Neurosurgery and Global Health

Isabelle M. Germano
Editor

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In memory of all neurosurgeons worldwide who dedicated and sacrificed their lives while caring for their patients during the COVID-19 pandemic.

Preface

My passion for and dedication to neurosurgery education throughout my career have given me the opportunity to meet with many dedicated and brilliant neurosurgeons around the world. This was accentuated during the past 4 years when I served as the chair of the Education and Training Committee for the World Federation of Neurosurgical Societies (WFNS), a nonprofit, non-governmental organization representing 119 national neurosurgical societies worldwide. During this journey, I recognized that the similarities of our neurosurgical experiences were far greater than the differences. Regardless of the geographical context, the common goal of the neurosurgeons I was working with was to better understand our field and, by so doing, to better serve our patients. Scientific curiosity, deep dedication, incredible work ethics, entrepreneurship, and creativity were common traits among neurosurgeons around the world, and not the exception. Finally, I sensed a common theme that transcended geographical boundaries: the desire to collaborate and exchange ideas and experiences.

To continue the journey we started in the field, while setting up training course and lectures, I envisioned creating a project that would bring us together and perhaps could build a foundation for future collaboration, not just among ourselves but with all the trainees we have in common. Therefore, I decided to create this book with more than 150 authors spanning all 5 continents. I encouraged the lead author of each chapter to find collaborators from each of the five continents. This had a doubly positive net effect. First, the chapter is seen and rendered through multiple lenses and therefore most likely to be more representative of reality. Second, the opportunity to write together started or fostered continued collaborative efforts.

The book opens with an excursive on the role of neurosurgery in worldwide health care. This chapter touches on disparities and proposes strategies and opportunities to overcome them. The history of neurosurgery is then briefly reviewed. The many areas pioneered and developed by neurosurgeons are extraordinary. The overarching theme over the years was to develop new, more effective high-end solutions for complex diseases and to provide access to neurosurgical services for all patients.

In developing the structure for this book, I had in mind the needs of several groups of readers. The first group was those readers who question why neurosurgery

should be part of global health. For that group, We created chapters to provide a concise descriptive account of what neurosurgery is all about. In so doing, it became evident that it was not going to be an easy task. Neurosurgery has expanded to cover many sub-specialties. Additionally, it touches on other fields like disaster response, ethics, quality, and safety of care.

The second group of readers to whom I have striven to cater are those who are already familiar with the multifaceted aspects of neurosurgery but have a desire to learn how future neurosurgeons are trained around the world. Current literature on this topic is scant.

My third audience was those neurosurgeons who, like myself, focused on the art and the science of medicine during medical school. Many have mastered technical expertise, pushed the boundaries of discovery, and developed new treatment paradigms. Yet, many were not given the tools to integrate the art and science with the economic forces influencing our work. Hence, I designed the third part of the book to highlight some of the economic aspects of neurosurgery.

This book was written when the COVID-19 pandemic first started. Without a doubt, the pandemic has caused tremendous disruption in global neurosurgery. Yet I believe it has also caused us to unite as a global community and to harness collective efforts for positive changes. Many of the lessons learned during this time have contributed to our resilience and preparedness for the future; some of the changes might even have pushed our neurosurgery boundaries to places where we wouldn't have been without it.

New York, NY, USA Isabelle M. Germano

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Part I
The Role of Neurosurgery in Global Health

Isabelle M. Germano

Global health has been defined as the area of study, research, and practice that places a priority on improving health by prevention and clinical care and achieving equity in health for all people worldwide. The concept of global health is one that includes all involved, as opposed to the term "international health" which usually excludes one's own country, is less inclusive, and possibly adds a connotation of paternalism/colonialism. The main focus of global health has evolved over the years to include not just infectious diseases, such as influenza, tuberculosis, yellow fever, cholera, AIDS, and more recently Covid-19, but to include chronic diseases or conditions such as obesity and diabetes that have become prominent global health issues as well. Additionally, global health is taking into account issues that transcend borders such as climate change, urbanization, health equity, social justice, and income disparity, to mention a few. Global health also focuses on "public health" issues, defined as the actions a community takes to ensure that members of that community can remain healthy (prevention). A few examples of public health-related projects include vaccination programs, fluoridation of drinking water, improved family planning, reduction in the rate of occupational injury, and greater motor vehicle safety.

