The impact of African-trained neurosurgeons on sub-Saharan Africa

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OBJECTIVE Sub-Saharan Africa (SSA) represents 17% of the world's land, 14% of the population, and 1% of the gross domestic product. Previous reports have indicated that 81/500 African neurosurgeons (16.2%) worked in SSA—i.e., 1 neurosurgeon per 6 million inhabitants. Over the past decades, efforts have been made to improve neurosurgery availability in SSA. In this study, the authors provide an update by means of the polling of neurosurgeons who trained in North Africa and went back to practice in SSA.

METHODS Neurosurgeons who had full training at the World Federation of Neurosurgical Societies (WFNS) Rabat Training Center (RTC) over the past 16 years were polled with an 18-question survey focused on demographics, practice/case types, and operating room equipment availability.

RESULTS Data collected from all 21 (100%) WFNS RTC graduates showed that all neurosurgeons returned to work to SSA in 12 different countries, 90% working in low-income and 10% in lower-middle-income countries, defined by the World Bank as a Gross National Income per capita of ≤ US\$995 and US\$996–\$3895, respectively. The cumulative population in the geographical areas in which they practice is 267 million, with a total of 102 neurosurgeons reported, resulting in 1 neurosurgeon per 2.62 million inhabitants. Upon return to SSA, WFNS RTC graduates were employed in public/private hospitals (62%), military hospitals (14.3%), academic centers (14.3%), and private practice (9.5%). The majority reported an even split between spine and cranial and between trauma and elective; 71% performed between 50 and more than 100 neurosurgical procedures/year. Equipment available varied across the cohort. A CT scanner was

ABBREVIATIONS CME = continuing medical education; DRC = Democratic Republic of Congo; GNI = Gross National Income; LMIC = low- and middle-income countries; RTC = Rabat Training Center; SSA = sub-Saharan Africa; WFNS = World Federation of Neurosurgical Societies.

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available to 86%, MRI to 38%, surgical microscope to 33%, endoscope to 19.1%, and neuronavigation to 0%. Three (14.3%) neurosurgeons had access to none of the above.

CONCLUSIONS Neurosurgery availability in SSA has significantly improved over the past decade thanks to the dedication of senior African neurosurgeons, organizations, and volunteers who believed in forming the new neurosurgery generation in the same continent where they practice. Challenges include limited resources and the need to continue expanding efforts in local neurosurgery training and continuing medical education. Focus on affordable and low-maintenance technology is needed.

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KEYWORDS sub-Saharan Africa; neurosurgery training; global neurosurgery; low- and middle-income countries; LMIC

ACCORDING to current data, there are an estimated 49,940 neurosurgeons in the world with a great disparity in ratio among countries, ranging from 0 to 59 per 1 million people.¹¹ Sub-Saharan Africa (SSA) represents 17% of the world's land, 14% of the world's population, and 1% of the world's gross domestic product.^{22,25} Reports from the beginning of the 21st century indicated that only 81 (16.2%) of the 500 African neurosurgeons worked in SSA, with a neurosurgeon ratio of approximately 1 per 6 million people.⁴⁻⁷ This limitation in workforce was highlighted as one of the major barriers to neurosurgical care.^{2,3}

To address this issue, efforts were made to improve neurosurgery training in SSA. Among these efforts, the World Federation of Neurosurgical Societies (WFNS) Rabat Training Center (RTC) was established in 2002 after an agreement between the Mohammed V University, the Faculty of Medicine and Pharmacy of Rabat, and the WFNS Foundation.⁴ Over the past 16 years, this center allowed for full or partial training of many African neurosurgeons.^{7,8} Through this passion for training engendered by the WFNS initiative, the number of neurosurgeons in SSA increased 5-fold over the past 18 years, from 79 in 1998 to 369 in 2016.⁶

To follow up on the local integration and the challenges the WFNS RTC African neurosurgeons face after their return to SSA, we surveyed all fully trained neurosurgeons. In this study, we provide the data relative to this cohort.

