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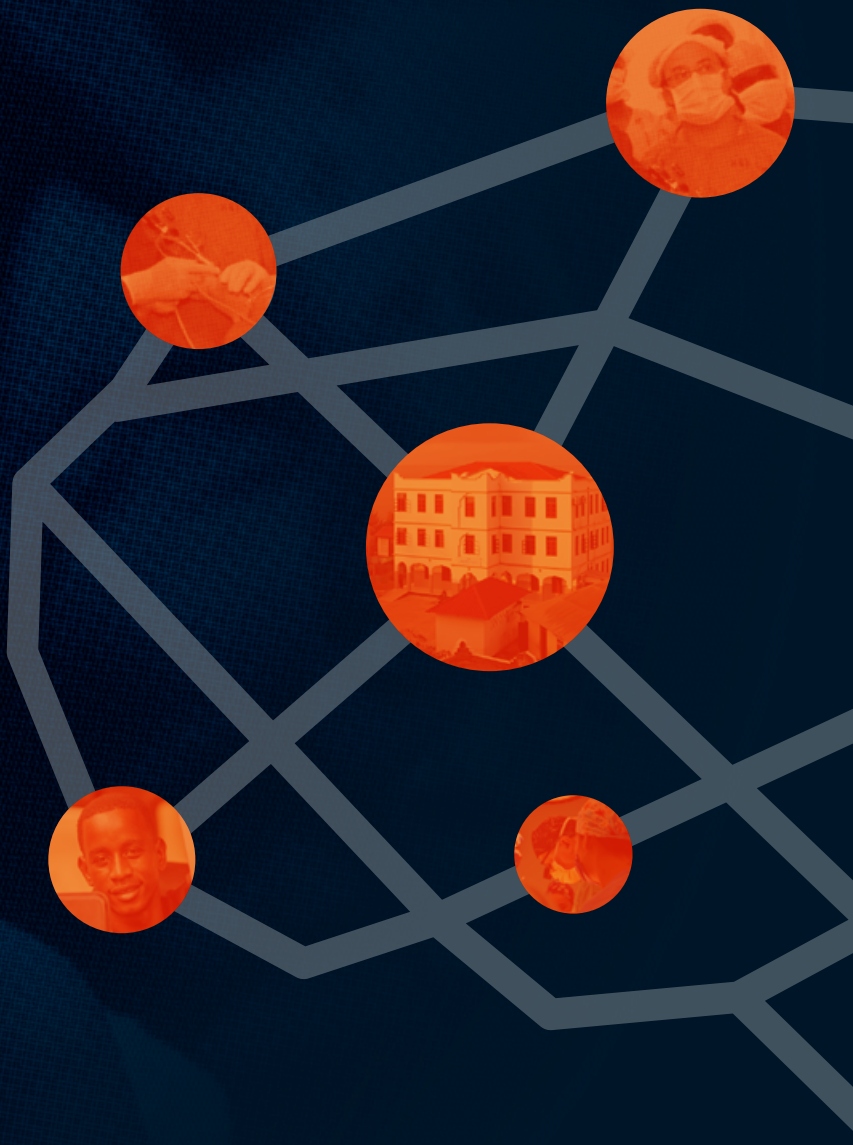
Global Neuroscience and Social Change:

A Model for Healthcare Cooperation



Authors:
Jose Piquer Martínez
María J. García-Rubio
Rubén Rodríguez Mena
Luis Moreno Oliveras
y Jose Piquer Belloch

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VIU-NED Chair in Global Neuroscience and Social Change.

The VIU-NED Chair in Global Neuroscience and Social Change aims to put neuroscience at the service of social change. To this end, it promotes research, teaching, and national and international cooperation in the field of global neuroscience. The Chair is a joint initiative of the International University of Valencia (VIU) and the Neurosurgery, Education and Development (NED) Foundation.

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Global neuroscience and social change:

A model for healthcare cooperation

Authors:
Jose Piquer Martínez[1,2] ✉,
María J. García-Rubio[1,3],
Rubén Rodríguez Mena [1,2,4]
Luis Moreno Oliveras [1,2,5]
y **Jose Piquer Belloch**[1,2,4],

[1] VIU-NED Chair in Global Neuroscience and Social Change. Valencia, Spain.

[2] NED Foundation. Valencia, Spain.

[3] Faculty of Health Sciences of the International University of Valencia. Valencia, Spain.

[4] Neurosurgery Department, Hospital de la Ribera. Valencia, Spain.

[5] Nursing Service of Hospital de la Ribera. Valencia, Spain.

✉ Main author:
catedra.neurociencia@campusviu.es

Content

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List of acronyms and abbreviations

DALY: Disability-Adjusted Life Year
BRAIN: Brain Research through Advancing Innovative Neurotechnologies
COSECSA: College of Surgeons of East, Central and Southern Africa
DALYs: Disability-Adjusted Life Years
ETE: Equip, Treat, and Educate
FEDACE: Spanish Federation of Cerebral Damage
FENS: Federation of European Neuroscience Societies
HBP: Human Brain Project
NED: Neurosurgery, Education, Development
WHO: World Health Organization
GNI: Gross National Income
AIDS: Acquired Immune Deficiency Syndrome
TBI: Traumatic Brain Injury
ICU: Intensive Care Unit
HIV: Human Immunodeficiency Virus
VIU: Valencian International University
YLD: Years Lived with Disability
YLL: Years of Life Lost

Summary

/ Structure of the report

Neuroscience is revolutionizing medicine today. Over the past decade, billions have been spent to better understand how the human brain works and why it fails when it gets sick. This research is not only expanding our knowledge, but has the potential to transform the prevention and treatment of many diseases. Yet millions of people around the world are unable to benefit from these advances. There are profound inequalities in the resources that countries can devote to addressing these diseases. Moreover, not all healthcare systems are prepared to address the neurological problems of their populations, especially those living in low-income countries.

The good news is that we know how to transform these conditions. In most cases, it is not a problem of knowledge but of will, capacity and resources. This report highlights the role of global neuroscience in promoting social change in the field of health. In line with similar efforts in global health, specialists, organizations, and donors are working to extend the opportunities provided by neuroscience to the most disadvantaged populations. Everyone should benefit from these opportunities, regardless of where they live.

In this paper we present a model for healthcare cooperation that has improved a low-resource healthcare system based on the development of neurosurgery. This model was conceived by the Neurosurgery, Education and Development (NED) foundation and has guided interventions in the field of medical infrastructure, clinical care, and the education of health personnel in the Zanzibar archipelago (Tanzania). These interventions have focused on Equipping, Treating, and Educating (ETE) at the same time and have involved a variety of specialists from neurosurgeons to neuropsychologists, anesthesiologists, and neurorehabilitation specialists.

This model can be relevant to any organization interested in health development and social change, beyond the development of any specific medical specialty. We have the opportunity to respond to needs that have been historically neglected. And we now have the experience and knowledge to improve the health of millions of people. We are convinced that if more people and organizations work together, we can achieve this goal sooner.

The report is divided into three parts. The first part identifies the scope of global neuroscience, defines what we mean by social change and shows the relationship between the two concepts. Although social change is associated with processes of different nature, all these processes share the same objective: the transformation of the conditions in which a society lives through actions aimed at improving reality. Here we identify different types of health interventions with the potential for social impact in several areas: (1) research, (2) healthcare, (3) knowledge transfer, (4) outreach and (5) public policy.

The second part of the report emphasizes an area that has been historically neglected: the development of (neuro)surgery in low-resource countries. Historically, global health policies have focused on the prevention, treatment, and eradication of specific diseases. But these policies have overlooked the development of surgical and anesthesia services in low-resource countries, an essential component of any healthcare system. Today, more than 5 billion people in the world are unable to receive quality surgical care.

This part presents evidence on global inequalities in terms of access to surgical treatment and specialists. Sub-Saharan Africa is the region in greatest need of specialized medical care, such as neurosurgery. We therefore advocate prioritizing global (neuro)surgery through joint interventions between local governments and multilateral and philanthropic organizations. This investment saves lives, prevents disability, and promotes economic growth.

Finally, the last part presents a model that makes it possible to offer better treatment to more people. In this section we explain the NED model for healthcare cooperation in detail. We argue that cooperation in this field should aim to Equip, Treat, and Educate (ETE) at the same time. And we show how this has been done in the specific case of the Zanzibar archipelago.