Why should global health matter to everyone, everywhere? For some, improving health globally is just "*the right thing to do*." For others, improving global health is important because it *potentially* leads to *incredible worldwide economic growth*. Vaccination is a prime example of this. Before the Covid-19 pandemic, between 2010 and 2015, vaccines prevented at least 10 million deaths worldwide. The more people who receive vaccinations, the less likely a disease will spread. As a global community, if our neighbors do not have what they need to prevent and treat diseases, it puts everyone at greater risk. The opposite is also true; when everyone can access health care, we are all better able to combat diseases, which in turn increases worldwide productivity.

Neurosurgery is among the youngest of the surgical disciplines. Although evidence of skull trepanation dates back to over two million years ago [1, 2], it is not until the late nineteenth century, when anesthesia, antisepsis, and hemostasis became available, that our field expanded. It continues to expand. Recent technological advances rapidly progress, to the point that inoperable tumors and pathologies once

thought to be incurable are successfully managed and corrected by neurosurgeons. Neurosurgery is considered a tertiary care specialty, meaning that patients being treated require a high level of care that is dependent on highly specialized physicians and equipment. In turn, this typically implies a higher financial cost to the hospital/institution where the neurosurgery procedures occur and higher cost to the patient receiving the care/their insurance intermediary. This assumption is only partially true, as many basic neurosurgical procedures are life-saving procedures and do not depend on equipment more sophisticated than some of the other surgeries. Recognizing the importance of neurosurgery within the basics of global health has propelled neurosurgery to become an active voice in global health in recent years.

In 2015, the Lancet Commission on Global Surgery provided global needs-based evidence pushing global surgery into the field of global health [3, 4]. In this seminal article, the dire need for global surgery is reviewed, showing the vast inequities present in global access to safe, affordable quality surgery. This called for a global response. Since then, projects and interventions have continued to expand and flourish, with many innovative and impactful approaches developed worldwide, some of which include neurosurgery. The focus of neurosurgery within global health is that of prioritizing improving the health outcomes and achieving health equity worldwide for all people who are affected by neurosurgical conditions or have a need for neurosurgical care.

This Part of the book provides a thorough understanding of the role of neurosurgery in global health in each of the subspecialties. Over 27 million people are estimated to sustain traumatic brain injury (TBI) every year. Chapter 3 highlights specific issues faced in low-resource settings and proposes strategies on how this can be resolved, including an exciting new methodology to improve care for patients suffering from TBI.

Chapter 4 highlights the importance of pediatric neurosurgery in providing services to the children of the world. Current projections show that the global population will be 8 billion by 2025 and the next billion global inhabitants will still be children by then. Over 90% of them will be born in low and intermediate income (LMIC). Better quality neurosurgical care to pediatric patients can be provided through the rapid advances in technology and surgical techniques.

The burden of cerebrovascular diseases (CVD) continues to rise in LMIC. Eighty percent of all CVD-related deaths occur in LMIC, yet the amount of global health spending on noncommunicable disease prevention and treatment remains disproportionately low when compared to the global burden of these diseases. Chapter 5 reviews how the field of cerebral vascular neurosurgery has evolved over recent years to position neurosurgery as a key player for the care of CVD.

Over the past decade, neurosurgical oncology has made strides on each of the five continents. With an aging population and worldwide increased quality of healthcare delivery and resources, the burden of oncological diseases, including those affecting the brain and spine, is projected to increase over the next two decades. Chapter 6 develops concepts of the epidemiology of brain tumors and the

current cross-collaboration of national and international neurosurgical organizations focusing on these diseases to improve the field.

Whereas the vast majority of spine disorders do not require surgical intervention, surgical intervention, when indicated, can prevent lifelong disability. Patient selection is a key element in this field in ensuring a successful neurosurgical outcome. Chapter 7 reviews the role of spine neurosurgeons worldwide to create education for patients and physicians aimed at improving outcomes for patients with spine disorders.

