Giantini Larsen AM, Pories S, Parangi S, **Robertson FC**. Barriers to pursuing a career in surgery: an institutional survey of Harvard Medical School students. Annals of Surgery. 2021;273(6):1120-6.
32. **COVID Collaborative**. 1013 Preoperative Nasopharyngeal Swab Testing and Postoperative Pulmonary Complications in Patients Undergoing Elective Surgery During The SARS-Cov-2 Pandemic. British Journal of Surgery. 2021;108(Supplement_2):znab135. 039.
33. Bin Alamer O, Haider AS, Haider M, Sagoo NS, **Robertson FC,** Arrey EN, et al. Primary and radiation induced skull base osteosarcoma: a systematic review of clinical features and treatment outcomes. Journal of neuro-oncology. 2021;153(2):183-202.
34. Death following pulmonary complications of surgery before and during the SARS-CoV-2 pandemic. **(COVID Collaborative includes Robertson FC)** British Journal of Surgery. 2021;108(12):1448-64.

35. Takoukam R, Kanmounye US, **Robertson FC,** Zimmerman K, Nguembu S, Lartigue JW, et al. Prehospital conditions and outcomes after craniotomy for traumatic brain injury performed within 72 hours in Central Cameroon: a cross-sectional study. World Neurosurgery. 2020;142:e238-e44.
36. **Robertson FC,** Sha R, Amich J, Lal A, Lee B, Wu K, et al. Computer Vision Registration as a Novel and Accurate Approach for Frameless Stereotactic Neuronavigation. Neurosurgery. 2020;67.
37. **Robertson FC,** Gnanakumar S, Karekezi C, Vaughan K, Garcia RM, Bourquin BAEE, et al. The World Federation of Neurosurgical Societies Young Neurosurgeons Survey (Part II): barriers to professional development and service delivery in neurosurgery. World neurosurgery: X. 2020;8:100084.
38. **Robertson FC,** Esene IN, Kolias AG, Khan T, Rosseau G, Gormley WB, et al. Global perspectives on task shifting and task sharing in neurosurgery. World neurosurgery: X. 2020;6:100060.
39. **Robertson FC,** Esene IN, Kolias AG, Kamalo P, Fieggen G, Gormley WB, et al. Task-shifting and task-sharing in neurosurgery: an international survey of current practices in low-and middle-income countries. World neurosurgery: X. 2020;6:100059.
40. **Robertson FC,** Briones R, Mekary RA, Baticulon RE, Jimenez MA, Leather AJ, et al. Task-sharing for emergency neurosurgery: a retrospective cohort study in the Philippines. World Neurosurgery: X. 2020;6:100058.
41. Ota HC, Smith BG, Alamri A, **Robertson FC,** Marcus H, Hirst A, et al. The IDEAL framework in neurosurgery: a bibliometric analysis. Acta neurochirurgica. 2020;162:2939-47.
42. Linzey JR, **Robertson F,** Haider AS, Graffeo CS, Wang JZ, Shasby G, et al. Online impact and presence of a specialized social media team for the journal of neurosurgery: descriptive analysis. Journal of medical Internet research. 2020;22(5):e17741.
43. Ji YD, **Robertson FC,** Patel NA, Peacock ZS, Resnick CM. Assessment of risk factors for suicide among US health care professionals. JAMA surgery. 2020;155(8):713-21.
44. Gnanakumar S, Bourquin BAEE, **Robertson FC**, Solla DJF, Karekezi C, Vaughan K, et al. The world federation of neurosurgical Societies young neurosurgeons survey (Part I): demographics, resources, and education. World neurosurgery: X. 2020;8:100083.
45. Barr C, Lasso A, Asselin M, Pieper S, **Robertson FC,** Gormley WB, et al., editors. Towards portable image guidance and automatic patient registration using an RGB-D camera and video projector. Medical Imaging 2020: Image-Guided Procedures, Robotic Interventions, and Modeling; 2020: SPIE.
46. Delaying surgery for patients with a previous SARS-CoV-2 infection. Journal of British Surgery. 2020;107(12):e601-e2.

