



Global neurosurgery over a 60-year period: Conceptual foundations, time reference, emerging Co-ordinates and prospects for collaborative interventions in low and middle income countries



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ABSTRACT

Introduction: We evaluated salient initiatives invested in global neurosurgery over a 60-year period, **Research question:** What are the Phases, Achievements, Challenges, and Lessons of Global Neurosurgery. **Methods:** A 60-year retrospective study from 1960 to 2020 analyzing the major phases, lessons, and progress notes. We reviewed the foundational need questions and innovated tools used to answer them. **Results:** Three phases defining our study period were identified. In the early phase, birthing academic units and the onset of individual volunteerism were dominant concepts. The 2nd phase is summarized by the rise of volunteerism and surgical camps. The third phase is heralded by advocacy and strategies for achieving care equity. The defining moment is the Lancet commission for global surgery summit in 2015. Lessons include the need for evaluation of the resources of recipient and donor locations using novel global surgery tools. **Conclusion:** Global neurosurgery over the 60-year study period is summarized by indelible touchstones of personal and group efforts as well as triumphs derived from innovations in the face of formidable challenges.

1. Introduction

Global neurosurgery is an evolving field concerned with addressing disparities in neurosurgical access and care worldwide using adaptive public health strategies. The World Federation of Neurological Societies' Global Neurosurgery Committee (WFNS GNC) defines global neurosurgery as, "The clinical and public health practice of neurosurgery with the primary purpose of ensuring timely, safe, and affordable neurosurgical care to all who need it (KanmounyeUlrick Sidney and Eseneignatius, 2021).

For more than 5000 years, constant study, craft and transmitted generational experiences has helped neurosurgery arrive at its current high point (Goodrich, 2009; Marsh, 2014). Conquests in modern

neurosurgery are among the most remarkable of mankind's innovative accomplishments in the 20th and 21st centuries. (Ausman, 2000; Goodrich, 1999; Jones and Mendell, 1999) These giant leaps have successfully altered the natural history of previously surgically untreatable diseases bringing them under complete control in many cases while reducing associated risks in some others (Jones and Mendell, 1999; Voorhees et al., 2005). These strides were achieved mostly through innovation and rational deployment of a wide array of translational neurosurgical concepts, nuances, smart tools and devices together with multimodality solutions crafted by related specialties and fields across scientific frames (Buonanno et al., 1983; Guthrie, 1994; Mamelak et al., 2008; Oluigbo and Rezai, 2011; Senft et al., 2011; Zamorano et al., 2004; Yaşargil and Kraysenbühl, 1970). Unfortunately, significant inequities

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exist in the distribution of these capabilities thereby denying under-served locations in low and middle income countries (LMIC) their salient benefits (Dewan et al., 2018; Vander Ark., 2018). While survival from surgically treatable diseases continue to improve in high income countries (HIC), unfortunately morbidity and mortality have continued to rise within the last 25 years among LMIC countries thereby widening the survival gap. Global neurosurgery strives to evolve multidimensional solutions to these disparities which vary across geopolitical landscapes. Global strategies are currently transiting from quick fix models, fatigable bursts of personal motivation and intellectual exchanges as well as short term pulses of clinical partnerships to more engaging conceptual frameworks that underpin evaluable and durable field applications of long range capacity building paradigms defined by structured longevity plans. Advances in creed, scope and applications of global strategies should be guided by a remodeled global compass for this evolving transition to succeed. Therefore, a fundamental understanding of the contextual frames of unmet neurosurgery and foundations of capacity inequity required to properly map the need landscape as well as standardize applied solutions using benchmarking references. For example, the root global questions for a long period were as follows: **Where does the bell toll? and how can I offer help where the bell tolls?** While answering these questions have enabled conceptual in roads into global need silos domiciled in Low Middle Income Countries (LMIC), experiences from the early works and developing collaborations suggest the need for a review of these critical covariates in light of current realities. In this regard our study provides a salient offering of this essential global neurosurgery review. It also provides innovative tools for obtaining rational answers to both the new and the old posers. The initiative provided by the Lancet commission for Global Surgery in 2015 has provided a primary grid reference for the reprioritization of basic and essential surgery in global public health as well as progressive ascendancy of the universal clamor for equity (Meara et al., 2015; Meara and Greenberg, 2015).

This has accelerated the pace of collaborations between High Income Countries (HIC) and LMIC with many desirable benefits. It has also repositioned essential surgery in some ways from an unenviable status of a neglected stepchild to a coveted poster child of global health (Branch et al., 2018; Rouseau et al., 2020). It must be emphasized, however, that global collaborations and volunteerism in neurosurgery predate the Lancet Global Surgery initiative. These include multiple innovative projects initiated by the Federation for International Education in Neurosurgery (FIENS) as well as many notable universities and neurosurgical associations in HIC which over the years have invested significant resources in building capacity in LMIC (Almeida et al., 2018; Budohoski et al., 2018; Dempsey and P, 2013; Uche et al., 2020a). This study highlights select a priori frameworks from the vast array of indelible contributions together with emerging strategies within the global landscape. Linking past grid references and contemporary co-ordinates will help to map successful paradigms and categorize persisting or developing challenges. Using the adjustable lens of the different phases of our study to view, enumerate and analyze past strategies will represent a high point of this paper, while synthesis of their notable contributions will be the salient dividends.

2. Objective

To retrospectively study the 60 years of application of global neurosurgical strategies in LMIC from 1960 to identify landmark and emerging collaborations while highlighting root and stem global neurosurgery need questions, challenges and progress tips. In the last 3 years of our study period, we innovated and applied novel assessment tools for the evaluation of neurosurgical resources in three donor and 3 recipient global surgery nations. We also categorized the global neurosurgery activity profiles of these nations under study.