Over the course of more than a decade, these interventions have made it possible to treat thousands of patients, train dozens of local healthcare professionals and equip the first neurosurgical institute in Zanzibar. In addition, through the promotion of international volunteering, hundreds of professionals have worked towards a common goal. This experience has put faces and names to unknown realities.
In many cases, it has also served to improve people's lives. For all these reasons, we want to highlight the transforming potential of cooperation in our societies.

“ANYONE SHOULD BENEFIT FROM THE OPPORTUNITIES OFFERED BY NEUROSCIENCE”

AUTHOR: AÑAÑOS, NED VOLUNTEER

Main messages

"ANYONE SHOULD BENEFIT FROM THE OPPORTUNITIES OFFERED BY NEUROSCIENCE. That is why global neuroscience is bringing together specialists from different areas of neuroscience to extend these opportunities to the most disadvantaged populations."

"SOCIAL CHANGE TRANSFORMS THE CONDITIONS IN WHICH A SOCIETY LIVES THROUGH ACTIONS AIMED AT IMPROVING REALITY. In the field of health and neuroscience, many interventions can improve our quality of life. For example, through research, better treatments, knowledge transfer and the formulation of evidence-based public policies."

"IN RECENT YEARS WE HAVE SEEN GREAT ADVANCES IN GLOBAL HEALTH, BUT THE SURGICAL NEEDS OF THE MOST DISADVANTAGED POPULATIONS HAVE BEEN NEGLECTED. In the past decade, only 3 out of every 100 operations were performed in the poorest countries, where 35% of the world's population lives. More than half of the operations were performed in rich countries, where less than 20% of the population lives."

"GLOBAL INEQUALITIES ARE GREATEST IN THE AREA OF SPECIALIZED MEDICAL-SURGICAL CARE SUCH AS NEUROSURGERY. The greatest understaffing is found in Africa, where less than 1% of practicing neurosurgeons work, despite the fact that the region accounts for 15% of the world's neurosurgical disease burden."

"DEVELOPING (NEURO)SURGERY WAS BELIEVED TO BE TOO EXPENSIVE. TODAY WE KNOW THAT SOME SURGICAL PROCEDURES ARE EQUALLY OR MORE COST-EFFECTIVE THAN COMMON PUBLIC HEALTH MEASURES. For example, treating hydrocephalus in low- and middle-income countries is more cost-effective than anti-retroviral therapy for HIV/AIDS or performing a cesarean delivery."

"DEVELOPING (NEURO)SURGERY SAVES LIVES, PREVENTS DISABILITY AND PROMOTES ECONOMIC GROWTH. Surgical services are a prerequisite in areas as diverse as cancer treatment, injury, infection, reproductive, maternal, neonatal and child health."

"THE SUSTAINABLE DEVELOPMENT GOALS WILL NOT BE ACHIEVED WITHOUT INVESTING IN GLOBAL SURGERY. According to The Lancet Commission on Global Surgery, it will be impossible to achieve the health targets set out in the 2030 Sustainable Development Goals without ensuring that surgical care is accessible, safe, timely and affordable."

"IMPROVING LOW-RESOURCE HEALTHCARE SETTINGS REQUIRES INVESTMENT IN INFRASTRUCTURE, MEDICAL CARE AND EDUCATION. That is why the NED model for healthcare cooperation proposes to Equip, Treat, and Educate at the same time. This contributes to a sustainable transformation of the system in the long term."

1 Global neuroscience and social change

1.1. Global neuroscience

1.2. Social change

1.3. Health and neuroscience interventions for social change

1. Global neuroscience and social change

In recent years, billions have been allocated to fund research in neuroscience. The discoveries associated with these studies have enabled us to better understand how the brain works and why it fails when it gets sick. In addition, neurological problems are becoming a public health priority for many governments. As a result, there is growing interest in investing in neuroscience.

Yet the global picture is uneven. There are great inequalities in the resources that countries devote to addressing these problems. Only a few countries concentrate most of the resources. As a result, populations in low-income countries are unable to benefit from many of the opportunities provided by neuroscience. This is why initiatives that are sensitive to this reality are becoming more necessary than ever.

Global neuroscience is bringing together the efforts of specialists from different disciplines to promote social change through transnational and intersectoral action. In this section, we define the concepts of global neuroscience and social change and show the relationships between them. In addition, we present a typology to explore the link between different health and neuroscience interventions and social change. This first part lays the conceptual foundation for the rest of the report.

1.1. Global neuroscience

In the last decade, neuroscience has expanded the frontiers of knowledge. For years it was believed, for example, that certain structures in our body had no obvious connection to each other. But recent discoveries suggest that some structures may be more tightly connected than we thought.

For instance, hundreds of publications have revealed that the microbiota could have profound effects on our brain health and be related to several neurodevelopmental disorders (Willyard, 2021). The key to better understanding these disorders could lie in the trillions of bacteria that populate our gut. But how would these microorganisms communicate with our brain? It is not entirely clear, although it is thought that it could be through the vagus nerve, the longest of the twelve cranial nerves. This nerve would act as a highway, carrying some signals from the gut to the brain and from the brain to the gut (Kim et al., 2019 ; Svensson et al., 2015). This discovery is revolutionizing the design of new therapies to prevent and treat certain diseases (Barandouzi et al., 2020 ; Nikolova et al., 2021).

Another relevant example of these advances is the U.S. initiative Brain Research through Advancing Innovative Neurotechnologies (BRAIN). This project has set out to create a dynamic atlas of the brain that will show how individual cells and complex neural circuits interact in time and space for the first time. BRAIN has already been funded with $2.5 billion and is expected to reach $5.2 billion in funding by 2026. In the European Union (EU) alone, there are more than 44 scientific societies and 22,000 researchers working on neuroscience-related studies (FENS, 2022).

This has resulted in an exponential increase in related publications. Of the 396,428 articles published on science in the last 5 years in the Web of Science database, 21,531 have a link to some branch of neuroscience[1]. Research originating in different areas such as neurobiology, neurophysiology, neurosurgery, neurology, and neuropsychology have contributed to this boom. Contributions from various scientific disciplines and collaboration between multidisciplinary teams are key to the progress of neuroscience.

This progress has resulted in increased funding for research. A good example of this is the Human Brain Project (HBP), one of the largest research projects in Europe. This pioneering study is funded with more than 600 million euros and aims to gain an in-depth understanding of the complex structure and function of the human brain. This investment demonstrates the growing interest of governments in prioritizing this field of knowledge.

But this interest also has healthcare reasons. Neurological problems are becoming a public health priority. Stroke is already the leading cause of disability and the second leading cause of death in the world (WHO, 2019). And the impact of degenerative neurological diseases such as Alzheimer's has increased in older societies. If we know more about how the brain works, we will be able to prevent and treat these diseases better.

Globally, however, the picture is very uneven. There are profound inequalities in the resources that countries devote to addressing these problems. A few countries concentrate most of the resources, whether it be researchers, research funds or specialists to treat neurological diseases.

EU and the United States allocate billions to funding studies, while in Africa barely 8% of neuroscience research is funded locally (Maina et al., 2021). Japan currently has more than 8,000 certified neurosurgeons to serve a population of 125 million people (Miyamoto, 2021). In all of Africa, fewer than 2,000 neurosurgeons must meet the needs of more than 1.2 billion people.

These inequalities exacerbate other problems. For example, the lack of educational centers prevents the training of sufficient specialists in the countries where they are most needed. The transfer of knowledge in the form of patents, new drugs and treatments generally takes place in high-income countries. These opportunities take a long time to reach the poorest countries. This prevents their populations from benefiting from advances that could dramatically improve their quality of life. For all these reasons, initiatives that are sensitive to this reality are much needed.

Global neuroscience is bringing together the efforts of specialists from different branches of neuroscience to promote social change through transnational and intersectoral action.

In this sense, global neuroscience is bringing together the efforts of specialists from different branches of neuroscience to promote social change through transnational and intersectoral action. In line with similar efforts in global health, it is an area of study, research and practice whose main objective is to extend the opportunities provided by neuroscience to the most disadvantaged populations, whether at the level of knowledge, treatment, or training. Anyone should be able to benefit from these opportunities, regardless of where they live.

1 This exploratory search was performed using the terms 'Neuroscience' and 'Science' as topic in the Web of Science database on December 23, 2022.