Disability caused by tremor, epilepsy, depression, and central pain accounts for more worldwide disability than cancer, heart disease, or HIV-related disorders. Functional neurosurgeons address these important neurological diseases using precision surgery and novel technologies to restore network disorders. Chapter 8 reviews the past and present of this multifaceted subspecialty within neurosurgery and provides exciting views on its future directions.

Both natural and man-made mass casualty events, known as disasters, result in hundreds of thousands of deaths each year. Neurosurgery can play an important role in the humanitarian response to mass casualty disasters. Chapter 9 reviews the critical role of neurosurgeons in disaster response. This is primarily focused on head and spine trauma; however, it expands to other aspects as well.

Poorly coordinated efforts in healthcare delivery and medical errors contribute to increased patient mortality, decreased patient satisfaction, and increased cost in all medical fields including neurosurgery. With its complex nature, neurosurgery is deeply associated with a very slim margin for error and a very high potential for life adverse events. Chapter 10 reviews the key facts on safety and their impact on medical care within neurosurgery, including future opportunities to further enhance quality and safety of neurosurgery patients worldwide.

Medical ethics is a fundamental element at the core of our daily medical practice, regardless of our specialty and/or where we practice in the world. Chapter 11 highlights some of the ethical considerations common to all neurosurgeons worldwide. These include the concept of mental capacity, and the fine line between innovation, clinical research, conflict of interest and the many other gray areas present in the bioethical landscape.

Over the past century, neurosurgery has made significant progress in each of the subspecialties that today allow us to provide care for a broader number of neurological disorders worldwide. Chapter 12 reviews efforts necessary to further raise the standard of neurosurgical care across the globe. These include not only volunteerism, but also creating sustainable, self-sufficient, neurosurgical global infrastructures.

In conclusion, our field spans an incredibly wide range of techniques and technologies focused on caring for an expanding number of patients with neurological and other disorders currently accounting for a large burden of global diseases. Neurosurgeons remain passionate about their work. We envision that the increased desire to collaborate and to build infrastructure to care for patients with neurological disorders will result in improved care worldwide.

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Chapter 1
The Role of Neurosurgery in Worldwide Health Care and Its Disparities: An Overview

Franco Servadei and Ismail Zaed

Abbreviations

HIC	High-income country
ICP	Intracranial pressure
LMIC	Low- or middle-income country
RCT	Randomized clinical trial
RTA	Road traffic accidents
SCI	Spinal cord injury
TBI	Traumatic brain injury
WFNS	World Federation of Neurosurgical Societies

Neurosurgery is a relatively new branch of surgery that became an independent specialty in the large majority of countries only after World War II. Despite being a specialty field within surgery that cares for a relatively small percentage of patients, neurosurgery plays an important role globally in reducing the overall burden of diseases. This is particularly true in countries with limited resources, also known as low-and middle-income countries (LMICs).

Neurosurgery is increasingly important in global health because, *when both neurosurgical and anesthesiology services are available*, a significant number of common conditions can be effectively treated or eliminated by neurosurgical interventions (Table 1.1). For example, traumatic brain injury (TBI) has been

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Table 1.1 The impact of neurosurgical interventions on health care

Neurosurgical intervention	Health-care impact
Traumatic brain injury (TBI)	TBI is the first cause of death and disability in multi-trauma patient
Spinal cord injury (SCI)	SCI remains the first cause of long-term disability in the young population
Pediatric neurosurgery	In 40 African countries where over 50% of the population is below the age of 20 years, many curable diseases in children are related to our specialty
Brain tumors	A large part of intracranial tumors are benign and can be cured by surgery
Cerebrovascular (CV) diseases	CV diseases remain a top cause of death worldwide and can be treated minimally invasively
Movement/psychiatric disorders and epilepsy	They are increasingly recognized as major causes of death and disability worldwide and can be treated minimally invasively
Degenerative spine conditions	They are increasingly recognized as major causes of disability worldwide and can be treated by neurosurgeons

reported to be the primary cause of death and disability in any multi-trauma patient. Spinal cord injuries (SCIs) remain the first cause of long-term disability in the young population, significantly impacting the national workforce. Spinal cord tumors and most of the other spine degenerative diseases are cared for by neurosurgeons all over the world. A large proportion of intracranial tumors are benign and can be cured with an appropriate surgical treatment. Finally, it is important to note that in 40 African countries, where over 50% of the population is below the age of 20 years [1], many curable diseases in children such as hydrocephalus, spina bifida, and myelomeningocele are successfully treated by neurosurgeons.