3. Methods

In this 60- year study, we retrospectively review the evolutionary course of global neurosurgery from 1960 to 2020 highlighting landmarks (grid references), current projects and evolving collaborations. We reframed the global neurosurgery need questions to align them with current rescue strategies. To achieve our objective, we also displayed previous successful efforts while highlighting past and current challenges. Global neurosurgery core questions as well as previous versions are presented with their defining time periods. We categorized the 6 decades of our study period into 3 phases. The first phase lasts from 1960 to 1989, the second phase spans 1990 to 2009, while the third phase starts from 2010 and ends in 2020. The year 2020 is also significant because it will highlight the immediate effects of sudden disruptions of the global neurosurgery momentum by a viral pandemic. To assist in resolving the contemporary questions using a uniform paradigm, we applied a novel tool, the **GLOBAL Surgery Recipient Evaluation (GLOS-RE)** to assess the neurosurgical needs of 3 recipient locations namely Nigeria, Liberia and Malawi. GLOS-RE is a synthesis of the assessment template proposed initially by the Swedish African Neurosurgical Collaboration (SANC) as well as a schema published by Haglund et al. (Haglund and Fuller, 2019; Senft et al., 2011) This will help answer questions 1 and 2. We applied the Global Neurosurgery Recipient Needs evaluation (GLOS-RE) form in the evaluation of the unmet needs in Nigeria, Liberia and Malawi in our study. These 3 countries are LMIC located in Sub-Saharan Africa. We also applied a new tool – the global neurosurgery surveillance profile (gns-P) for evaluating country resource profiles so as to provide a wholesome measurement for neurosurgery education and resource capacity both in LMIC and HIC. gns-P will help answer Question 3 to 7. This new paradigm is based on 5 resource or performance based parameters namely:

1. Skill/training status,
2. Elective surgery volume and waiting times,
3. Support units and resources
4. Global surgery activity
- 5 Unmet surgical need to assess

gns-P provides a Likert scale categorization of the global neurosurgical performance status or resource profile of countries. Using gns-P values, countries are HIC categorized as High Neurosurgically Resourced Country (HNRC) or donors, Upgraded LMIC are Middle Neurosurgically Resourced Countries (MNRC) or facilitators, while other LMIC are Low Neurosurgically Resourced Countries (LNRC) or recipient locations. Using gns-P to profile both countries is intended to offer some help in matching the peculiar strengths of different HNRC benevolently engaged in donor global initiatives with customized and prioritized needs identified with specified LNRC locations. Evaluating the impact of past and current global strategies will further contribute to answering 2 to 7 by providing both plain and hindsight. We have assessed in our study, the gns-P profiles of the 3 LNRC in Sub-saharan Africa, two HNRC in Europe namely Sweden and Norway as well as the USA-a HNRC in North America. Using the Global surgery activity profiles we further classified countries as Active (Donor or Recipient), Facilitator, Observer, Dormant, Inert. Finally we highlight sustainability paths for global neurosurgical initiatives through a critical analysis of concepts with lessons garnered from past and recent on-going projects.

4. Results

Table 1 shows the salient global need questions with their identified time period. Prior to the turn of the century, 2 salient questions defined the need space in LMICs as shown in **Table 1**. Beyond year 2000, additional questions emerged as global neurosurgery began to expand in creed and depth. **Table 2** shows the 3 phases of our study period highlighting the projects, sponsors or donor organizations as well as recipient

Table 1
Global neurosurgery core questions.

Time period	Description	Question
Before 2000 AD (1960–2000)	Previous Era	1. Where does the bell toll? 2. How can I offer help where the bell tolls?
After Year 2000 AD(2001–2020)	Contemporary Era	1. What is the help required where the bell tolls? 2. How can We deliver help maximally and cost effectively to where the bell tolls 3. Who best can deliver the help required where the bell tolls? 4. How do we account for help delivered so as to achieve set objectives where the bell tolls? 5. How can we sustain help where the bell tolls? 6. How can we integrate local resources where it tolls to the solution plan 7. How can we transform where the bell tolls to regional facilitators or donors of global neurosurgery resource ?

countries and continents with dates and where necessary the team leaders. The first phase covers the period from 1960 to 1989. Endowments of academic units, training and fieldwork by.

FIENS in Taiwan and the beginning of volunteerism are seen in this phase. The 2nd phase which began in 1990 and ended in 2010 is highlighted by the progressive rise of volunteerism, birth of surgical camps, twinning strategies and reference training centers (Burton, 2015). This period includes the pioneering work of Dr Marsh in Ukraine, FIENS field trips coordinated by Dr Merwyn Bagan and Dr Paul Young, the WFNS Reference Training Centers in Rabat, Recife and Nairobi pioneered by WFNS under the leadership of Prof Madjid Samii. The last phase of our study period began in 2010 and ended in the 1st half of 2020. This period is marked by visible advocacy for essential and basic surgery, pursuit of health equity and building of a global coalition for change. During this period, there has been an explosion in the scope of global initiatives such as FIENS, ICRAN and WFNS through the visionary leadership of Prof Franco Servadei. The scope of global neurosurgery activities was amplified by the Bogota declaration of ICRAN on global neurosurgery, the multisectoral activities of the Harvard program in Global Surgery and.

Social Change, establishment of the WFNS Global surgery committee led by Dr Kee Park and Dr Abdessamad El Ouahabi (Bogota Declaration: Global Neurosurgery Committee, 2022; Dempsey and P, 2013; Dewan et al., 2018; WFNS Global Neurosurgery Committee, 2020). the global surgery projects of the AANS and other neurosurgical associations, global strategies from Canada, European nations as well as twinning universities. We liken this rapidly expanding network of neurosurgeons and related specialties to an allied force for change, hence the name Global Neurosurgery Allied Force (GNAF). The Lancet global surgery initiative and the Bogota Declaration of 2016 provide a contextual reference to this phase (Meara et al., 2015; Meara and Greenberg, 2015; WFNS Global Neurosurgery Committee, 2020).