GLOBAL NEUROSCIENCE

"AN AREA OF STUDY, RESEARCH AND PRACTICE WHOSE MAIN OBJECTIVE IS TO EXTEND THE OPPORTUNITIES PROVIDED BY NEUROSCIENCE TO THE MOST DISADVANTAGED POPULATIONS THROUGH TRANSNATIONAL AND INTERSECTORAL ACTION"

1.2. Social change

While health sciences and neuroscience have made great contributions to humanity, can we think of these contributions as generating social change? It is not an obvious association. We tend to relate social change to processes of a political, economic, or legal nature, such as the democratization of a country or the recognition of social rights. Think, for example, of the Spanish political transition or the civil rights movement of the African-American community in the United States.

Such diversity of examples suggests that social change is a broad concept, which makes it difficult to pin down. It is therefore necessary to define it in relation to more specific spheres of action. In our case, we associate these transformations with interventions originating in the field of health and neuroscience. The following section clarifies this relationship (1.3), but first we must ask ourselves whether all processes of social change share some features.

We believe they do. In general terms, social change has to do with the transformation of the conditions in which a society lives through actions aimed at achieving better outcomes, be it in terms of development, health standards or the recognition of rights[2] .

Social change has to do with the transformation of the conditions in which a society lives through actions aimed at achieving better outcomes.

The conditions that interventions aim to transform are related to the material, political, economic, or cultural reality of a society. To have a 'social' impact, these interventions must affect the life experience of a large and diverse number of people. Consequently, social change refers to our experiences as individuals living in a community.

Interventions that promote social change are defined as concrete actions aimed at improving reality. Simply because changing reality without intervening in it is more complicated. In some contexts, doing nothing can lead to change. But this is usually not the case.

Consider the international efforts to eradicate smallpox, one of the most devastating diseases known to mankind. WHO declared the disease officially eradicated in 1980. But this achievement was only possible after several decades of immunization and prevention campaigns (WHO, 2010).

2 In relation to this concept, the 'valence' of the change is a relevant aspect. Change can be positive or negative. Here we focus on 'positive' social change; that is, on those transformations that result in an improvement of existing conditions. We understand that change processes can also have 'negative' consequences. But this dimension is outside the proposed conceptualization

Recall too how social perceptions of mental health have changed. We have gone from confining people to asylums -often in deplorable conditions- to offering more humane, integrative, and adapted solutions to different mental disorders[3]. In short, change is often preceded by specific interventions that aim to transform the conditions in which we live.

In the field of health and neuroscience, many interventions are aimed at improving the healthcare services received by a population or a group; for example, children, women, or people suffering from a certain disease. But there are very different ways of intervening in reality. How can all these interventions contribute to social change?

1.3. Health and Neuroscience interventions for social change

In this section, we present a typology that helps us bring order to the diversity of possible interventions and explore their relationship with social change (Table 1). This typology identifies interventions in five areas: (1) research, (2) healthcare, (3) knowledge transfer, (4) outreach and (5) public policy. Although related, these areas are sufficiently delimited from one and other to stand on their own. In addition, we pinpoint interventions of different types (or modalities) in each area. The typology highlights the following interventions:

- First of all, **scientific research** is a relevant field of action, given that many interventions have their origin in research findings. Research can be basic, in that the main goals are to gain information and improve our understanding of a given object of study; for example, studying stem cell activation in an adult brain (Li et al., 2022). Or it can be applied, if the goal of the research is to find a solution to a given problem and apply it in a clinical context; for example, to develop ways to prevent cognitive decline in Alzheimer's patients based on a better understanding of the pathogenesis of the disease (see, for example, Cuchillo-Ibañez et al., 2021).

- In the field of **healthcare**, it is useful to distinguish between ***clinical*** interventions intended, for example, for the care of vulnerable groups and those interventions that require surgery and involve operating room specialties such as ***surgery***, nursing, or anesthesia.

  This distinction is particularly relevant when interventions are performed in low-resource health systems. Today billions of people remain without access to basic surgical care, as we discuss in more detail in the second part of the report. Many of the diseases associated with poverty require surgical treatment. In contexts of extreme need and few resources, "surgical-type care interventions have enormous potential to reduce suffering, prolong life, and restore health and economic productivity to the sick and injured" (Schecter and Adhikari, 2015, p. 353).

- As for interventions linked to **knowledge transfer**, the main objective is to share with society the resources that did not exist before, or that were only available to a small number of people and entities. In this area, the typology distinguishes between actions aimed at developing new products, ***services*** and ***training*** actions. We can identify interventions with social value for all three types.

3 In the Spanish context, this was possible thanks to the psychiatric reform. This reform promoted the General Health Law of 1986 which recognized the right of people with a mental disorder to receive treatment in the community setting, as well as access to the necessary services for rehabilitation and social reintegration.

Typically, the transfer of knowledge from the laboratory to the rest of society occurs through the development of a new good or product (e.g., a drug). This drug could serve, for example, to treat previously untreatable diseases such as multiple sclerosis. This knowledge transfer can also culminate in the development of a service, rather than a good. For example, in the form of improved therapeutic strategies[4] . In both cases we would be dealing with interventions with the capacity to improve the living conditions of many people.

But knowledge transfer can go beyond a service or a product. The typology highlights those interventions aimed at training professionals. These interventions have a high social and economic value. In particular, if they are developed in contexts where there is a great need to employ qualified professionals but in which training opportunities are limited.

In these circumstances, modest interventions can have a large societal impact. For example, training a new neurosurgeon in Japan -the country with the highest density of neurosurgeons per capita in the world- will not change the health care that Japanese people receive. But doing so in Sierra Leone may be the difference between life or death for hundreds of people with a neurological diagnosis (Piquer and Garcia-Rubio, 2022).

- In the area of **outreach**, awareness-raising actions can contribute to the promotion of social change. Particularly valuable are those interventions that seek to influence public debate through campaigns, publications, and public advocacy actions; for example, to combat the social stigma associated with mental illness (Community of Madrid, 2020).

- Finally, **public policies** are an area of action with great transformative potential. Public policies can create the necessary conditions to improve the well-being, care, and social integration of specific social groups. They can also serve to remove the barriers that hinder these objectives, as in the case of social perceptions of mental health mentioned above.

  The spectrum of possible actions in this area is immense. However, it is important that any intervention program uses the best available evidence and is supported by experts in the field. For example, in case a government wants to develop a new program for neurodiversity inclusion in school classrooms.

4 A good example would be the approval of an intervention protocol for the neuro-rehabilitation of children with brain damage in the educational setting (FEDACE, 2021).

TABLE 1. *Interventions for social change: A typology*

AREA	TYPE	EXAMPLES
Research	Basic	Study on the activation of adult brain stem cells (Li et al., 2022)
	Applied	Discovery of a protein that protects the brain from Alzheimer's disease (Cuchillo-Ibañez et al., 2021)
Healthcare	Clinic	Evaluation and diagnosis of neuropathologies in vulnerable populations
	Surgical	Surgical treatment of pediatric hydrocephalus in low-income settings
Knowledge transfer	Product	New drug for the treatment of severe-stage multiple sclerosis in young adults
	Service	New stimulation protocol for early intervention in children with autism
	Training	Training program for health specialists in low-resource healthcare systems
Outreach	Public awareness	Media campaign to combat the social stigma associated with mental illness
Public policies	Evidence-based programs	New program for the inclusion of neurodiversity in school classrooms

AUTHOR: NED FUNDATION

2 Global Health and (Neuro) surgery in low-resource countries

2. Global Health and (Neuro)surgery in low-resource countries

Global health has dramatically improved in recent decades. However, it is estimated that more than 5 billion people worldwide are still unable to receive quality surgical care (Alkire et al., 2015). This lack of access to surgical treatment prevents millions of people from living healthier and more productive lives, especially in low-income countries.

Lack of access to surgical treatment prevents millions of people from living healthier and more productive lives, especially in low-income countries.

This must change. The good news is that we know how to do it. We can improve low-resource healthcare systems by developing both essential and specialized surgical services such as neurosurgery. These interventions should be aimed at building the necessary medical infrastructure, treating patients and training more local specialists. With the will of local governments and the support of multilateral and philanthropic organizations, health cooperation can promote long-term social change.