Methods

Neurosurgeon Cohort

Over the past 16 years, neurosurgery residents from 18 countries in SSA joined the WFNS RTC.⁶ Twenty-two neurosurgery residents had a formal 5 years of full training; among these was RTC's first trainee, Dr. Mudjir Didier Balanda from the Democratic Republic of Congo (DRC) who passed away in 2012. An additional 7 residents include 6 trainees from Nigeria and 1 from Tanzania who had a combined training and graduated from the home universities and regional surgical colleges. This methodology explains differences with previously reported information.⁸

Survey Specifics

Using an online SurveyMonkey poll, we administered a voluntary neurosurgery-specific survey to the last 21 con-

secutive neurosurgeons who had received formal training from the WFNS RTC.

Key outcome measures included demographic information, country neurosurgical workforce, access to imaging modalities and instruments, volume, and breakdown of neurosurgical cases. The survey remained open for 30 days starting from October 29, 2018. Three neurosurgeons who could not access it online were surveyed interactively by phone with the same questions. The number of neurosurgeons in each country was provided by the neurosurgeons who participated in the survey with data pertinent to October 2018. In case of information discrepant from previously published data or between 2 neurosurgeons from the same country, the survey responders were contacted (C.K., I.M.G.) and asked to provide additional documentation until such discrepancy was resolved.

Statistical Analysis

Descriptive statistics are reported either as the total number of events with valid percentage or as an average. An unpaired Student t-test was used to analyze the data. A p value < 0.05 was considered significant. Data were analyzed using commercially available Microsoft Excel software.

Results

Demographic Data

Table 1 summarizes the cohort's and countries' characteristics. All (100%) fully trained neurosurgery residents who graduated from the WFNS RTC replied to the survey (N = 21). Twenty of 21 surveys had complete responses (95.2%). All neurosurgeons surveyed (100%) returned to work in 12 different SSA countries: Benin, Burkina Faso, Cameroon, Republic of Congo, DRC, Guinea Conakry, Mali, Mauritania, Niger, Rwanda, Togo, and Uganda. The age range was 30–59 years, with 52% of the respondents between 30 and 39 years. Sex was predominantly male, with 2/21 women (9.5%). Trainees were predominantly from francophone countries (90.5%). The reported number of neurosurgeons per country listed by the respondents is shown in Table 1.

Upon completion of training, 90% of graduates work in low-income and 10% in lower-middle-income countries, defined by the World Bank (2019) as a Gross National Income (GNI) per capita of ≤ US\$995 and US\$996–\$3895, respectively.²⁰ The cumulative population in the geograph-

TABLE 1. Characteristics of WFNS RTC neurosurgery graduates and countries

Country	No. of WFNS RTC Graduates	Total No. of NS Surveyed	Sex	Country's Total No. of NS	Population (M)*	Area (mi ²)†	Country's NS/Inhabitant Ratio
Benin	3	3	M	10	11.485	44.310	1:1.118
Burkina Faso	1	1	M	5	19.751	105.869	1:9.595
Cameroon	1	1	M	16	25.216	183.569	1:1.576
Republic of Congo	2	2	M	5	5.245	132.047	1:1.052
DRC	2	2	M	7	84.069	905.400	1:11.61
Guinea Conakry	2	2	M, F	5	12.72	94.926	1:2.544
Mali	3	3	M	13	19.077	478.800	1:1.467
Mauritania	1	1	M	10	4.403	397.700	1:0.44
Niger	1	1	M	8	22.442	489.700	1:2.685
Rwanda	1	1	F	6	12.301	10.169	1:2.035
Togo	3	3	M	6	7.890	21.925	1:1.3
Uganda	1	1	M	11	42.723	93.065	1:3.896
Total	21	21	19 M, 2 F	102	267.322	2957.480	1:2.620

NS = neurosurgeons.

* Per 2018 <https://data.worldbank.org/country/> (World Bank, ref. 25).† Per <https://www.google.com/> and World Bank, ref. 25.

ical areas in which they practice is 267 million, with a total of 102 neurosurgeons reported, resulting in 1 neurosurgeon per 2.62 million inhabitants.