Table 3 shows the GLOS-RE profiles of 3 recipient locations in sub Saharan Africa. It highlights their specific need profiles, required interventions, sustainability projections and possible challenges. Figs. 1–3 are color coded global maps depicting the different coordinates between HIC (HNRC) and LMIC (MNRC and LNRC) during the different phases. The development of facilitators among LNRC which have been upgraded in some ways by sustained donations from HRNC in Fig. 3 in the case of Uganda.

Morocco, Brazil and Egypt is shown in Fig. 3 highlighting the significant progress made over this period. Table 4 highlights the gns-P profiles of 3 LMICs and 3 HIC. It illustrates the gns-P of six countries selected from 3 continents namely North America, Europe and Africa.

Three of the countries Nigeria, Liberia and Malawi are LMIC while the remaining three-Norway, Sweden and the United States are HIC. The gns-P categorization provided a Likert Scale rating showing the 3 poorly resourced LMICs with gns- P profile less than 3 and HIC with gns-P >4. From our study, the gns-P of studied countries range from 1 to 2.1 for Liberia and Nigeria respectively to 4.6, 4.6 and 4.7 Sweden, the USA and Norway respectively Table 3. The global surgery event profiles of select countries have been provided in Table 5. Active countries are either HIC (donors) or LMIC (recipients) engaged in ongoing beneficial collaborations. The USA, Canada, France, Norway, Sweden, are examples of active HIC, while Nigeria, Uganda, Kenya, Malawi, Senegal are examples of active LMIC. Facilitators are upgraded LMIC which offer critical help to active HIC to enhance their global projects in other LMIC locations. Examples are locations of WFNS reference centers such as Brazil, Uganda, Egypt and Morocco. Facilitators may also be national or multinational neurosurgical organizations as well as frontline twinning universities. These organizations may be donors primarily or through their networking, directly or indirectly promote the projects of other groups. Observers are LMIC preparing for global collaborations evidenced by sponsorship of neurosurgeons to global meetings and formal interest or applications to donor nations or organizations for collaboration. It also includes HIC actively in search of a LMIC prospects for collaboration. Dormant global locations represent those countries both HIC and LMIC with documented previous record of global neurosurgery engagements but have been inactive for 10 years or more. Inert locations are HIC and LMIC with no documented previous experience of a formal or informal global neurosurgery engagement.

5. Discussion

5.1. Evolutionary phases, concepts, time reference and need posers

In this study, the three evolutionary phases of global neurosurgery are highlighted. The first phase covers the period from 1960 to 1989. Its grid reference is represented by the conception, birth and initial activities of the Federation for International Education in Neurosurgery (FIENS). A summary of this period is depicted in Table 2 and Fig. 1. Besides FIENS, early foundations of academic neurosurgery in sub-Saharan Africa together with training in Taiwan are the other salient landmarks. The 2nd phase as shown in Table 2 and Fig. 2 began in 1990 and ended in 2010. This phase is summarized by the progressive rise of global volunteerism albeit in fragmentary modes within its early half period (1990–1999) followed by initiation of structured global strategies in the later half (Bagan, 2010; Goodrich, 1999; Marsh, 2014; Vander Ark., 2018). These strategies paved the way for the birth of surgical camps, twinning strategies and reference training centers (Burton, 2015; Haglund and Fuller, 2019) which became dominant models during its second half period (2000–2009). The 3 models have now become symbolic of global surgery across the globe (Haglund and Fuller, 2019; Uche et al., 2020b). The last phase of our study period began in 2010 and ended in the 1st half of 2020. It is uniquely defined by a rising wave of advocacy and the establishment of a global coalition for collective action. The Cambodian neurosurgery project exemplifies the positive effect of advocacy on training and practice on a nationwide scale (Park, 2013). We liken this growing network of neurosurgical and related health army to an allied force for change, hence the name Global Neurosurgery Allied Force(GNAF). The 2015 Lancet global surgery initiative represents a salient reference project for this phase (Meara et al., 2015; Meara and Greenberg, 2015). It was complemented by the Harvard program in Global Surgery and Social Change and the 2016 Bogota declaration, a global neurosurgery advocacy summit pioneered by the International Conference for Recent Advances in Neurotraumatology (ICRAN) - the International forum of the Neurotrauma committee (NTC) of the WFNS (Bogota Declaration: Global Neurosurgery Committee, 2022; Dewan et al., 2018). The consensus process of the Bogota declaration was led by Dr Kee Park and the document was presented to Dr Walter Johnson of the

Table 2
Global surgery phases and select projects.

