Neurosurgery in East Africa: Foundations

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This article is the first in a series of 3 articles that seek to provide readers with an understanding of the development of neurosurgery in East Africa (Foundations), the challenges that arise in providing neurosurgical care in developing countries (Challenges), and an overview of traditional and novel approaches to overcoming these challenges to improve healthcare in the region (Innovations). We review the history and evolution of neurosurgery as a clinical specialty in East Africa. We also review Kenya, Uganda, and Tanzania in some detail and highlight contributions of individuals and local and regional organizations that helped to develop and shape neurosurgical care in East Africa. Neurosurgery has developed steadily as advanced techniques have been adopted by local surgeons who trained abroad, and foreign surgeons who have dedicated part of their careers in local hospitals. New medical schools and surgical training programs have been established through regional and international partnerships, and the era of regional specialty surgical training has just begun. As more surgical specialists complete training, a comprehensive estimation of disease burden facing the neurosurgical field is important. We present an overview with specific reference to neurotrauma and neural tube defects, both of which are of epidemiologic importance as they gain not only greater recognition, but increased diagnoses and demands for treatment. Neurosurgery in East Africa is poised to blossom as it seeks to address the growing needs of a growing subspecialty.

INTRODUCTION

Neurologic surgery is an advanced subspecialty of surgery, and its expertise is needed in both rural and urban areas, and in rich and poor communities. With an increase in motor vehicle traffic and resulting crashes, frequent injuries, increased recognition and awareness of congenital defects and brain tumors, the need for access to neurologic surgery has increased dramatically. In parallel, with advances in operative equipment, imaging modalities, and sophisticated perioperative care, the ability to diagnose and treat these conditions with minimal risk has improved dramatically. The availability of neurosurgical skill and resources varies between communities, regions, and countries around the world. In this upcoming series

Key words
- Disease burden
- East Africa
- Low-middle income countries
- Neurosurgery

Abbreviations and Acronyms

ASEA: Association of Surgeons of East Africa
COSECSA: College of Surgeons of East, Central and Southern Africa
CT: Computed tomography
DALY: Disability-adjusted life year
ECSA: East, Central, and Southern Africa
ETV: Endoscopic third ventriculostomy
FIENS: Foundation for International Education in Neurological Surgery
LMIC: Low and middle-income country
MCS: Member of College of Surgery
MMC: Muhimbili Medical Center
MOI: Muhimbili Orthopedic Institute
MRI: Magnetic resonance imaging
MUSM: Makerere University School of Medicine
NED: Neurosurgery, Education and Development
NTD: Neural tube defect
PAANS: Pan African Association of Neurological Sciences
TBI: Traumatic brain injury
WFNS: World Federation of Neurosurgical Societies
WHO: World Health Organization

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of articles, we focus on East Africa and hope to provide a brief overview of several aspects of neurological surgery in the region. From the late 1960s, when the first modern neurosurgical procedures were performed, to the present day—as neurosurgeons are trained locally—the region has undergone great political, economic, and social change. The practice of medicine has also advanced but is severely resource deficient. Although self-sufficiency is closer than ever before, challenges remain; fortunately, governmental and nongovernmental organizations continue to work to overcome them.

This article is the first in a series of 3 that seeks to provide readers with an understanding of the current state of neurosurgery in East Africa (Foundations), the challenges that arise in providing surgical care in underdeveloped countries (Challenges), and what is being done to overcome these challenges and to improve healthcare in these areas (Innovations). Despite being distinct, the 3 articles will bridge into each other and offer a full view of the practice of neurosurgery in East Africa. In this article, we review the history and current state of neurosurgical care and the burden of neurosurgical diseases in East Africa.