2.1. Global Surgery: The neglected need

In recent decades we have witnessed significant advances in the field of global health (WHO, 2022 a ; Vos et al., 2020). Smallpox was officially eradicated from the planet in 1980. Wild polio was eradicated in Africa in 2020, bringing the world closer to complete eradication of this disease (still endemic in Pakistan and Afghanistan). Today we have irrefutable evidence of lifesaving, effective and relatively inexpensive health interventions (Jamison et al., 2013 ; Remes et al., 2020).

For example, many parasitic diseases can be cured with a pill that costs less than a dollar. With the right logistics, these drugs can be quickly distributed to areas with a high incidence of these diseases. Malaria can also be prevented by using insecticide-treated bed nets. Thanks to such interventions, nearly 7 million malaria deaths have been averted worldwide since 2001 (WHO, 2022c) .

In addition, improved sanitation, hygiene and oral rehydration have been sufficient to reduce the number of diarrhea deaths among children under 5 years of age over the past two decades (WHO, 2022 c). We know that a bag of salt and sugar mixed with a liter of water can save hundreds of thousands of children (Bornstein, 2007, p. 248).

During this time, billions of dollars have been channeled into combating AIDS, malaria, and tuberculosis with positive results: the mortality rate for all three diseases has been declining. More recently, with the COVID-19 pandemic threatening global prosperity and putting the world's healthcare systems to the test, it has been possible to develop (and commercialize) more than 10 vaccines in record time[5] . We should celebrate these achievements. For they show that through long-term international efforts, sufficient funding and public attention, important changes can be achieved.

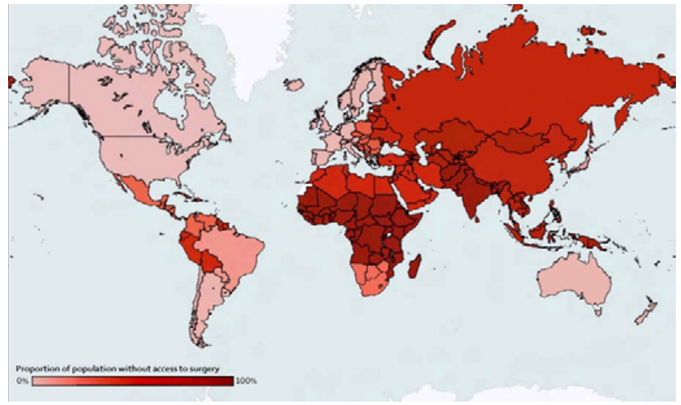
5 As of December 2022, there were 175 vaccines in clinical development and 199 in pre-clinical development (WHO, 2023).

At the same time, however, the surgical needs of the world's poorest people are being neglected. For too long, it has been difficult to find a place for surgery in global health policies that are more focused on combating specific diseases. This must change.

In 2015, coinciding with the end of the Millennium Development Goals adopted by the United Nations, an international commission of experts (The Lancet Commission on Global Surgery) published the first report on the state of surgery worldwide (Meara et al., 2015). This report revealed a previously unknown reality.

The analysis showed that more than half of the world's population - 5 billion people - did not have access to safe surgical and anesthesia care. This access is worse where it is most needed: **9 out of 10 people are unable to receive surgical care in low- and middle-income countries**[6]. In a majority of African countries, more than 90% of the population cannot receive reliable surgical and anesthesia care, as shown in Figure 1. Globally, this lack of access was causing almost three times as many deaths as HIV/AIDS, tuberculosis, and malaria (Meara et al., 2015 ; Park et al., 2016).

FIGURE 1. *World population without access to surgery (%)*



Note. Rretrieved and adapted from "Global access to surgical care: a modelling study" (p. e321), by B. C. Alkire et al, 2015, The Lancet *Global Health*, *3*(6). Darker areas indicate a higher proportion of people in the country without access to surgical care.

These data have revealed the magnitude of the problem and its unmet needs. In 2014 Jim Kim himself, then president of the World Bank, had already stated that "surgery is an indivisible and indispensable part of healthcare that can help millions of people lead healthier and more productive lives" (Kim (2014), cited in Meara et al., 2015, p. 57). And in 2015, the new Sustainable Development Goals opened an opportunity to incorporate surgical care into the global health paradigm resulting in the Global Surgery 2030 Initiative.

Surgical care is essential for the treatment of many conditions, from infectious, maternal, and neonatal diseases to injuries and cancer. Investing in the development of global surgery should be a priority for the international community. For this investment saves lives, prevents disability, and promotes economic growth.

6 The World Bank classifies the world's economies into four income groups: low, lower-middle, upper-middle and high. Low-income countries are those whose Gross National Income (GNI) per capita was equal to or less than $1,085 in 2021; lower-middle income economies are those with GNI per capita between $1,086 and $4,255; upper-middle income economies are those with GNI per capita between $4,256 and $13,205; and high-income economies have GNI per capita above $13,205.

GLOBAL SURGERY

““AN AREA OF STUDY, RESEARCH, PRACTICE, AND ADVOCACY THAT SEEKS TO IMPROVE HEALTH OUTCOMES AND ACHIEVE HEALTH EQUITY FOR ALL PEOPLE WHO NEED SURGICAL AND ANESTHESIA CARE, WITH A SPECIAL EMPHASIS ON UNDERSERVED POPULATIONS AND POPULATIONS IN CRISIS” (MEARA ET AL., 2015, P. 572)

Although we know the benefits, developing surgery in low-resource healthcare systems is not easy. Transforming these conditions requires vision, resources and a long-term commitment from governments, multilateral agencies and national and international entities involved in global health.

Building hospital capacity and training specialists in low- and middle-income countries is an enormous challenge, especially in specialties such as neurosurgery. The following section discusses this challenge and presents an overview of the current situation of global neurosurgery, the surgical specialty of neuroscience. The analysis highlights the situation in sub-Saharan Africa, the region with the greatest need for care and with the greatest shortage of specialists.

2.2. Global neurosurgery and inequality

Imagine you are riding your bicycle on your way to work. As you cross a crosswalk, a car hits you from behind and you fall to the ground. You hit your head hard. The impact causes an open skull fracture and a cut on your forehead. In any high-income country, you are likely to be receiving medical assistance within half an hour at the scene of the accident. An ambulance will then transport you to the nearest medical center or the one best prepared to treat you at that moment.

In countries with advanced healthcare systems, anyone with an open fracture should be seen in less than two hours in more than 80% of the national territory, one of the goals of the Global Surgery 2030 program. But the same accident can be a death sentence or lead to permanent disability in almost any rural area of sub-Saharan Africa.

To treat a traumatic brain injury such as this one, it is necessary to have a specialist who knows how to diagnose a possible brain injury. Imaging tests, including CT and MRI scans, would also be necessary to detect any possible hemorrhage that may require immediate surgical attention.

This is not an isolated case. Road traffic injuries are among the top ten causes of years of life lost due to illness, disability, or premature death in the world[7]. It is the leading cause in people between 10 and 50 years of age (see Table 2 of Vos et al., 2020). A total of 93% percent of road fatalities worldwide occur in low- and middle-income countries (WHO, 2022 b). Many of them would have needed urgent surgical care.

7 The disability-adjusted life year (DALY) is a measure of the overall burden of disease (Disability-adjusted life years, DALYs). One DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of years of life lost due to premature mortality (YLL) and years lived with a disability (YLD) due to prevalent cases of a disease or health condition in a population (Alvis and Valenzuela, 2010).

In the past decade, however, only 3 out of every 100 operations performed worldwide were in the poorest countries, where 35% of the world’s population lives. More than half of the operations were performed in rich countries, where less than 20% of the population lives (Mock et al., 2015, p. 8). Inequality is greater when it comes to problems requiring specialized surgery.

Each year, more than 22 million people suffer neurological disorders or injuries that warrant the assistance of a neurosurgeon. More than half of these people require surgery. Traumatic brain injuries, stroke-related conditions, tumors, hydrocephalus, and epilepsy account for the majority of essential neurosurgical care worldwide (Dewan et al., 2018).

The problem is that not all healthcare systems are prepared to address these needs (Piquer and Garcia-Rubio, 2022). In the specific case of neurosurgery, more than 20,000 additional neurosurgeons would be needed worldwide to meet the estimated volume of cases (Dewan et al., 2018). The largest understaffing is in Africa, where less than 1% of practicing neurosurgeons work, despite the region accounting for 15% of the world’s neurosurgical disease volume (Fuller et al., 2020). The latest estimates indicate that the number of specialists would need to increase by more than 1,700% just to meet the needs of the region!