Phase/Main focus	Global Initiative Provider or Project	Recipient Country	Continent/region	Date	Team Leader
1st Phase Training 1960–1989	Rockefeller Foundation New York/1st Academic Neurosurgery Unit in Africa	Nigeria	Africa	1962	Prof Odeku
	FIENS Birth		North America	1969	
	First neurosurgical Training Training Volunteer	Taiwan	Asia	1979	David Fairholm
2nd Phase Training + Surgical Camps + Twinning 1990–2009	Do no Harm/Volunteer FIENS/Volunteer	Indonesia Ghana Ukraine Honduras	Asia Africa Europe North America	1984 1989 1992–2005 1992	Dr Henry Marsh
	FIENS/Neurosurgical unit procreation Bethany Kids	Nepal Kijabe Kenya	Asia	1995 1997	Dr Dick Branford/Dr Leland Albright Prof Madjid Samii
	WFNS Foundation/Geneva 2000	Conceptualized Reference Training Centers – Hannover, Brazil, Morocco, Algeria, Nairobi etc	LMIC worldwide	2000	
	FIENS/1st Microsurgery Lab	Honduras	North America	2000	
	Cure International/Cure Children's Hospital/Harvard Global Health	Mulago/Uganda	Africa	2000	Dr Benjamin Warf
	FIENS/Neurovascular Workshop	India	Asia	2001	
	WFNS Reference training Center	Africa/Morocco	Africa	2002	Prof El Khamlichi
	FIENS/East African Training Program	Kenya/East Africa	Africa	2005	Dr Mahmoud Qureshi
	Bergen University Norway Neurosurgery Education and Development Foundation(NEDF)	Ethiopia Tanzania	Africa Africa	2006 2006	Dr Knut Wester Dr Jose Piquer
	Duke University FIENS/Weill Cornell University	Uganda Tanzania	Africa Africa	2007 2008	Dr Michael Haglund
	FIENS/Establishment of Neurosurgical Training	Ecuador	South America	2009	FIENS
	Swiss/Myanmar Twinning Project	Myanmar	Southeast Asia	2011	
	FIENS/Foundation of Neurosurgical Dyads(Twinning)	LMICs	Worldwide	2012	FIENS
	NED Institute Birth of CAANS with FIENS/WFNS support	Tanzania Africa	Africa Africa	2013 2013	Dr Jose Piquer WFNS/FIENS
Cambodia Neurosurgery Project	Cambodia	Southeast Asia	2013–2016	Dr Kee Park	
Lancet Global Surgery Initiative	LMICs	Worldwide	2015	Lancet Global Health	
Bogota Declaration on Global Neurosurgery	LMICs	Worldwide	2016	ICRAN	
Swedish African Neurosurgical Collaboration	Nigeria and Ghana	Africa	2018	Dr Enoch Uche/Dr Mats Ryttefjors/Dr Magnus Tisell	
Weill Cornell University WHO-WFNS Liaison Committee through WHA	Senegal Worldwide	Africa Worldwide	2018 2017/2018	Dr Philip Stieg Dr Franco Servadei/Dr Gail Rousseau/Dr Walter Johnson	
Mapping of the Global Profile of Unmet Neurosurgery	Worldwide	Worldwide	2018	Harvard Program in Global Surgery and Social Change-Dr Kee Park	
Birth of WFNS Global Surgery Committee	Worldwide	Worldwide	2019	WFNS	

World Health Organization ([Bogota Declaration: Global Neurosurgery Committee, 2022](#)). The WFNS Global Neurosurgery Committee was subsequently established in 2019 ([WFNS Global Neurosurgery Committee, 2020](#)). Our index study period is also bisected into 2 unequal time frames by foundational need questions addressed through the variously

applied global initiatives. [Table 1](#). Between 1960 and 2000, most global initiatives were applied to birth and support few training units in existence within LMIC. Accordingly, **where does the bell toll?** was the main poser addressed. ([Marsh, 2014](#)) The rise of individual and corporate volunteerism towards the end of the last millennium heralded a new

Table 3
Global surgery recipient evaluation (GLOS-RE) form.

1. Country	NEED=Capacity			
	A. Education/Skill	B. Infrastructure	C. System Strengthening	Combined(e.g. A + B + C)
Nigeria(N)	yes	yes	yes	Nigeria
Liberia (L)	yes	yes	yes	Liberia
Malawi(M)	yes	yes	yes	Malawi
2. Interventions Project(Specify)				
	Local Unit	Surgical College	University Division of Neurosurgery	other
i. Educational Curriculum	N	N	N	
	L	-	-	
Specialty	M		M	
	Neurosurgery	Neurosurgical Nursing	Neuroanaesthesia/Neurointensive Care	other
	N	N	N	Neurophysiology, Biomedical, Physiotherapy
	L	L	L	
	M	M	M	
ii. Research/Audit				
3. Care Interventions	Nigeria	Liberia	Malawi	
Surgical Camps (Team visit)	yes	yes	yes	
Specialty Surgeon visit only	no	yes	yes	
Infrastructure donation only	no	no	no	
Infrastructure + Surgical camps	yes	yes	yes	
4. Systems Intervention Required	infrastructure	Training	Organization	Audit
Unit				
Hospital				
Regional				
5. Sustainability Projections	5-year	5year	5 year	Other
Education	30 fellows/residents	Commence training for Liberia	5 residents/fellows	Commence subspecialty training for Nigeria
Infrastructure	10 fully equipped microsurgical and minimally invasive OR	1 fully equipped microsurgical and minimally invasive	1 fully equipped microsurgical or minimally invasive OR	
Care Capacity	Reduce Unmet need by 30%	Reduce Unmet need by 30%	Reduce unmet need by 30%	Set up Governance mechanism to manage collaboration portfolios
Other facilities or teams required	Operative navigation, endoscope radiosurgery, endovascular suite, MRI and molecular pathology laboratory	Microsurgery, endoscope MRI, operative	Operative navigation, endoscope, radiosurgery, endovascular, MRI and molecular pathology laboratory	
Funds Projections	National Government Foreign Donors	National Government, Foreign Donors	National Governments, Foreign Donors	
Funding organizations				
6. Possible Challenges	Sociopolitical	Economic	Health(Epidemic/Pandemic)	other
	Political Instability, Terrorism	Global economic recession	Infectious diseases: Corona Virus, Ebola, Lassa fever	

phase but also imposed the need for a review of global need posers to underpin new strategies and revive existing projects. (Marsh, 2014, Meara et al., 2015) The question; **how can I provide help where the bell tolls?** therefore became a necessary addendum. However with the rapid evolution of strategies, concepts and technology, the new millennium has witnessed within a short time, an increase in global collaborations requiring further review of engagement questions. The huge global need profiles of LMICs require collective and organized action for holistic improvements to occur. Therefore needs assessment, structured action plan for both short and long term solutions that match need profiles in specific locations, networking, note comparisons, as well as audit and advocacy are now vital tools for global neurosurgery. Accordingly the new global engagement posers proposed by our study in Table 1 are to properly situate these new concepts within the needs field of global neurosurgery. Recent reported experiences corroborate our submissions: Dempsey and P, 2013, Haglund and Fuller, 2019, Marsh, 2014, Rousseau et al., 2020, Uche et al., 2020a) Enumeration and analysis of local needs in a recipient location is a recognized prerequisite for a meaningful and beneficial global collaboration (Almeida et al., 2018; Haglund and Fuller,