Employment, Neurosurgical Caseload, and Available Resources

Table 2 summarizes the cohort's professional experience. Upon return to SSA, WFNS RTC graduates were employed in public/private hospitals (62%), military hospitals (14.3%), academic centers (14.3%), and private practice (9.5%). There was no statistical difference between their completion of residency and years in practice, signifying a prompt employment upon return.

Neurosurgical caseload showed that 71% of neurosurgeons performed between 50 and more than 100 neurosurgical procedures per year, with the majority reporting an even split between spine and cranial and between trauma and elective (Fig. 1).

Equipment available varied across the cohort (Table 3). A CT scanner was available to 86% of neurosurgeons and MRI to 38%. Only 33% of the surveyed neurosurgeons had access to a surgical microscope, and only 4 (19.1%) had an endoscope. Neuronavigation was not available to any neurosurgeons (0%). Additionally, 3 (14.3%) neurosurgeons had access to none of the above.

Discussion

Africa as a continent has been facing heavy challenges in terms of healthcare over the last decades. Surgery in general has been left behind for many years, and neurosurgery has particularly been overlooked and falsely considered as expensive and luxury care.^{3,4,11,18} In 2015, the Lancet Commission on Global Surgery estimated that 143 million additional surgical procedures are needed in low- and middle-income countries (LMIC) each year,^{10,19} and further studies revealed that approximately 15% of those

surgical procedures are neurosurgical.^{13,15,16} Neurosurgical conditions affect people worldwide, regardless of age, sex, income, or level of education. These conditions include traumatic brain injuries, degenerative diseases, and congenital disorders, which seem to affect even more people in low-income settings and in Africa. These diseases altogether cause more than 6.8 million deaths per year, the same number as that of deaths caused by AIDS, tuberculosis, and malaria.^{11,18} Numbers show that an estimated 5 million essential neurosurgical cases go untreated in LMIC each year and that more than 23,000 more neurosurgeons are needed in these countries by 2030 to address this issue.^{1,3,13}

Neurosurgery arrived in Africa a bit later than in Europe and North America, especially in the sub-Saharan

TABLE 2. Professional work experience

Professional Experience & Workplace	No. of NS (N = 21)	%
Employment type		
Public hospital	7	33.3%
Public & private	6	28.6%
Private practice	2	9.5%
Military hospital	3	14.3%
Academic institution	3	14.3%
Yrs since residency		
1 to <5	16	76.2%
≥5 to <10	3	14.3%
≥10	2	9.5%
Yrs in practice		
1 to <5	15	71.4%
≥5 to <10	4	19.1%
≥10	2	9.5%

FIG. 1. Pie charts summarizing the types of neurosurgical cases. **A:** Elective versus trauma. **B:** Cranial versus spine. **C:** Summary of yearly caseload.

region; neurosurgical training came even later.^{4–6} This delay is a combination of many factors. These include the historical colonial context of Africa and the choice of the majority of African countries, after their independence, to train their young doctors—including neurosurgeons—outside of Africa (in Europe and North America), which resulted in significant brain drain during the second half of the 20th century.⁶ In addition, the paucity of existing neurosurgeons, the failure to integrate neurosurgical training into existing surgical curricula due to limited equipment and supplies to support diagnostic imaging capabilities, and an inadequate surgical infrastructure restricting the few available neurosurgeons in providing adequate care, along with the limited financial ability of patients.