47. Stopa BM, **Robertson FC,** Karhade AV, Chua M, Broekman ML, Schwab JH, et al. Predicting nonroutine discharge after elective spine surgery: external validation of machine learning algorithms: Presented at the 2019 AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves. Journal of Neurosurgery: Spine. 2019;31(5):742-7.
48. **Robertson FC,** Ullrich NJ, Manley PE, Al-Sayegh H, Ma C, Goumnerova LC. The impact of intraoperative electrocorticography on seizure outcome after resection of pediatric brain tumors: a cohort study. Neurosurgery. 2019;85(3):375-83.
49. **Robertson F,** Mutabazi Z, Kyamanywa P, Ntakiyiruta G, Musafiri S, Walker T, et al. Laparoscopy in Rwanda: a national assessment of utilization, demands, and perceived challenges. World Journal of Surgery. 2019;43:339-45.
50. Muskens IS, Gupta S, **Robertson FC,** Moojen WA, Kolias AG, Peul WC, et al. When time is critical, is informed consent less so? A discussion of patient autonomy in emergency neurosurgery. World Neurosurgery. 2019;125:e336-e40.
51. Liu J, Gormley N, Dasenbrock HH, Aglio LS, Smith TR, Gormley WB, **Robertson FC**. Cost-benefit analysis of transitional care in neurosurgery. Neurosurgery. 2019;85(5):672-9.
52. Broekman ML. Ethics of innovation in neurosurgery. Springer International Publishing; 2019.
53. **Robertson FC,** Lepard JR, Mekary RA, Davis MC, Yunusa I, Gormley WB, et al. Epidemiology of central nervous system infectious diseases: a meta-analysis and systematic review with implications for neurosurgeons worldwide. Journal of neurosurgery. 2018;130(4):1107-26.
54. Hirji SA, **Robertson FC,** Chao GF, Khurana B, Gates JD. Phytobezoar: A Brief Report with Surgical and Radiological Correlation. Case Reports in Surgery. 2018;2018.
55. Hirji SA, **Robertson FC,** Casillas S, McPhee JT, Gupta N, Martin MC, et al. Asymptomatic portal vein aneurysms: To treat, or not to treat? Phlebology. 2018;33(8):513-6.
56. Dewan MC, Rattani A, Fieggen G, Arraez MA, Servadei F, Boop FA, et al. Global neurosurgery: the current capacity and deficit in the provision of essential neurosurgical care. Executive Summary of the Global Neurosurgery Initiative at the Program in Global Surgery and Social Change. Journal of neurosurgery. 2018;130(4):1055-64.
57. Terabe M, **Robertson FC,** Clark K, De Ravin E, Bloom A, Venzon DJ, et al. Blockade of only TGF-β 1 and 2 is sufficient to enhance the efficacy of vaccine and PD-1 checkpoint blockade immunotherapy. Oncoimmunology. 2017;6(5):e1308616.
58. Robinson S**, Robertson FC,** Dasenbrock HH, O'Brien CP, Berde C, Padua H. Image-guided intrathecal baclofen pump catheter implantation: a technical note and case series. Journal of Neurosurgery: Spine. 2017;26(5):621-7.

59. **Robertson FC,** Logsdon JL, Dasenbrock HH, Yan SC, Raftery SM, Smith TR, et al. Transitional care services: a quality and safety process improvement program in neurosurgery. Journal of neurosurgery. 2017;128(5):1570-7.
60. **Robertson FC,** Dasenbrock HH, Gormley WB. Decompressive hemicraniectomy for stroke in older adults: a review. Journal of neurology & neuromedicine. 2017;2(1):1.
61. Pernar LI, **Robertson FC,** Tavakkoli A, Sheu EG, Brooks DC, Smink DS. An appraisal of the learning curve in robotic general surgery. Surgical endoscopy. 2017;31:4583-96.
62. Fehnel CR, Gormley WB, Dasenbrock H, Lee Y, **Robertson F,** Ellis AG, et al. Advanced age and post–acute care outcomes after subarachnoid hemorrhage. Journal of the American Heart Association. 2017;6(10):e006696.
63. Dasenbrock HH, **Robertson FC**, Vaitkevicius H, Aziz-Sultan MA, Guttieres D, Dunn IF, et al. Timing of decompressive hemicraniectomy for stroke: a nationwide inpatient sample analysis. Stroke. 2017;48(3):704-11.
64. **Robertson FC,** Abd-El-Barr MM, Mukundan S, Gormley WB. Ventriculostomy-associated hemorrhage: a risk assessment by radiographic simulation. Journal of Neurosurgery. 2016;127(3):532-6.
65. Dasenbrock HH*, **Robertson FC*,** Aziz-Sultan MA, Guittieres D, Du R, Dunn IF, et al. Patient age and the outcomes after decompressive hemicraniectomy for stroke: a nationwide inpatient sample analysis. Neurocritical care. 2016;25:371-83.
66. Terabe M, **Robertson F**, Kato S, De Ravin E, Clark K, Mizra AM, et al. Abstract LB-233: Blockade of TGF-beta1 and 2 without TGF-beta3 blockade is sufficient to facilitate tumor vaccine efficacy. Cancer Research. 2015;75(15_Supplement):LB-233-LB-.
67. Spector NL, **Robertson FC,** Bacus S, Blackwell K, Smith DA, Glenn K, et al. Lapatinib plasma and tumor concentrations and effects on HER receptor phosphorylation in tumor. PLoS One. 2015;10(11):e0142845.
68. **Robertson FC,** Berzofsky JA, Terabe M. NKT cell networks in the regulation of tumor immunity. Frontiers in immunology. 2014;5:543.