2019; Senft et al., 2011; Uche et al., 2020a). GLOS- RE assessment tool proposed by our index study offers a template to guide collaborating teams. Our analysis and presentation of the need profiles of three LMIC using this tool is presented in Table 3. Our current experience shows that a deep knowledge of the peculiar circumstances of a recipient location is required to obtain accurate data. In our experience, lead local collaborators in recipient LMIC locations are best endowed with the experience to satisfactorily perform this role. Further discussions by the local team followed by collaborative discussion through teleconference platforms completes the cycle. This 3 stage process will help prevent the occurrence of omissions that may prove costly (Haglund and Fuller, 2019; Uche et al., 2020a, 2020b). While GLOS- RE may serve as a reliable guide, we recognize that neurosurgical needs vary among locations and no specific assessment tool can summarize all profiles.

5.2. Past and emerging Co-ordinates

Throughout our study period, the scope of global collaborations has continued to widen. However a closer look at donor (HIC) profiles and

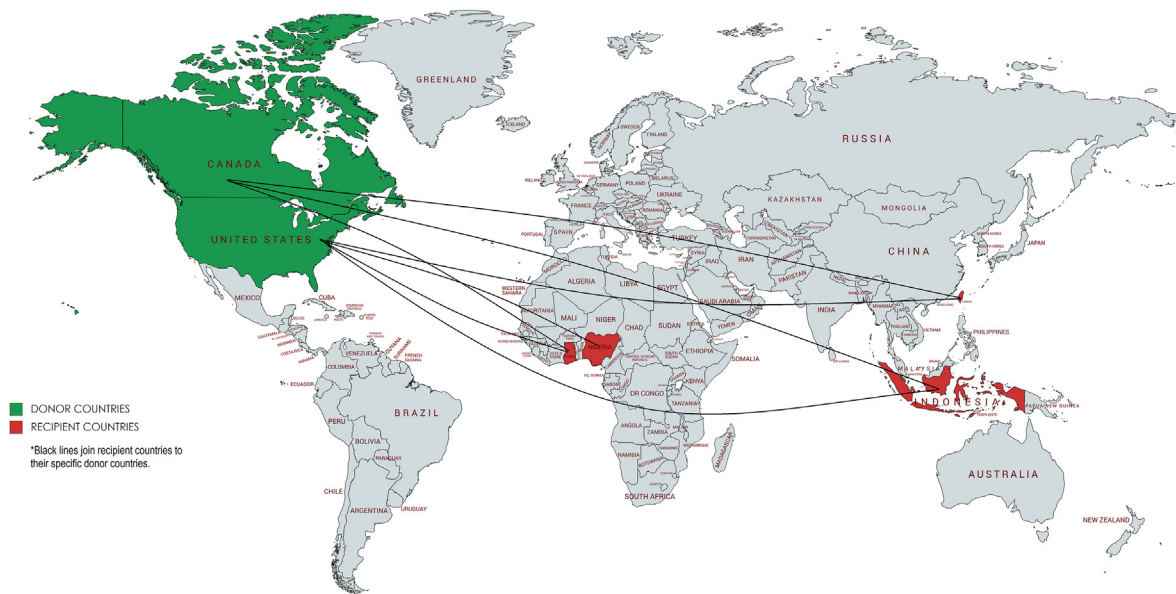


Fig. 1. Global neurosurgery coordinates for the period between 1960 and 1989.

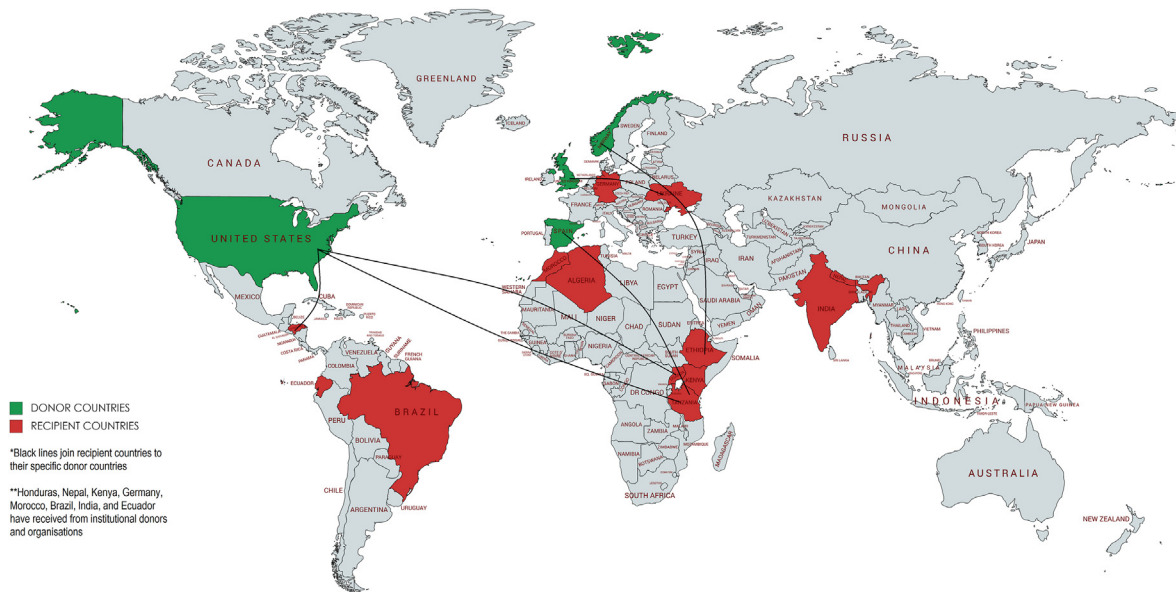


Fig. 2. Global neurosurgery coordinates for the period between 1990 and 2009.