On the African continent, regional disparities are enormous. Of the estimated 1,974 neurosurgeons working in Africa in 2020, a majority of specialists (73%) practiced in North Africa and South Africa[8]. The remaining specialists meet the neurosurgical needs of 48 countries. In East Africa, for example, the ratio of neurosurgeons per capita is 1 per 10 million people[9]. One country alone, South Africa, has more neurosurgeons than the entire East African or Central African regions.

When we analyze the data by country, the gap between urban and rural areas is also significant. Most specialists practice in the capital city. As a result, entire populations are unable to receive neurosurgical care. This pattern is repeated even in those countries where we have observed a moderate growth of specialists in recent years.

In Tanzania, for example, there were only 3 formally trained neurosurgeons in 2006. All were practicing in the capital, Dar es Salaam. A decade later the country had 9 licensed neurosurgeons: 6 working in the capital, 1 in private practice only, and another neurosurgeon who had moved to Botswana, an example of ‘brain drain’. Only 1 neurosurgeon practiced in Mwanza, outside the capital (Santos et al., 2021). Tanzania now has 20 neurosurgeons to serve a population of over 60 million people. But most continue to work in the capital.

These inequalities prevent hundreds of thousands of patients from accessing lifesaving and disability-preventing treatments. The pertinent question is why?

8 In 2020, 1,451 neurosurgeons were practicing in these countries. Egypt had the most neurosurgeons, followed by Algeria, Morocco, South Africa, and Nigeria; four countries and territories (Sao Tome and Principe, Seychelles, Sierra Leone, and Western Sahara) had no neurosurgeons (Ukachukwu, 2021).

9 As if in Spain a single neurosurgeon had to attend to the needs of the population of Madrid, Barcelona, Valencia, Seville, Zaragoza, Malaga, Murcia, Palma, Las Palmas de Gran Canaria, Bilbao, Alicante, and Cordoba.

A luxury for the poor?

Historically, international donors, public health experts and government officials have considered neurosurgery to be a luxury: too expensive and complex to be a public health priority. If there are basic needs in a country that are not covered -it is often argued- how are we going to develop neurosurgery? The implicit assumption is that it is not desirable to address a complex need before more basic needs have been addressed. Supposedly, when facing a patient with a brain tumor, we should ask ourselves: how are we going to operate on him if he only gets one meal a day, or why are we going to train neurosurgeons if some children are still dying of diarrhea?

It is often argued that developing surgery services, and neurosurgery in particular, is too expensive. Or to be precise, that the investment required is not 'cost-effective'[10]. The truth is that until recently we did not have sufficient evidence. But today we know that the development of essential surgical services is among the most cost-effective interventions in terms of economic and social returns. In fact, many surgical procedures are equally or more cost-effective than common public health measures such as vitamin supplementation or anti-retroviral therapy for HIV/AIDS (Mock et al., 2015, pp. 7-8).

The published results are similar when it comes to procedures specific to neurosurgical practice. Currently, treating hydrocephalus in low- and middle-income countries is more cost-effective than anti-retroviral therapy or performing a cesarean delivery (Meara et al., 2015, p. 596). Moreover, in resource-limited settings, innovation is providing creative solutions and helping reduce the costs of developing these services.

GLOBAL NEUROSURGERY

"AN AREA FOR STUDY, RESEARCH, PRACTICE, AND ADVOCACY THAT PLACES PRIORITY ON IMPROVING HEALTH OUTCOMES AND ACHIEVING HEALTH EQUITY FOR ALL PEOPLE WORLDWIDE WHO ARE AFFECTED BY NEUROSURGICAL CONDITIONS OR HAVE A NEED FOR NEUROSURGICAL CARE." (PARK ET AL., 2016)

The cost of an intervention is a relevant factor for decision-making. But it cannot be the only reason for prioritizing some interventions over others. There are, after all, moral reasons. The philosopher Peter Singer popularized the following argument: If it is in our power to prevent something bad from happening, without sacrificing anything of comparable moral importance for it, we should, morally, do so (Singer, 2017).

Faced with an obvious need, it seems reasonable to try to do something to improve the situation. Looking at it from this perspective, offering a possibility of treatment to a child with congenital hydrocephalus becomes (almost) a moral duty anywhere in the world, for we have the knowledge and the resources to do so. The last part of the report presents a model that can offer this possibility of treatment to more people.

10 Health economic evaluations quantify the differences between the resources devoted to alternative investments (or interventions) and the results obtained. It involves assessing how much of an aggregate measure of health - for example, death, disability or quality-adjusted life years (DALYs) - can be obtained from a given level of resources devoted to alternative interventions. This 'cost-effectiveness' analysis allows comparison of the attractiveness of interventions that address different health outcomes; for example, tuberculosis treatment versus cesarean section. This type of analysis predominates in economic evaluations of surgery and health interventions in general. Here we follow the definition and collect the results published in Devas et al. (2015).

3 Neurosurgery, Education and Development: The NED Model

3. Neurosurgery, Education and Development: The NED Model

In this section we present the experience of the NED Foundation in the development of neurosurgery in Zanzibar (Tanzania). We highlight the results obtained after more than a decade of health cooperation in the country. We then describe the model that has guided the various interventions over time (Leidinger et al., 2018a; Leidinger et al., 2018b).

The model is based on what we have called the Equip, Treat, and Educate (ETE) approach. To transform a low-resource healthcare system, it is necessary to intervene in all three areas at the same time: healthcare infrastructure, medical care for patients, and education of local professionals. Our model has helped develop neurosurgery in Zanzibar. But it may be useful for promoting other specialties in similar contexts. It may also be relevant to any organization interested in promoting social change in the field of health.

3.1. "Where there was nothing..."

In 2008, a team of volunteers from the NED Foundation traveled to the archipelago of Zanzibar (Tanzania)[11]. They were to work at the Mnazi Mmoja Hospital, the only referral hospital on the island[12]. Although operational since 1955, this hospital had never offered neurosurgical care to patients on the island. No local neurosurgeon had ever practiced in Zanzibar before.

An under-resourced hospital is not just a place where more people die than they should. It is a place where very little can be done to prevent it. It lacks staff, drugs, and time. And problems abound. Almost every day, the needs outstrip the capacity of the healthcare facility to cope. Until at some point the system collapses. When this collapse can be avoided, it is a matter of surviving -hopefully- another day.

> *An under-resourced hospital is not just a place where more people die than they should. It is a place where very little can be done to prevent it.*

In 2008, no newborn with hydrocephalus could be treated at the Mnazi Mmoja hospital. This possibility was reserved for those living on the mainland and only a few wealthy families could travel to get treatment. Most patients died before receiving neurosurgical care, especially if the need for care was urgent.

In 2008, for example, only 4 people with severe head trauma had been admitted to the hospital's precarious Intensive Care Unit (ICU). None of the patients had undergone surgery and none survived past the fifth day of admission. There were certainly many more trauma cases in Zanzibar that year. But no other patients were admitted to the ICU. Probably because there was no admission protocol and no staff experienced in the management of head trauma. Many more people died that year than should have. Little could have been done to prevent it.

11 This initial group of volunteers consisted of neurosurgeons Paul. H. Young (USA), Mahmood M. Qureshi (Kenya), José Piquer (Spain) and nurse Toni Gómez (Spain).

12 Tanzania has been considered a low-income country by the World Bank until July 2020, when it formally became a lower-middle-income country.

Upon arrival at Mnazi Mmoja, the only instrument the NED volunteers found was a valve introducer or tunneler like the one pictured (Figure 2). Everything else had to be provided through donations. Despite this, the NED team cared for as many patients as they could, taught local health workers how to perform some simple procedures, and donated the equipment they had managed to transport to the island.

FIGURE 2. *Only instrumentation for ventricular catheter placement at Mnazi Mmoja Hospital in Zanzibar (2008)*

After this first trip, things began to change. The local health authorities asked the foundation to go further. They needed to develop long-term neurosurgery. The challenge was enormous. For this task required creating the necessary infrastructure to provide medical care to patients and to train local healthcare professionals.

The development of (neuro)surgery requires investment in each of the interdependent components of a healthcare system. Anesthesiologists, operating room staff, biomedical engineers, critical care services, and nursing staff need to collaborate closely with surgeons from various specialties (Park et al., 2016).