Letters to the Editor / Commentary

1. **Robertson FC,** Nahed BV. Reply: Letter to the Editor. Tracking neurosurgery resident performance on simulation-based training tasks. Journal of Neurosurgery. May 2023. PMID: 37243557 DOI: 10.3171/2023.3.JNS23610
2. **Robertson FC,** Lippa L, Broekman ML. Task shifting and task sharing for neurosurgeons amidst the COVID-19 pandemic. Journal of Neurosurgery. 2020;133(1):5-7

3. **Robertson FC.** Response to the Comment on "Gender Parity in Cardiothoracic Surgery Training: Significant Strides but Miles to Go". Annals of Surgery. 2021;274(6):e849.
4. Ji YD, **Robertson FC,** Patel NA. Universal Suicide Prevention for Health Care Professionals—Reply. JAMA surgery. 2021;156(3):291-.
5. Kanmounye US, **Robertson FC,** Sichimba D, Graffeo CS. In Reply to the Letter to the Editor Regarding" Bibliometric analysis of the 200 most cited articles in World Neurosurgery". World Neurosurgery. 2021;149:293-.
6. **Robertson F.** Presence of Histopathological Treatment Effects at Resection of Recurrent Glioblastoma: Incidence and Effect on Outcome COMMENT. OXFORD UNIV PRESS INC JOURNALS DEPT, 2001 Evans Rd, Carry, NC 27513 USA; 2019. p. 800-.

Book Chapters

1. Robertson FC, Park KB, Johnson WD. The Role of Policy in Global Neurosurgery. Neurosurgery Clinics of North America on Global Neurosurgery. 2024 Oct;35(4):401-410. doi: 10.1016/j.nec.2024.05.002. Epub 2024 Jul 2. PMID: 39244312.
2. Kalyvas A, Bernstein M, Baticulon RE, Broekman ML, **Robertson FC**. The impact of the COVID-19 pandemic on neurosurgery worldwide. Neurosurgery and Global Health. 2022:341-56.
3. **Robertson FC,** Mathiesen T, Broekman ML. Informed Consent for Neurosurgical Innovation. Ethics of Innovation in Neurosurgery. 2019:11-25.
4. Hirji, S, **Robertson FC**, Anderson K, and Harskamp R. Chapter 2: Percutaneous versus Surgical Coronary Revascularization in the Current Era and Beyond: Is the Debate Over? *Coronary Artery Disease: Characteristics, Management and Long-Term Outcomes.* Cardiology Research and Clinical Developments. Nova Science Publishers. 2016. ISBN: 978-1-63485-330-9.

Report of Regional, National, and International Invited Teaching and Oral Presentations

International

2023 **Robertson, FC**, Grand Rounds: Innovation in Neurosurgery & Global Neurosurgery. Department of Neurosurgery. Santa Casa Hospital. Sao Paolo, Brazil. May 16, 2023.

2020 **Robertson, FC**, Virtual Lecture: Ethics and Neurosurgery: innovative practice during COVID -19. Task Shifting and Task Sharing in Neurosurgery. Virtually with *Leiden University Medical Center*. Leiden, Netherlands, Sept 25, 2020.

2020 Barr C (presenter), Lasso A, Asselin M, Pieper S, **Robertson FC**, Gormley WB, et al., editors. Towards portable image guidance and automatic patient registration using an RGB-D camera and video projector. Medical Imaging 2020: Image-Guided Procedures, Robotic Interventions, and Modeling; Houston, TX, 2020: International Society for Optics and Photonics.