Neurosurgery has recently benefited from a general technological improvement that increased the armamentarium of neurosurgical options for the treatment of diseases. One example is the use of endoscopy for skull base tumors and stereotactic radiosurgery. Another is vascular neurosurgery that has made enormous scientific and technological progress; in collaboration with endovascular physicians, interventions are minimally invasive and provide successful outcomes. Functional neurosurgery has expanded its boundaries to play a primary role in the treatment of what were once considered to be classical "neurological" and "psychiatric" diseases, such as extrapyramidal disorders and obsessive-compulsive disorder.

According to a recent study about the neurosurgical workforce around the globe, there are currently around 50,000 neurosurgeons in the workforce. Their distribution among the world population is not homogeneous. In the majority of high-income countries (HICs), such as the USA, Canada, Australia, Japan, and Western European countries, the current ratio is 1 neurosurgeon per 100,000 inhabitants. However, in other parts of the world, particularly in Africa and Southeast Asia, there is a drastic lack of neurosurgical workforce, which results in the absence of urgently needed neurosurgical procedures [2]. Recent data show that globally approximately 5 billion people lack access to surgical care of any kind, leading to an estimated 16.9 million deaths annually that could potentially have been avoided [1]. These

disparities are particularly concentrated in LMICs, where nine out of ten people cannot access even the most basic surgical care [1].

Modern medicine is based on high-quality papers that generate evidence-based guidelines for everyday clinical activities. In this context, randomized clinical trials (RCTs) are critically important, since they provide the highest level of scientific evidence in clinical settings. Unfortunately, less than 9% of all RCTs in neurosurgery were performed in LMICs [3]. The situation is self-explanatory when RCTs focused on neurotrauma are considered. There are currently two published RCTs on the topic of cranial decompression. In the DECRA study, all of the patients were from HICs [4]. Similarly, in the RESCUE ICP study, about 91% of patients were from HICs [5]. Yet, the majority of TBI occur in LMICs, not in HICs, raising the question that such RCTs are not representative of and/or applicable to the global burden of TBI disease. There is disparity between countries with a high burden of TBI and those in which most of the research is conducted [6]. In the two RCTs mentioned above, the improvement in clinical outcomes observed in the surgical patients between 6 and 12 months after injury [4, 5] is most likely due to improvement in perioperative management of long-term complications. These include hydrocephalus, cranioplasty, sepsis, and a longer period of intensive rehabilitation. How many countries in the world have the appropriate infrastructure and/or the financial means to afford this?

Furthermore, these and other RCTs have generated evidence-based guidelines [7] which cannot be applied in many countries because of the absence of available resources. As an alternate approach, there is another process that can allow the so-called practical suggestions such as the consensus conference method. In this case, we can include in the process of consensus even non-class I or II papers coming from areas of the world where trauma is an endemic disease. We can also include experts from Africa, Southeast Asia, and Central America [8].

If we examine the publication input from LMICs, we can see how less than 5% of published papers in the neurosurgical literature come from these countries [9]. More specifically, in traumatic brain injury (TBI), almost 80% of published papers come from the USA and Europe [6], and similar data are reported in spinal cord injury [10]. In the same papers, it is reported that there is an inverse relationship between publications and the incidence of both head and spine trauma. This results in a paradoxical scenario, where we have very few scientific publications from the countries in which trauma is an endemic disease, whereas in countries where the incidence of trauma is decreasing, we have most of the published papers. This scientific gap is also increased by the important clinical differences in patient cohorts: whereas, in the "Western" countries such as Europe, the mean age of patients is over 60 years and the main cause of trauma is falls at home [11], in LMIC, patients are much younger, and the main cause of TBI is road traffic accidents (RTA) [12]. This difference is also reflected by the frequency and the diversity of post-traumatic hematomas: in Europe and the USA, patients experience mostly brain contusions and chronic subdural hematomas, whereas in LMICs, they typically sustain acute epidural and subdural hematomas. Besides all these differences, it should be pointed out that the large majority of state-of-the-art monitoring devices, like microdialysis,