Initially, the most viable option was the organization of short-term surgical missions carried out by volunteers. In parallel, the foundation adapted technology available in European hospitals to work in centers that did not yet have the appropriate infrastructure. Thus, volunteers operated with a portable neuroendoscope (such as the one shown in Figure 3) that allowed them to attend patients without the need to have this technology locally (Piquer et al., 2015). At the same time, they could start training local professionals using a high-impact surgical technique. This is a good example of innovation and adaptation to the local context (Piquer et al., 2010 ; Qureshi et al., 2013; Qureshi and Piquer, 2009).

3a) *3b)* *3c)*

FIGURE 3. *Portable neuroendoscope used in the surgical missions of the NED foundation.*

Note. *3a:* Mobile endoscopy unit adapted by the NED Foundation. *3b:* Surgical mission of the foundation using the portable endoscope. *3c:* NED foundation surgeons teaching neuroendoscopy to local surgeons.

NED Institute in Zanzibar

Starting in 2013, the foundation scaled up its interventions. By then it had been shown that specialty hospitals are one of the most effective options for specialty care in low-resource systems (Mock et al., 2015, p. 8). These hospitals are more sustainable if they are established together with physicians living and working in the country. This makes it possible to promote training and ensure adequate postoperative care. Over time, these centers evolve to be run entirely by local professionals.

With this goal in mind, in 2014 the foundation funded the construction of the first neurosurgical monographic institute, known as the NED Institute (Figure 4B). This building was constructed within the Mnazi Mmoja hospital compound (Figure 4A) but was given sufficient autonomy to hire its own staff and function as a specialty center.

The general maintenance and equipment of the building became the joint responsibility of the hospital administration, under the Zanzibar Ministry of Health, and the foundation. From the very beginning, the local staff were involved in the project. This made it possible to learn about the most prevalent pathologies and to have a fluid relationship with all the local partners.

Initially, two physicians received accelerated training to deal with neurosurgical emergencies and simpler surgeries. Progressively, the training of the professionals and the equipment of the center was advanced by levels, as explained by the model we present in the next section.
In 2018, the NED Institute was accredited by the College of Surgeons of Eastern, Central and Southern Africa (in English, COSECSA) for the training of neurosurgical specialist residents. The first female neurosurgical resident in the history of Zanzibar, Dr. Mulhati Abdalla, is currently training.

There are places that change a lot in a short time. In 2017, 90% of trauma surgeries had been performed by local physicians at the NED Institute.

FIGURE 4. *NED Institute in Zanzibar*

Note. Land where the NED Institute was built in Zanzibar. 4b: NED Institute today within the grounds of the Mnazi Mmoja Hospital.

In 2022, 113 patients were admitted to Mnazi Mmoja with a diagnosis of severe TBI. Of these patients, 70 were admitted to the ICU and 47 of them underwent surgery. As of November 2022, 2,817 neurosurgical procedures have been performed at the hospital (Figure 5a) and more than 30,000 patients have been seen in consultation (Figure 5b). More than 1,000 volunteers have contributed to this work at the NED Institute.

Milestones achieved and impact

2008 First neurosurgical missions to the Mnazi Mmoja Hospital of Zanzibar

2014 Inauguration of the NED Institute

2018 Accreditation of the NED Institute to train specialists in neurosurgery.

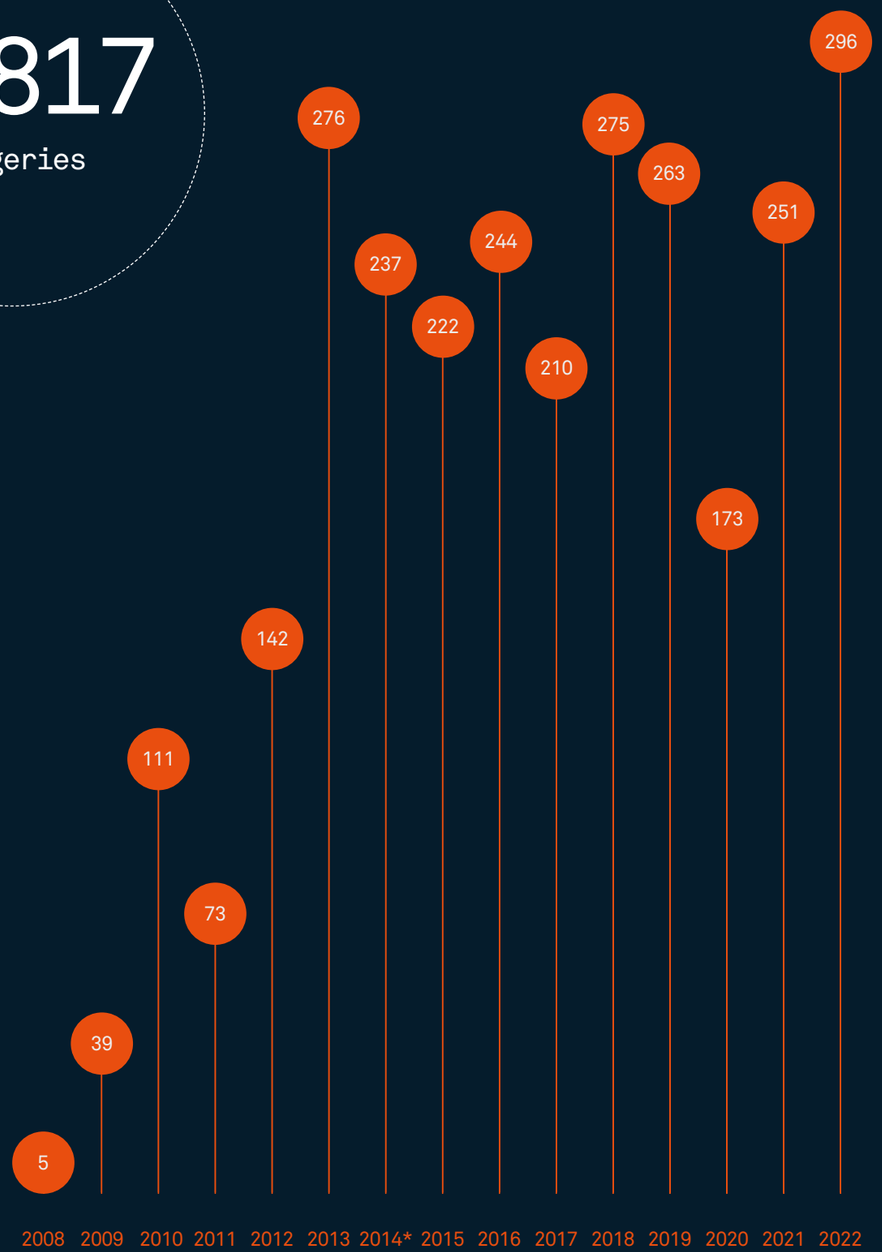
2022 + 2.800 surgeries performed
+ 30.000 medical consultation
+1.000 volunteers

FIGURE 5. *Number of patients undergoing surgery and consultation from 2008 to 2022*