Our study shows that only approximately one-third of neurosurgeons surveyed perform more than 100 cases per year. Although our survey was not powered to explore the causes of this fact, it is plausible to suggest that these well-trained neurosurgeons cannot be used to their full potential without the infrastructure needed to increase their reach. Another important factor is the reality that in countries with low income, patients with neurosurgical conditions do not have the means to care for themselves, and they present at very late stages—making the treatment difficult and increasing morbidity and mortality.^{1–5}

Previous publications on African neurosurgery have shown inequality in terms of neurosurgeon distribution in the African continent, with most of the practitioners being located in North Africa.⁴ Reports from the beginning of the 21st century indicated that only 81 (16.2%) of all 500 African neurosurgeons worked in SSA with a rate of approximately 1 neurosurgeon per 6 million inhabitants,

and that approximately 70.8% were in North Africa.^{4–6,8} The realities of such a misdistribution made the training in neurosurgery even more difficult. Training did not exist in many countries until the late 1990s. Most senior African neurosurgeons trained abroad, and some were able to establish neurosurgical training in their home countries. Our study shows a considerable improvement in alignment with more recent reports.^{6,20} Using 2018 population data we report 102 fully trained neurosurgeons working in 12 SSA countries, corresponding to a ratio of 1 neurosurgeon per 2.62 million people.²² The difference in the ratio of neurosurgeons/population compared to published reports^{7,8,20} can be explained by different facts. First, our study is pertinent to only 12 of the 46 United Nations–defined SSA countries, namely the 12 where the WFNS RTC graduates practice. Second, our study was conducted in 2018 and the 2018 population data were used as published by the World Bank.²⁵ Third, the number of neurosurgeons in each country is self-reported by each neurosurgeon or group of neurosurgeons residing in that country.

Neurosurgical Education and Training in SSA

Providing a comprehensive and effective neurosurgical service requires adequate numbers of well-trained, well-resourced, and well-motivated neurosurgeons, but many factors still make this practice difficult in SSA: geographic isolation of many communities, bureaucratic resistance, political instability, constant socioeconomic changes, and high rates of poverty and illiteracy in rapidly growing populations.^{2,15,16,18} Many efforts have been made to improve neurosurgery training in SSA over the last 2 decades.⁶ Our

TABLE 3. Available operating room equipment

Type of Equipment	No. of NS w/ Access (N = 21)	%
CT scanner	18	85.7%
MRI	8	38%
Microscope	7	33.3%
Endoscope	4	19.1%
Neuronavigation	0	0%
Ultrasound	2	9.5%
None	3	14.3%

paper shows that the vision of the WFNS RTC to train neurosurgeons in the same continent in which they would practice was very successful, with 100% of the trainees retained within the African continent and 90% of them working in low-income countries in SSA.

The success of the WFNS RTC, the permanent support of the WFNS, and the engagement of senior African neurosurgeons led to the creation of other WFNS Regional Training Centers in Africa (Algeria, Kenya, and Senegal).^{6–8} At the same time, the number of African countries involved in a national neurosurgery training program moved from 5 in 1998 to 21 in 2018; among them 16 in SSA countries. Some of these training programs in SSA countries are still integrated with surgical education. Many other organizations—private and/or with government/university support—have also contributed to neurosurgeon training in Africa, including the Africa 100 Project.^{6,17} Hopefully, all of these concerted efforts will continue to result in an increased number of trained African neurosurgeons.

Resource Availability

Neurosurgical practice highly depends on the availability of surgical equipment, especially in LMIC where resources are limited. The WFNS Foundation has been providing basic instruments to young neurosurgeons starting their career, with a positive influence on their neurosurgical practice. Our study shows that only 1 in 3 neurosurgeons has access to a surgical microscope. This clearly is a limiting factor to the types of neurosurgical procedures that can be performed and poses questions about safety. Imaging modalities like CT and MRI are also essential tools in neurosurgery. These are not luxury items; they are needed to provide basic care in emergency settings for diagnosis of all neurotrauma cases, infections, and acute stroke. Multiple studies have shown that the advent of CT imaging reduces mortality in the setting of trauma and infections, which are more frequent in lower-income settings.^{9,12,14,23} Lack of timely imaging leads to delay in surgical management and poor patient outcomes.^{18,23} Creating awareness of such need and involving all stakeholders, including the local governments, is essential to ensure sustainability and durability of instrument provision.²⁴