2019 **Robertson, FC**, I Esene, A Kolias, T Khan, G Rossuea, WB Gormley, MLD Broekman, KB Park. Global Perspectives on Task-Shifting and Task-Sharing in Neurosurgery. European Association of Neurosurgical Societies. Dublin, Ireland. Sept 25 2019

2019 **Robertson, FC**, RC Briones, WB Gormley, R Baticulon, KB Park, A Leather, LL Lucena. Task-Shifting and Task-Sharing in Neurosurgery: A Retrospective Cohort Study in the Philippines. *International Conference on Recent Advances in Traumatology.* Peshawar, Pakistan. March 6, 2019 [Postponed in setting of military conflict. Nov 2019].

Stopa, BM, **FC Robertson,** A Karhade, M Chua, MLD Broekman, JH Schwab, TR Smith, WB Gormley. Predicting Non-Routine Discharge After Elective Spine Surgery: External Validation of Machine Learning Algorithms Using Institutional Data *(Presentation by BM Stopa)*. King's College London International Neurosurgical Conference, London, UK, November 2018. PMID: 30903190

2018 **Robertson, FC**, RC Briones, WB Gormley, R Baticulon, KB Park, A Leather, LL Lucena (speaker). Task-Shifting and Task-Sharing in Neurosurgery: A Retrospective Cohort Study in the Philippines. *International Symposium and Workshop on Neurotrauma and Neurointensive Care.* Indonesia. August 12th, 2018.

2018 **Robertson, FC**. Why we should ask "Why?" The importance of research in your medical career. Visiting lecturer. *Monthly Interdepartmental Conference, Bicol Medical Center,* Naga City, Philippines. June 2018

2017 **Robertson, FC**. What is Global Surgery? Speaker and Panelist for the *Annual National Medical Student Surgery Conference at Kings College London*, London, UK. December 2017.

2017 **Robertson, FC,** and WB Gormley. A Transitional Care Program for Elective Neurosurgery. *Grand Rounds for the Division of Neurosurgery and Neurosciences, Royal London Hospital*, Bart's NHS Trust, London, UK. November 2017.

2017 **Robertson, FC**,* HH Dasenbrock,* MA Aziz-Sultan, D Guittieres, IF Dunn, R Du, WB Gormley. Predictors of Decompressive Craniectomy Utilization in Ischemic Stroke in the United States. *European Stroke Conference. Berlin, Germany. May 2017.*

National

2023 Introduction to Global Neurosurgery: Building Partnerships and Making an Impact. *NYU Grossman School of Medicine AANS Interest Group*. Webinar. Nov 28, 2023. Online.

2023 The Future of Neurosurgical Training, Panelist. *Digital Neurosurgery* Annual Meeting. October 14, 2023. Palo Alto, CA.

2023 Introduction as Course Director at the Quality in Neurosurgery Practice Symposium. *Congress of Neurological Surgeons* Annual Meeting. September 9, 2023. Washington, DC.

2023 Guidelines Session III: Pituitary Adenoma – Overview of Guidelines Impact. *Congress of Neurological Surgeons* Annual Meeting. September 9, 2023. Washington, DC.

2023 Predictors for Andexanet Use for Intracranial Hemorrhage in the US. Hematology and Coagulation for Neurosurgeons Lunch Seminar. *Congress of Neurological Surgeons* Annual Meeting. September 13, 2023. Washington, DC.

2023 Social Media and the Journal of Neurosurgery. Annual update at the American Association of Neurological Surgeons Board Meeting. April 21, 2023. Los Angeles, CA.

2022 Social Media and the Journal of Neurosurgery. Annual update at the American Association of Neurological Surgeons Board Meeting. April 30, 2022. Philadelphia, PA.

2021 **Robertson FC,** Sha R, Amich J, Lee B, Lal A, Calvachi P, et al. Frameless Neuronavigation with Computer Vision and Real Time Tracking for Bedside External Ventricular Drain Placement: A Cadaveric Study. *Congress of Neurological Surgeons*. October 2021. Austin, TX.

2021 Social Media and the Journal of Neurosurgery. Annual update at the American Association of Neurological Surgeons Board Meeting. August 26, 2021. Virtual.

2020 Cost-Benefit Analysis of Transitional Care in Neurosurgery. Paper of the Year: Socioeconomics. *Congress of Neurological Surgeons* Virtual Visiting Professor program. November 12, 2020. Chicago, IL, USA.