a) Number of patients operated per year

2.817
surgeries

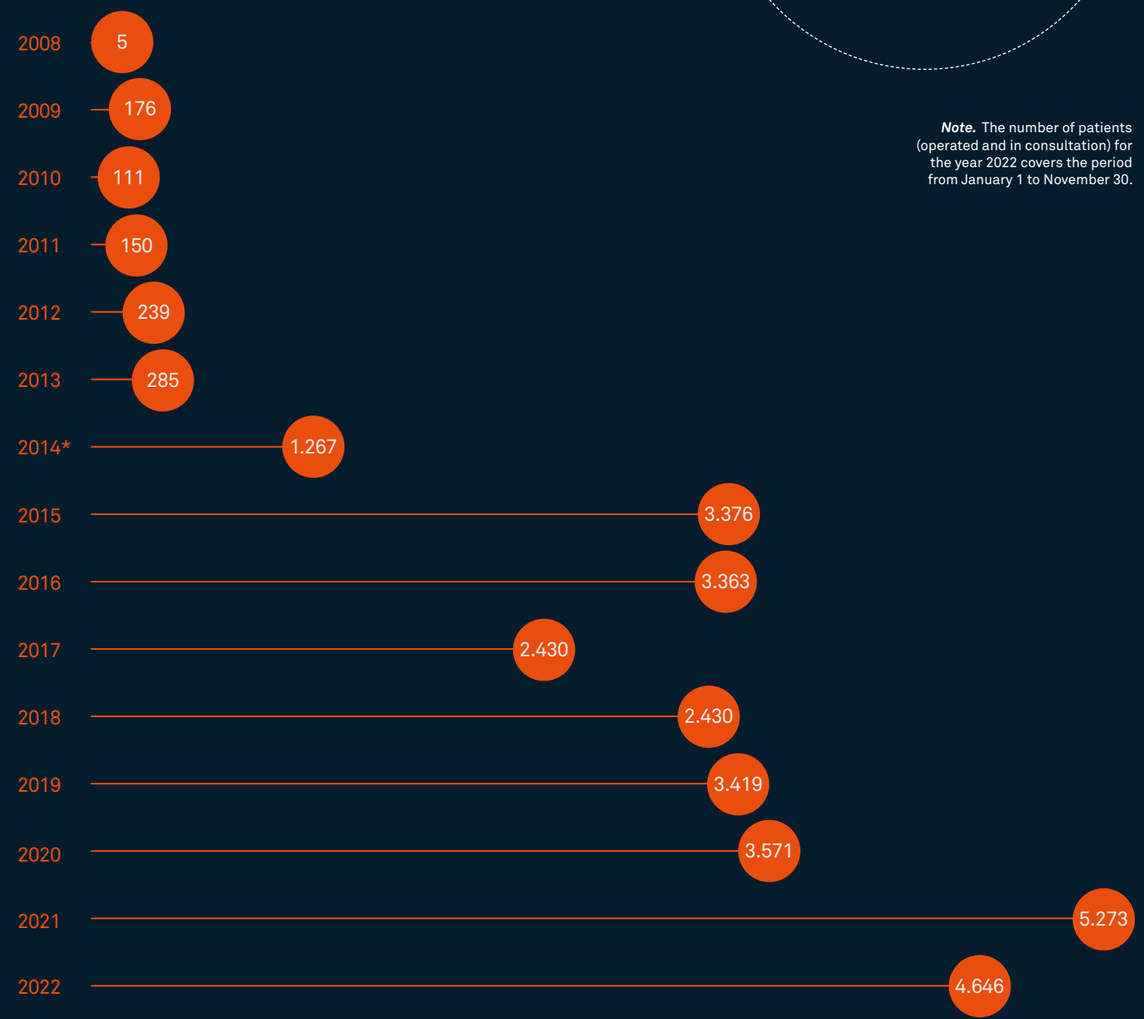
Note. Inauguration of the NED Institute in 2014*



b) Number of patients attended per year

31.583
outpatient consultations

Note. The number of patients (operated and in consultation) for the year 2022 covers the period from January 1 to November 30.



INAUGURATION OF THE NED INSTITUTE (NED)FOUNDATION

3.2. The NED model: A model for healthcare cooperation in low-resource systems

The model we present here has guided the NED Foundation's promotion of global neurosurgery for more than a decade. But this model and the tools that accompany it can also guide the design of new interventions in similar healthcare contexts. It is a model for healthcare cooperation that we make available for public discussion and validation.

Developing a low-resource health system in a sustainable manner requires intervention in three areas: infrastructure, healthcare, and education, given that many of these systems are characterized by deficiencies in all three areas (Mills, 2014). In the worst-case scenario, physical spaces and equipment will be inadequate or non-existent; medical care for patients will be limited and present numerous complications; and the level of education of healthcare staff will generally not be sufficient to manage the volume and complexity of cases. Interventions in the area of health cooperation must therefore aim to **Equip, Treat, and Educate (ETE)** at the same time. These are the three pillars of the method we present here.

The logic of the model: Complexity and Autonomy

A model for the comprehensive development of medical specialties must consider two key parameters: the degree of difficulty of the interventions (their level of complexity) and the capacity of the professionals to carry them out (their degree of autonomy).

The model assumes that any (complex) process can be divided into different levels of difficulty, according to the requirements, resources and knowledge needed to perform certain tasks or reach certain milestones. This is standard practice in almost any profession.

For example, it is common for physicians to start their profession following a similar logic. The complexity of the procedures that a junior resident aspires to learn by the end of his first year of residency will not be the same as the complexity of the procedures that she will have mastered by the end of her training. Similarly, a senior resident is expected to be able to autonomously treat a greater variety of pathologies (and more complex ones) than a junior resident.

In a low-resource health system, the promotion of a medical or surgical specialty should adopt a model of phases or levels. The NED model identifies three general levels of complexity (1, 2 and 3), which correspond to different stages of development[13]. The model applies the principle of increasing levels of complexity beyond the care ("treat") and training ("educate") domains, extending it to the equipment ("equip") domain too, given that it is also possible to model infrastructure needs on the basis of differentiated levels, as detailed below.

As for autonomy - the second parameter of the model - it is a matter of understanding the degree of external support that local teams will need in each phase of development. This is a particularly relevant parameter when the objective is (1) to develop a specialty 'from scratch' and when (2) the interventions involve organizations or individuals external to the local system.

13 The number of levels varies according to context, will depend on whom we ask, and is ultimately arbitrary. In our case, we believe that the three levels are adequate to reflect NED's experience in the development of neurosurgery in Zanzibar and maintain the utility of the model as a heuristic tool.

External support may be necessary in all three domains. But it will not be equally necessary in all phases. The objective is that this support is progressively reduced so that the local team becomes fully autonomous and independent. In the specific case of NED, interventions were aimed at building sufficient capacity to enable the local team to provide neurosurgical services autonomously once Level 3 has been reached.

From the point of view of the external organizations, therefore, the aim is to cease to be necessary when the time comes. From the perspective of the beneficiaries of the support, the goal is to achieve full autonomy in the provision, management, and financing of medical-surgical care, thus improving the overall capacity of the healthcare system in which they operate.

The logic of the model is relatively simple. Interventions will have increasing complexity at each level of development (Level 1, Level 2, and Level 3). In parallel, each level will be associated with greater autonomy in healthcare delivery. Thus, interventions will go from less to more complex, and the local team will acquire more capabilities and autonomy at each stage. Figure 6 shows a visual representation of this logic.

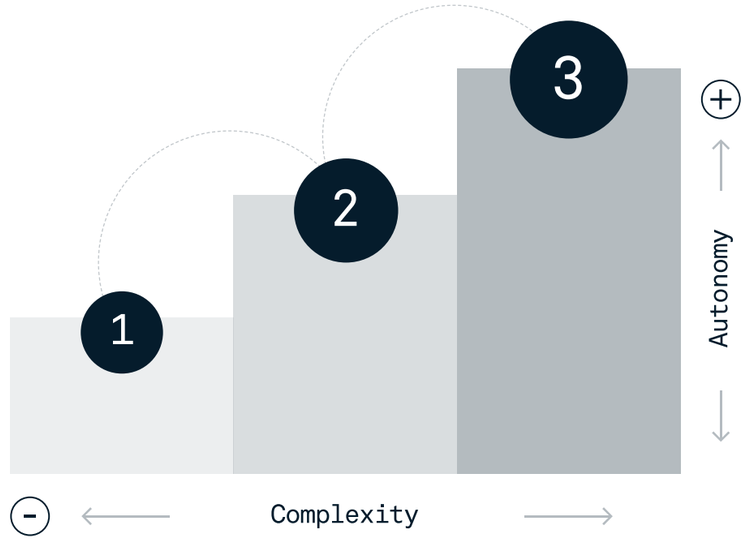


FIGURE 6. *Logic of the model: Complexity and autonomy.*

From the third level onwards, the provision of (neuro)surgical services should respond to a logic more typical of advanced healthcare systems, well equipped and with specialists trained to treat a wide spectrum of complex pathologies.

“INTERVENTIONS IN THE AREA OF HEALTH COOPERATION MUST AIM TO EQUIP, TREAT, AND EDUCATE (ETE)”

The ETE Method: Equip, Treat, and Educate

Table 2 details the healthcare cooperation model developed by the NED Foundation. The model is based on the method we have called ETE: Equip, Treat, and Educate. At each level, interventions will be needed in all three areas. As far as possible, actions will seek to equip, treat, and educate at the same time since a comprehensive and sustainable improvement of the system will require transforming the conditions associated with the three dimensions.

This method can be applied to almost any type of intervention, even the most modest. For example, the planning of a short-term surgical mission can include actions in all three areas: transport and donation of material, equipment or medical supplies; assistance to patients together with local professionals (consultations, surgeries); and training sessions given by volunteers (monographic sessions on certain pathologies, surgical techniques or protocols).