recipient (LMIC) profiles highlighted in Table 2, Figs. 1–3) shows that a few HIC including organizations such as universities and associations are actively involved concurrently across many LMIC recipients field. The United States of America (USA) in particular has led the way and through, her multisectoral channels has continued to invest huge resources in global neurosurgery. Significant investments from Canada, Norway, Sweden and Spain as well as the global neurosurgical community through WFNS and FIENS are responsible for most of the remaining activity. The team leaders of select past and current global projects have been displayed to highlight their invaluable contributions. Table 2 is by no means a complete compilation, however it represents a selection of those works critical to the phases of our study. At this point, the need for a template that previews the resource profile of countries engaged in collaborations has become a rational question. To this end we believe the gns-P proposed by our study may become useful for objective analysis of neurosurgical resources both among HIC and LMIC. This will help to identify the resource strengths of donors or facilitators and match them

with the needs of recipient locations (Uche et al., 2020a, 2020b). This in our opinion will help obtain best-fit models for emerging collaborations during the planning stages. This template provides the basis for comparison of notes among collaborators. Gns-P values helped us classify countries into 3 categories namely -High Neurosurgically Resourced Countries (HNRC) such as the USA, Canada, Sweden, Norway, the United Kingdom among others. HNRC are global donor countries identified with high gns-P (above 4.0). Middle Neurosurgically Resourced Countries (MNRC) have gns-P between 3 and 3.9. MNRC in our opinion are LMIC with upgraded neurosurgery resources which can be applied to facilitate global strategies in neighboring countries or regions. Egypt, Brazil and Morocco and Uganda are salient examples- Fig. 3 (Lepard et al., 2020). The transition of these nations from recipients to facilitators represents a salient success story for global neurosurgery and an encouragement for more global collaborations between HNRC and LNRC.

Low Neurosurgically Resourced Countries (LNRC) are defined by gns-P lower than 3 complete the log. These are the recipient targets of global

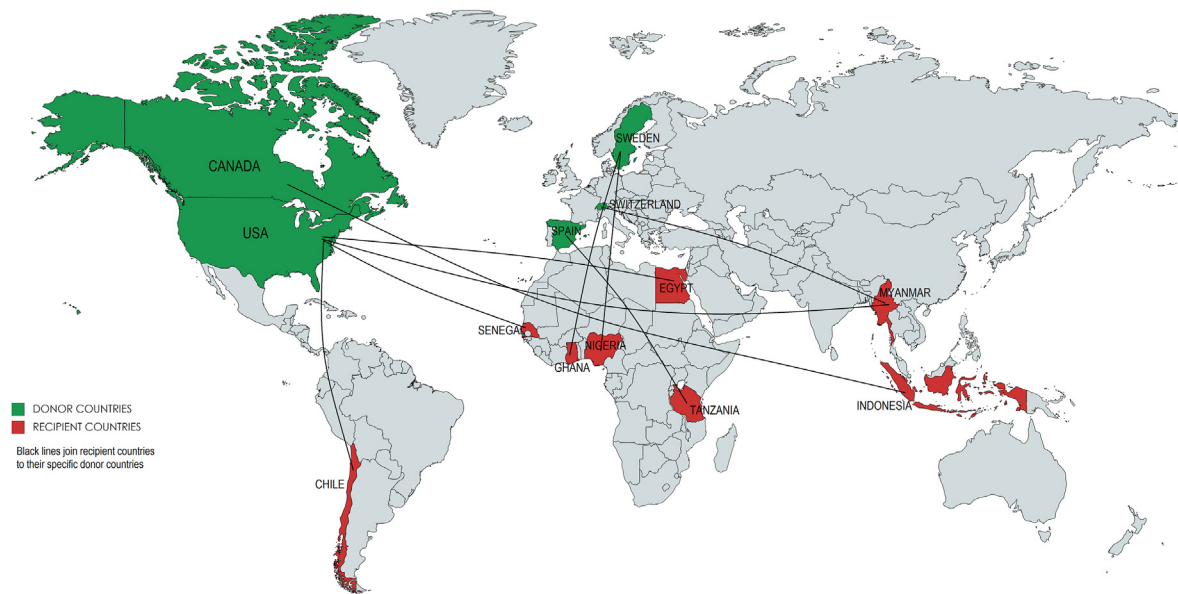


Fig. 3. Global neurosurgery coordinates for the period between 2010 and 2020(1st half).

initiatives aimed at correcting disparities in access and capacity. Gns-P categorization in our proposition is a customized scale for global neurosurgery. Its use is without prejudice to pre-existing globally accepted paradigms for socioeconomic categorization of countries into HIC and LMIC such as the Gross Domestic Product per capita and human development index (Uche et al., 2018; Warf and Campbell, 2008).