pO2, and intracranial pressure (ICP), are not easily accessible in those countries. Given all these documented differences, how can we believe that the same suggestions for management can be applied everywhere?

Is it possible to improve this situation and decrease these disparities? Yes, but it will take concerted efforts consistently made on a number of fronts. First, we know it is possible to improve the number of neurosurgeons in areas with a limited workforce because of success we have already witnessed in some LMICs. Through a passion for training engendered by the World Federation of Neurosurgical Societies (WFNS) initiatives and by the increasing number of training programs in many universities, the number of neurosurgeons in sub-Saharan Africa increased five times over 18 years (79 in 1998, 369 in 2016), and the ratio decreased from one neurosurgeon/eight million (1998) to one neurosurgeon/two million (2018) [13].

In order to improve access and decrease disparities, we must also meet the equipment needs of LMIC neurosurgeons. Recent surveys [14, 15] have shown that there is a clear lack of diagnostic devices and surgical instruments (microscope, endoscope, neuro-navigation) in most parts of Africa and Southeast Asia. For example, MRI is available in only 30 to 60% of hospitals. A recent paper demonstrated that the delivery of surgical instruments in these countries is effective and improves patient outcomes [16]. We clearly have to improve this experience and can do so by dramatically increasing donations of instruments even from non-profit organizations.

In order to reduce disparities, we must also increase the number of publications in countries with limited facilities. A recent survey showed that one of the top priorities for young neurosurgeons in LMICs is clinical research and publications [17]. There are many examples of collaborations resulting in clinical research and surgical help between Western universities and LMIC institutions in neurosurgery. The list includes Tanzania and Cornell University, USA [18]; Uganda and Duke University, USA [19]; Cambodia and Harvard University, USA [20]; Indonesia and Humanitas University, Italy, and Cambridge University, UK [9]; and Zanzibar and Valencia University, Spain [21]. The good news is that these represent only very few examples of a large number of "twin" institutions' collaborations. In addition, the recently completed RESCUE-ASDH (*R*andomised *Evaluation* of *S*urgery with *C*raniectomy for patients *U*ndergoing *E*vacuation of *A*cute *S*ub*D*ural *H*aematoma) study [22] included LMIC centers in its randomized clinical studies. Even more important, neurosurgeons from these countries (including India, Malaysia, and Hong Kong) were included in well-organized consensus conferences which resulted in important practical recommendations recently done by the University of Cambridge and by the WFNS [8].

It is also critical that we explore and maximize the use of low-cost devices for advanced surgical approaches in countries with limited resources. The Malawi and the Chhabra shunts developed for the treatment of hydrocephalus are two examples of low-cost devices. Dr. Benjamin Warf has reported the success of endoscopic third ventriculostomy in Ugandan children with hydrocephalus, limiting the usage of the ventriculoperitoneal shunt [23, 24]. Even awake surgery for brain tumors has been shown to be feasible in poor-resource settings [25] as well as endoscopic approaches both for hydrocephalus and skull base tumors [26].

The arrival of the worldwide COVID-19 pandemic has severely stressed global health-care delivery and has starkly demonstrated the public health inequities that we all knew existed but often have largely ignored. It has sparked an unprecedented need to share information worldwide. This need to collaborate and share information, and even equipment, is critically important in neurosurgery.