Future Directions and Opportunities

The components of each well-functioning health system include access to essential medical care, adequate health-care delivery by means of sufficient workforce, and health

information resources. These components are the same for neurosurgical care delivery. Thanks to the great efforts of the WFNS and many other organizations the workforce in SSA has been substantially increased. A strategy to increase the training capacity in all existing training centers in Africa (21 centers), with the goal to raise the current number of neurosurgeons in SSA to 369 has recently been proposed.⁶ In addition to increasing the neurosurgical workforce, there is still a lot of work to be accomplished, including creating an adequate infrastructure allowing African-trained neurosurgeons to function and progress as neurosurgeons. The existing barriers within the health systems must be addressed in order to allow a trained neurosurgeon to fulfill his/her responsibilities. There is also a need for developing other supportive specialties like neuroradiology, neuro-intensive care, neuro-anesthesia, neuropathology, and nursing—on which neurosurgery practice tightly depends. Recognizing these needs that must be addressed is an important step to implement efficient and quality neurosurgery delivery systems in LMIC.^{1,2,18}

Our study shows that 90% of WFNS RTC graduates work in countries with a GNI per capita of $\leq$ US\$995. It is therefore clear that affordable continuing medical education (CME) should be a goal for the next decade. It is very unlikely that such neurosurgeons can travel abroad to participate in international meetings in which the registration fee might be the equivalent of 50% of the annual GNI. A concerted effort of world organizations to work at providing such training could be beneficial to all parties. On the other hand, it is time to develop and expand an African CME program based on local pathology and working environment. The WFNS-RTC course for young African neurosurgeons,^{6,7} organized every year since 2007, should be duplicated by other African neurosurgical societies in collaboration with the WFNS and other international institutions.

The lack of availability of neurosurgical equipment can be an opportunity for industry to collaborate with local governments. Following the Lancet Commission Report, in 2015 the World Health Assembly 68 passed the A68.15 resolution²⁶ titled *Strengthening Emergency and Essential Surgical Care and Anaesthesia as a Component of Universal Health Coverage*. This proposition advocates for inclusion of surgical care in long-term governmental planning, and asserts that the problem is not solvable as a separate issue from social conditions or general healthcare planning. Moreover, surgical care is directly part of the 17 sustainable development goals action plan adopted by the United Nations in 2015.²¹ In 2018, during the 72nd World Health Assembly, a further resolution was passed, called *Emergency Care Systems for Universal Health Coverage: Ensuring Timely Care for the Acutely Ill and Injured*, addressing the staggering proportion of avoidable traumatic and surgical deaths.²⁷ As local governments are addressing these resolutions, the involvement of physicians and the medical industry will be essential to move healthcare to the next step.

Conclusions

Neurosurgery availability in SSA has significantly improved over the past 2 decades thanks to the dedication of

senior African neurosurgeons, organizations, and volunteers who believed in forming the new neurosurgery generation in the same continent where they practice. Challenges and opportunities include limited resources and the need to continue expanding efforts in local neurosurgery training to reach the 2030 strategy goal as well as CME offerings to allow progression of these well-trained neurosurgeons. A focus on affordable and low-maintenance technology is needed. Concerted educational efforts over the next decade should focus on further establishing neurosurgical subspecialty care.

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Disclosures

Dr. Germano: Brainlab and Integra (consultant), and Elminda (stock owner); neither is in direct conflict with this study. Dr. Servadei: Finceramica and Integra (consultant).

Author Contributions

Conception and design: Karekezi, Germano. Acquisition of data: Karekezi, Germano. Analysis and interpretation of data: Karekezi, Germano. Drafting the article: Karekezi, Germano. Critically revising the article: Karekezi, El Khamlichi, Servadei, Germano. Reviewed submitted version of manuscript: Karekezi, El Ouahabi, El Abbadi, Ahokpossi, Ahanogbe, Berete, Bouya, Coulibaly, Dao, Djoubairou, Doleagbenou, Egu, Ekouele Mbaki, Kinata-Bambino, Habibou, Mousse, Ngamasata, Ntalaja, Onen, Quenum, Seylan, Sogoba, Servadei, Germano. Approved the final version of the manuscript on behalf of all authors: Karekezi. Study supervision: Germano.

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