On the other hand, it is our considered opinion that gns-P represents a necessity invoked tool applicable to a more restricted but highly significant domain in global health. While we confine its application to neurosurgery, it could be modified to adequately preview resource profiles in other global health domains as well. Collaborations are progressively emerging between many African and south east Asian countries on the one hand and HNRC in Europe and North America on the other. The Swedish African Neurosurgical Collaboration, Collaboration between Norway and Malawi, the Weill Cornell University USA and Senegal are a few examples. We hope for an expansion of the WFNS reference training center project to provide more force for accelerating training and capacity development. It is also our hope that FIENS, Cure International, the Harvard and Duke global health programs and other frontline twinning universities and donor organizations will continue to sustain and perhaps escalate their global programs.

5.3. Global activity profiles, threats, prospects and responses

We have classified global neurosurgery profiles of different nations into active, facilitator, observer, dormant or inert. Table 5. The profiles of select countries and regions highlighted provides a synopsis of this classification. We believe that every country has a duty to respond to the global clarion call for the resolution of inequities in neurosurgical access and capacity. We also believe that the response should be based on the resource capacity available as well as unmet need burden suffered.

Accordingly, active nations describe those already heeding the call and collaborating visibly, evaluably and positively as donors and recipients. Therefore as both HNRC and LNRC could be active, reticence and inactivity on the part of LNRC in seeking for salient collaborations or networking with the global community constitutes in our opinion a vice against the global neurosurgery moral code and vice versa for HNRC. Collaborations can be conceived and nurtured during international scientific meetings, courses, seminars and other professional exchanges. (Meara et al., 2015) Therefore attendance to such events especially with presentation of salient experiences have proven to be useful in the past

(Uche et al., 2018, 2020a). Facilitators help to enhance the progress and success of global projects initiated by active HNRC. They may represent LNRC whose resources in certain sectors have been upgraded or enriched by previous collaborations such as Morocco, Egypt and Uganda. Following the success of the Cure International Hydrocephalus Program in Uganda, It has become a reference center for post residency fellowship in pediatric neurosurgery specifically for competency training in Endoscopic Third Ventriculostomy and Choroid Plexus Cauterization around the world. (Leopard et al., 2020, Warf, 2005, Warf and Campbell, 2008) In this instance the role of a facilitator represents an upward migration of resource and activity profile. Observation in our model represents a search or readiness to collaborate across profiles of resource strength. A dormant profile in our proposed schema represents paused or suspended activity in global initiatives for ten or more years. Many factors can lead to dormancy including difficulties related to funding, fatigue or expiration of tenure. It may also be related to recipient related challenges including apathy, failure to honor agreements, ethical issues as well as natural or man-made hazards. An Inert profile is descriptive of locations with no perceivable present or past interest. An inert profile in our opinion constitutes a red zone and shows disconnection with or gross disinterest in global neurosurgery. It represents a gross discouragement for the global neurosurgery movement and can be reversed through improvement in professional fellowships and mutual friendships between neurosurgeons from different backgrounds as highlighted previously. (Uche et al., 2020a, Uche et al., 2020b, Uche et al., 2018) A dynamic mobilization of neurosurgeons through national, regional, continental and global professional organizations into a global neurosurgery allied force (GNAF) will represent a salient silver lining and a realizable bright prospect for the future.

5.4. Immediate effects and response of global neurosurgery to Covid-19 pandemic

Finally, the short term effects of disruptions from a viral pandemic, Covid-19 on global neurosurgery are now clearly visible. Most global collaborations are understandably at the lowest ebb currently as the world refocuses most resources in fighting and defeating a common existential foe. GNAF –the world allied neurosurgical force is also responding albeit informally with a virtual remodeling of educational offerings and collaborative efforts previously delivered using conventional paradigms (Gallo. and Trompetto, 2020; Germano et al., 2020).

Table 4
gns-P of select LMIC and HIC.

Profile/score	Country Score								Remark
	N	L	M	D	No	U	B		
A. Neurosurgery skill/Training resource									
i. Neurosurgeon to population ratio 2=<1/100000–250000, 1 > 1/250000, 0=none	0	0	0	2	2		2	2	
ii. Subspecialty practice: 2 = all subspecialties, 1 = some specialties 0 = none	2	0	0	2	2		2	2	
iii. Neurosurgical hospital or unit/population ratio 1/<100000 = 5, 1/100,000–250,000 = 4, 1/250000–500,000 = 3, 1/500000–1/1000000.00 = 2, 1/>1000000.00 = 1, none = 0	1	1	1	4	5		4	4	
iv. neurosurgical training centers/population ratio 1/100000–250000 = 5, 1/250000–500000 = 4, 1/500000–1/1000000 = 3, 1/1000000–1/2500000 = 2, 1/>2500000 None = 0	1	0	1	5	5		5	5	
v. Neurosurgical Infrastructure Fully equipped hospital dept of neurosurgery in every state or sub region = 5 Fully equipped hospital dept of neurosurgery in more than 50% of state or sub region = 4 Fully equipped hospital dept of neurosurgery in more than 10% but less than 50% of states or sub regions = 3 Fully equipped hospital dept of neurosurgery in <10% of states or regions = 2 No fully equipped hospital dept of neurosurgery = 1 No separate neurosurgical department or division = 0	3	1	1	5	5		5	5	Fully equipped with neurosurgical Ward, OR,ICU,OPD, A/E
Mean NESCAPE profile of >50% of units Frontier Unit(NESCAPE 4) = 5 Institute Unit(NESCAPE 3) = 4 Training unit(NESCAPE 2) = 3 Practitioner only unit(NESCAPE 1) = 2 No formal neurounit = 1	3	1	1	5	5		5	5	Annual case volume average per training or practitioner unit as applicable
B. Elective surgery Volume and waiting times									
i. Total Annual Case volume(Major cases/unit)/score >5000 = 5 >1000–5000 = 4 >500–1000 = 3 >100–500 = 2 1–100 = 1 None = 0	3	1	1	5	5		5	5	
ii. Mean Elective Surgery Waiting Time(weeks) 0–1 = 5, 2–3 = 4, 4–5 = 3, 6–7 = 2, 7–8 = 1, >8 = 0	2	1	1	5	5		5	4	
C. Mortality Profile of elective cases (%) <1% = 5 1–5% = 4 >5–10 = 3 >10–15 = 2 >15–20 = 1 >20 = 0	3	2	2	4	4		4	4	
C. Support Units Score 0.5 for each(Surgical Residency, Neurosurgical Nursing, Neurology, Neuroanaesthesia, Neuroradiology, Neuropathology, Blood bank/serology, Biomedical Engineering, Physical Therapy, Radiotherapy,	5	3	3	5	5		5	5	
D. Global Surgery Profile Benefactor = 3 Facilitator = 2 None = 1 Recipient = 0	0	0	0	3	3		3	3	
E. Unmet need: 3=<10%, 2 = 11–20%, 1 = 21–49%, 0 = ≥50% Total Score: Maximum is 50 gnsP = Total score/10, Maximum = 5	0	0	0	3	3		3	3	
Categorization 4–5=high neurosurgically resourced country ... HNRC 3–3.9 middle neurosurgically resourced countryMNRC 0–2.9 low neurosurgically resourced country ... LNRC	2.1	1.0	1.1	4.4	4.5		4.4	4.3	
	Nigeria(N) = 2.1., Liberia(L) = 1.0 Malawi (M) = 1.1, Sweden(S) = 4.4, Norway(No) = 4.5 USA(U) = 4.4 Egypt(1 + 2+3 + 3+3 + 4+4 + 3+5 + 2) = 32, gns-P = 3.2								