The COVID-19 pandemic has shown globally how far we were from reality at the outset. The first mistake made by every single country and continent is that we all believed "We are different." We told ourselves "China is far away. COVID-19 will never cross oceans, we will protect ourselves; we are clever and prepared enough." WRONG! We told ourselves "The Italians have bad patient care and the population is old; therefore our mortality (in Spain, France, Belgium, UK) will never be like them." WRONG again: the mortality has been similar, if not higher. We said "We (in the USA, Brazil, Sweden) do not need to lock down; we are more clever. We will wait for mass immunization." WRONG! As we learned more about SARS-CoV-2, the pandemic experts in these countries all changed their minds. We told ourselves that the second wave will never arrive. Our current global situation shows how wrong we were about that assumption! Despite the development and distribution of vaccines, we remain in serious trouble worldwide, thanks in large part to individuals' resistance to common sense prevention methods such as masks and social distancing, to the development of viral variants, to governments lessening restrictions, and to general "COVID fatigue."

We also mistakenly told ourselves that neurosurgery will be preserved at any time, that we are indispensible for a large number of patients. Again we were WRONG. Our experience in Italy is such that in the most affected areas, like the city of Bergamo, for several weeks, neurosurgery was shut down and all neurosurgeons were sent to provide general care to COVID-19 patients [27].

Therefore, we have quickly reorganized patient evaluation and care to preserve at least some emergency activity [28]. The same situation happened in many other countries where the neurosurgical units were simply swept away by the COVID-19 tsunami. Surgical indications changed greatly overall. As an example, most of our non-tumoral and non-traumatic spine surgery disappeared from our operating lists, and even tumor surgery was re-formatted in this period [28, 29].

But we believe there are also positive messages from this disaster. We realized that we are NOT a separate body. Instead we are reminded we are doctors before becoming neurosurgeons. We learned how to deal with oxygen masks, how to intubate patients, and how to treat them properly. We showed that we are also able to quickly reorganize our services to provide neurosurgical emergency care with humility and a spirit of service in these difficult times [27]. We also found many ways of communicating without large or small meetings. We activated and became adept with webinars, teleconferences, etc. One positive effect was that many young neurosurgeons who could never travel to other continents for congresses are now exposed to the best possible teaching [29, 30]. We can and must continue to use these innovative communication methods to improve neurosurgery information access worldwide.

In conclusion, neurosurgery is a life-saving branch of surgery and an important part of neurosciences. To reach efficacy on a worldwide basis, we need strategies to reduce disparities between countries with more and countries with fewer resources. The COVID pandemic has taught us how to collaborate and how to find common solutions to a tremendous task. If we use the lessons learned, we can continue to make global progress to ensure increased access to safe and effective neurosurgery interventions in LMICs.

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Chapter 2
Historical Perspective: The History of Neurosurgery

Madjid Samii

Neurosurgery made a fascinating advancement in the last century. Its historical development, however, was somewhat slower than that of other surgical specialties due to the complexity of the central nervous system. Initial attempts to treat brain disease surgically have been related to high morbidity and mortality. Only the better understanding of brain structure and function localization and the introduction of antisepsis, anesthesia, and hemostasis at the end of the nineteenth century led to increased interest and rapid advancement in the field. The other line of development of neurosurgery was to distribute the acquired knowledge and make this highly specialized care available to all patients around the world.

Many prominent surgeons contributed to this advancement despite the initial rather frustrating results. Victor Horsley is considered the founder of modern neurological surgery. Fedor Krause was the first to study human cerebral cortex in detail and developed new operative approaches. Harvey Cushing – considered as the "father of modern neurosurgery" – contributed both with the introduction of new techniques and approaches, such as the application of silver clip and suction, but also laid the conceptual basis of neuro-oncology. The progress of neurosurgery was dependent to a large extent on and was influenced by the discoveries in allied fields [1]. The discovery of the X-rays by Wilhelm Roentgen in 1895 had a major impact in medicine. In 1901, Oppenheim applied the new technique to the skull (cranial rentgenology), and in 1918, Walter Dandy introduced the air ventriculography. The cerebral angiography, introduced by Moniz in the 1920s, allowed for more precise diagnosis and preoperative visualization of the pathological lesions in the brain, which was a prerequisite for more accurate planning of surgeries that did not rely anymore only on the symptoms of the patient. Still, the information from these studies only indirectly presented the brain tumors or lesions.

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