NED MODEL	1	2	3
Equip	**Basic infrastructure** • Operating room • Surgical instruments (skull and spine) • Consultation rooms • Meeting room	**Specialised infrastructure** • Hospitalization Unit • General ICU • Microscope • Neuroendoscope • Ultrasound scanner	**Advanced infrastructure** • Neurocritical ICU • Gas analyzer • X-ray arch • Vascular box • Skull base box • Incubators
Treat	**Level I Pathologies** • Traumatic brain injury • Hydrocephalus • Myelomeningocele • Encephalocele • Central Nervous system infections	**Level II Pathologies** • Ventricular endoscopy • Spinal cord injury • Spinal cord tumors • Hemispheric brain tumors • Degenerative spine	**Level III Pathologies** • Pituitary tumors • Pediatric tumors • Skull base surgery • Vascular pathology • Complex spinal surgery
Educate	**Mentoring** • Local talent recruitment • Motivation and • empowerment of staff • Basic training (eg.surgical instrumentation course) • Daily meetings	**Residency Program Official accreditation** • Residency Program • Specialized training (e.g. Neuro-oncology) • Fellowships • Weekly sessions (offline/online)	**Lifelong training Super-specialization** • Local specialists train new residents • Continuous training (advanced skills and new techniques)

TABLE 2. *The NED model for healthcare cooperation.*

Note. This table shows the specific application of the model to the development of neurosurgery in a specific case. However, the parameters and method of the model are applicable to the planning of other interventions and the promotion of other specialties. For this purpose we provide a template in the Annex.

The model starts from a first level (or phase) in which external support is essential to carry out the most basic procedures. Both to build the main infrastructure (the building or hospital wing that will host the service, the operating room and outpatient clinics), and to perform the simplest surgical procedures. For example, patient positioning, surgical field placement and incision planning in all surgeries.

According to the model, physicians will treat only the less complex pathologies at this first level (e.g., head injuries and brain and spinal infections), while educational interventions will prioritize the search, motivation, and empowerment of local talent. Training of local health-care workers will focus on the acquisition of basic skills through the organization of induction courses (e.g., on surgical instrumentation). At this level, mentoring – or external tutoring - will be the main educational tool (Leidinger et al., 2019).

The development of the specialty will progress gradually as the milestones defined for each level are met. In this sense, the second level contemplates a new set of milestones. In this phase, it will be necessary to develop and acquire what we call ‘specialized’ infrastructure: a more specific and generally more expensive type of technology and instrumentation (for example, a microscope for microsurgery or a neuro-endoscope for ventricular endoscopy). This infrastructure will be necessary to treat more complex pathologies than at Level 1 (e.g., hemispheric brain tumors). In turn, this new milestone will require the healthcare professionals to acquire greater specialization.

At the second level, therefore, local staff will have to learn new skills through more specialized training (e.g., neuro-oncology of the cerebral hemisphere). This training will enable them to treat more complex pathologies and cases autonomously. Educational interventions in this phase should be accredited locally by the competent bodies. Ideally, the main milestone will be the implementation of a specialist resident program, as the NED foundation did at the NED Institute in Zanzibar.

Finally, reaching the third level is a milestone in itself. It is the culmination of a set of previous interventions in the three areas. At this stage, local specialists should be able to address the most complex pathologies or at least a majority of them (e.g., pituitary tumors and vascular pathology). This will require more advanced infrastructure (such as an ICU for neurocritical patients). Experienced specialists with the capacity to train new residents should also be working in the department at this stage.

From the first to the third level of development, autonomy - the capacity of local professionals to practice the specialty independently - increases progressively in all areas (in Table 2 this is represented by the shade of the colors). Once the third level is consolidated, the local team should be completely independent and external support will be limited to that demanded on an ad hoc basis.

In general, the required interventions are consistent for each level of development (1, 2 and 3). Deployed together, these interventions will have a greater impact as they complement and feed off each other positively. There is, therefore, coherence between the actions required at each level and for each area (“equip, treat, and educate”). This makes it a particularly suitable cooperation model for underfunded healthcare systems, where long-term cooperation is often necessary beyond the scope of medical care.

Through this experience we wanted to show the potential of cooperation in a specific area of neuroscience. We believe that it is possible to promote social change through interventions that have an impact on equipment, training, research, and healthcare. These interventions should focus on meeting neglected needs - however complex they may seem at first glance - as well as working on behalf of those populations whose living conditions can (and must) be clearly better.

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AUTHOR: HASSAN, NED VOLUNTEER

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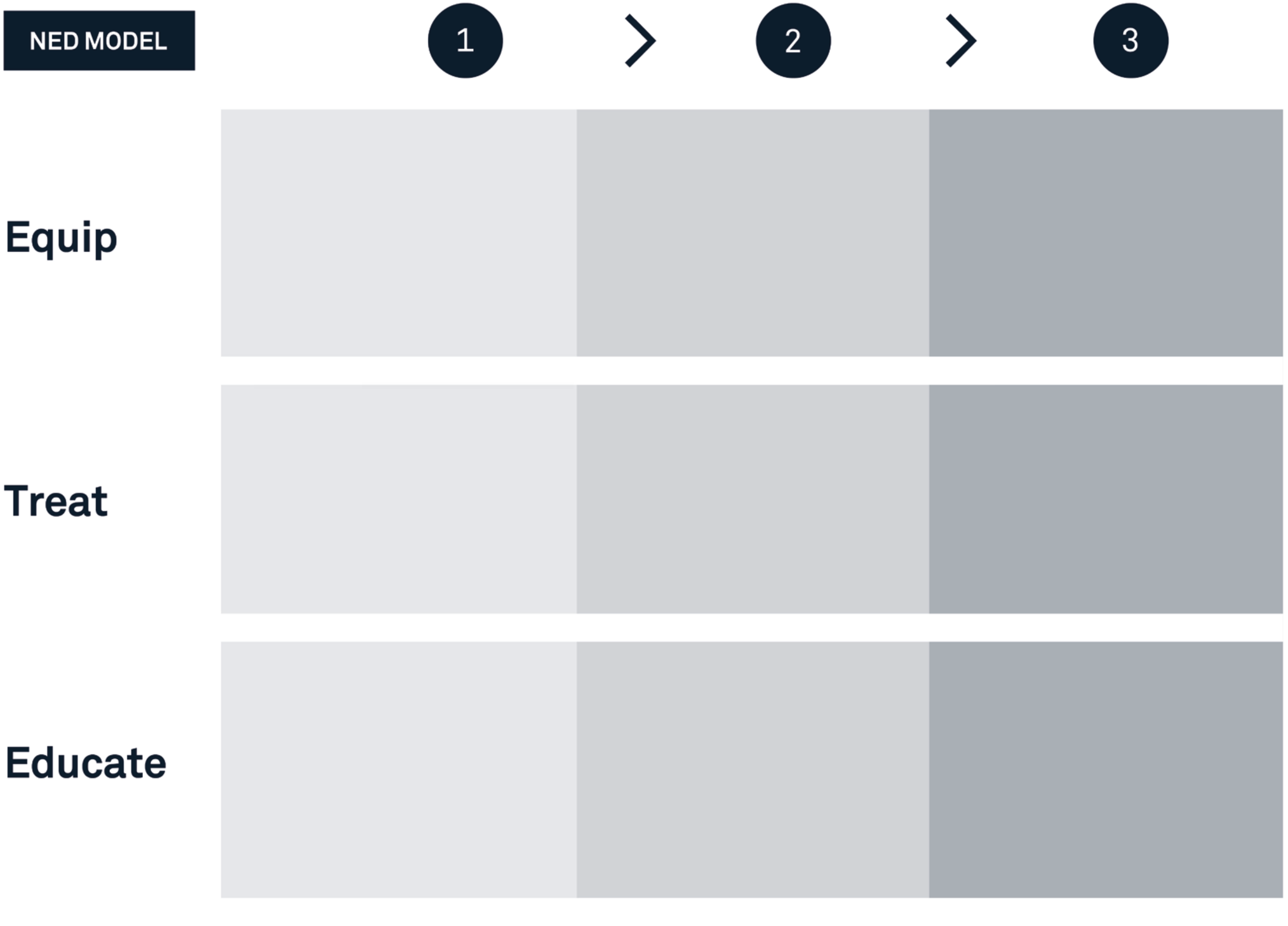
Annex



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