This may form the basis of a formal comprehensive review of protocols for global neurosurgical educational programs firstly, followed by rational adjustments in the mode of application of key global surgery offerings and concepts such as surgical camps, focused clinical partnerships and perhaps other global surgery engagements in the foreseeable

future (Gallo. and Trompetto, 2020; Germano et al., 2020). It is our expectation that the WFNS global neurosurgery committee and other major stake holders will provide the requisite leadership required to achieve this collective goal. At some point transition to hybrid global surgery programs that include time and event scaled virtual and hands on

Table 5
Global neurosurgery activity profile of selected countries and organizations.

Activity Profile	Continent	Country	Year of Last major global engagement	
1. Active				
HNRC	North America	United States of America	2020	
	North America	Canada	2020	
	Europe	Sweden	2020	
	Europe	Norway	2020	
	Europe	Spain	2020	
	Europe	Switzerland	2013	
	LNRC	Africa	Uganda	2020
		Africa	Kenya	2020
		Africa	Tanzania	2020
		Africa	Malawi	2020
Africa		Ethiopia	2015	
Southeast Asia		Myanmar	2011	
Africa		Nigeria	2020	
2. Facilitator Nations(Upgraded LMIC-MNRC)	Southeast Asia	Indonesia	2020	
	Africa	Morocco	2020	
	Africa	Egypt	2020	
	South America	Brazil	2020	
	Africa	Uganda	2020	
Facilitator Organizations	Global	FIENS, WFNS, AANS, SNS, Twinning Universities	2020	
	Global	Multiple profile	2020	
3. Observer				
HNRC	Europe, Asia, Oceania	Multiple profile	Not applicable	
LNRC	Africa	Liberia		
	Africa	The Gambia		
	Africa	Sierra Leone		
4. Dormant				
	Europe, Asia, Middle East, Oceania, Africa	Multiple both HNRC and LNRC	2010	
5. Inert				
	Europe, Asia, Middle East, Oceania, Africa	Multiple both HNRC and LNRC	No documented interest or activity	

renderings may supervene. It is too early to conclude if hybrid global surgery paradigm will become the dominant global surgery strategy in the post covid era.

6. Conclusion

The journey of global neurosurgery in the last 6 decades is defined by identifiable phases characterized by variable root questions, landmark contributions and progress notes. Current strategies and evolving coordinates are represented by a global movement united through advocacy, progressive commitment to social change leading to resolution of disparities in care access and capacity. A harmonized protocol of action and unified command chain will help rally the global community to collective action, neutralize threats and ensure universal success. A synthesis of the salient nuggets which are derivable benefits of the global neurosurgery journey such as global mobilization and advocacy together with rational deployment of proven sustainability solutions as well as application of dynamic virtual/smart tools where indicated will perhaps offer further mileage, yield more dividend and improve the overall impact of global neurosurgery.

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Availability of data and material

We hereby declare our compliance to data transparency.

Code availability

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Author contributions

Conception and Design: EOU, MT, MR:
Data collection and review: EOU, JS, UKU, MM, LE, PK, DFR Article
Drafting: EOU, MT, MR.
Critically Reviewing EOU, US, MT, MR.
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Declaration of competing interest

We the authors hereby declare no conflict of interest.

Appendix A. Supplementary data

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Glossary

- LMIC*: Lower Middle Income Country
HIC: High Income Country
LNRC: Low Neurosurgically Resourced Country
MNRC: Middle Neurosurgically Resourced Country
HNRC: High Neurosurgically Resourced Country
GLOS-RE: Global Surgery Resource Evaluation
gns-P: Global Neurosurgery Profile
NESCAPE: Neurosurgery Care Phase Evolution
GNAF: Global Neurosurgery Allied Force
FIENS: Federation for International Education in Neurosurgery
AANS: American Association of Neurological Surgeons
SNS: Swedish Neurosurgical Society
WFNS: World Federation of Neurosurgical Societies
ICRAN: International Conference for Recent Advances in Neurotraumatology