2020 Building your Brand. Generating Executive Presence for Personal and Professional Success in Social Media. Virtual Lecture. *Annual Meeting of The American Association of Neurological Surgery. May 20, 2020.*

Perils, Pitfalls and Pearls for Success: How to Build Your Brand without Jumping the Shark. *Faculty section of Social Medial for Neurosurgeons. Congress of Neurological Surgeons. San Francisco, CA. October 23, 2019*

2016 Robertson, FC*, Z Mutabazi*, P Kyamanywa, G Ntakiyiruta, V Dusabejambo, S Musafiri, T Walker, E Kayibanda, C Mukabatsinda, J Scott, A Costas-Chavarri. Barriers to Performing Minimally Invasive Surgery in Rwanda: an Assessment of National Demand, Utilization Rates and Perceived Challenges. *American College of Surgeons, Clinical Congress 2016. Washington, DC. October 2016.*

2016 **Robertson, FC***, JL Logsdon*, HH Dasenbrock, SC Yan, SM Raftery, TR Smith, WB Gormley. Transitional Care Services: A Quality and Safety Process Improvement Program in Neurosurgery. Plenary talk at the *Annual Meeting of The American Association of Neurological Surgery. Chicago, IL. May 2016.* DOI: 10.3171/2016.4.JNS.AANS2016

2015 **Robertson, FC**, N Ullrich, P Manley, C Ma, H Al-Sayegh, and L Goumnerova. The impact of tumor resection and intraoperative electrocorticography in patients with tumor-related seizures. *Annual Meeting of the American Association of Neurological Surgery and Congress of Neurological Surgeons Section on Pediatric Neurosurgery. Seattle, WA. December 2015.*

2015 **Robertson, FC**, H Dasenbrock, C O'Brien, C Berde, H Padua, and S Robinson. Image-guided intrathecal baclofen pump implantation: A technical note and case series. *Annual Pediatrics Medical Student Research Forum, American Association of Pediatrics. Orlando, FL. Sept 2015.*

Regional

2023 **Robertson, FC**. Applying objective metrics to neurosurgical skill development with simulation and spaced repetition learning. Mass General Hospital Resident Research Symposium. Boston, MA. June 8, 2023.

2020 **Robertson, FC**. Ethics of Big Data and AI in Neurosurgery. Speaker at 2nd Annual Computational Data Neuroscience Symposium, *Brigham & Women's Hospital/Harvard Dept of Neurosurgery & the Harvard School of Public Health Onnela Lab*, Virtually Friday Oct 23, 2020.

Liu, J, N Gormley, HH Dasenbrock, LS Aglio, TR Smith, WB Gormley, **FC Robertson.** Cost-Effectiveness of a Transitional Care Program for Elective Neurosurgery. *Annual Meeting of the New England Neurosurgical Society. Chatham, MA. June 2017.*

2017 **Robertson, FC**. Opening Address: The Journey to the Top. *Association of Women Surgeons: New England Regional Exchange. Yale Medical School. New Haven, CT. April 2017.*

2016 **Robertson, FC**, M Abd-El-Barr, S Mukundan and W Gormley. Ventriculostomy Associated Hemorrhage: a Risk Assessment by Radiographic Simulation. *Annual Meeting New England Neurosurgical Society. Wequassett, MA. June 2016.*

2016 **Robertson, FC.** Opening Address: Shining Light on Women in Surgery. *Association of Women Surgeons: New England Regional Exchange. Harvard Medical School. Boston, MA. March 2016.*

2015 **Robertson, FC,** HH Dasenbrock, C O'Brien, C Berde, H Padua, and S Robinson. Image-guided intrathecal baclofen pump implantation: A technical note and case series. *Annual Meeting of the New England Neurosurgical Society. Chatham, MA. June 2015.*

CURRICULUM VITAE

Dr. Faith Robertson grew up on a small farm in rural Ohio. Her mother's battle with breast cancer when she was a teenager inspired her pursuit of a career in medicine. Faith was valedictorian of her high school class and obtained her Bachelor of Science in Biology from Duke University, graduating with High Distinction for her thesis on breast cancer metabolism. After college, Faith completed a one-year fellowship in Tumor Immunology at the National Cancer Institute. She followed her passion for surgery and oncology to Boston, and completed her M.D. from Harvard Medical School, alongside an M.Sc. in Global Health and Global Surgery from King's College London. Seeing the importance of organizational management and financial resources in global health development, Faith also completed her M.B.A. at Harvard Business School. Dr. Robertson is currently a senior neurosurgery resident at Massachusetts General Hospital, a Harvard Medical School teaching hospital. Recent awards have included National Quality and Guidelines Scholar (2022), Neurosurgery Consultant of the Year (2022) Resident Research Excellence Award (2023), and Medical Education Research Award (2024). She plans to complete her residency training in 2026 and pursue a career in academic neurosurgery, with continued research and work in healthcare innovation and global neurosurgery.