HISTORY OF MODERN NEUROSURGERY

Harvey Cushing (1869–1939), an American neurosurgeon, devised basic operating techniques and instruments for performing brain surgeries, and he is widely considered the father of "modern neurosurgery." The post-Cushing era ushered in advanced neurosurgical procedures, including minimal access surgery, aneurysm clipping and coiling, all with dramatically reduced rates of mortality. Some important advances in the field of basic neurosurgery, more so as they pertain to the development of the field in low- and middle-income countries (LMICs), are noted here briefly. In the 1950s and 1960s, the use of the operating microscope pushed neurosurgery into the era of microsurgery, thus making it possible to perform complex surgeries with minimal complications. The next development responsible for advancing the field of neurosurgery was the development of computed tomography (CT). The first brain CT was performed in 1971, and it became commercially conventional over the next 2 decades. CT was followed by the development of clinical magnetic resonance imaging (MRI) in the late 1970s. In 1974, in the clinical neurotrauma arena, Teasdale and Jennett[1] described the Glasgow Coma Scale as the most practicable and reliable measurement of impaired consciousness in trauma patients. This was one of the first steps in the establishment of a uniform assessment of comatose patients with interobserver reliability and reproducibility, thus spurring the concept of specialized neurosurgical nursing care. These milestones in neurosurgery were first established in Western countries and then exported to other parts of the world with variable success and penetration.

SURGERY AND NEUROSURGERY IN AFRICA

Trephination of the skull is one of the oldest neurosurgical procedures performed, and it has been documented as a local traditional practice in several African sites, such as the Kisii tribe of Kenya.[2] Craniotomists, called *ababari ernetwe* (translation: surgeons of the skull) members of the Kisii tribe, performed trephination for 2 primary conditions: acute cranial trauma and posttraumatic headache.[2] This procedure has remained prevalent among some tribes until recently. Even with advancement of surgical techniques, a large majority of the population does not have access to modern neurosurgery and are at continued risk of neurosurgical diseases.

Historically, surgeons in East Africa fell into 5 categories.[3] The most numerous were government surgeons, exclusively Britons or of British descent, and fellows of the Royal College. Next were surgeons in private practice, either British-trained or of Asian descent. The third largest group was surgeons working for industries, who also had British qualifications. Fourth were surgeons in missionary hospitals. The least numerous were university professors—only a handful at the time—all of whom were at Makerere University School of Medicine (MUSM) in Kampala, the only such school in Africa at the time. Because of suspicion of non-native practices and a lack of widespread treatments offered by these doctors, the local population kept traditional medical practices alive.

Modern neurosurgery as an independent specialty originated in Cape Town, South Africa, after the return of Hermann de Villiers Hammann from his training at the University of Munich, Germany, in 1946. De Villers Hammann became a full honorary consultant in 1949, and he lectured at the University of Cape Town and Stellenbosch while continuing to learn newer techniques in America and Europe. Dr. Jacquez de Villiers became the first full-time neurosurgical chief-of-staff in 1970 and the first Professor of Neurosurgery in 1976. During this time, there were about 20 neurosurgeons in South Africa.

Meanwhile, neurosurgery also developed rapidly in Egypt where several Egyptian and visiting neurosurgeons practiced briefly during 1949–1956. Dr. Arne Torkildson from Norway was appointed as a visiting professor during 1951–1952 in Cairo, and he was later joined by Dr. Osman Sorour, who had trained for 2 years in Britain. Dr. Harvey Jackson, who trained at Queen Square followed, and in 1955, a 35-bed neurosurgical department was established in Cairo, and Dr. I. Shafei became its Chairman in 1957. In 1961, Prof. H. Olivecrona from Stockholm came to establish a modern setup, and specialized nursing and intensive care staff members were trained. By 1967, a full complement of neurologists, neurosurgeons, neuroanesthetists, neuroradiologists, and neuropathologists was assembled.

South Africa and Egypt remained the centers of neurosurgery in Africa and were home to the only neurosurgeons on the continent. In East Africa and Central Africa, neurosurgery remained scarce. In 1982, a review of pituitary tumors at Muhimbili Medical Centre, Tanzania, included a commentary: "The only help for patients with neurosurgical problems is from referral overseas."[4] In 1980, the ratio of neurosurgeons to the population was 1:75,000 in the United States, 1:140,000 in Canada, 1:400,000 in the United Kingdom, and 1:3,000,000 in Africa, which improved to 1:2,000,000 by 1990. However, 15 countries in Africa with a cumulative population greater than 46,000,000 had no neurosurgeons.

The most recently published data from 2004 for the number of neurosurgeons per region is as follows: 8856 in Europe, 6546 in the United States, and 565 in Africa. Of those in Africa, 485 are in Egypt, Tunisia, Morocco, Algeria, and South Africa. In East Africa, there are 27 neurosurgeons for 270 million people (ratio of 1:10 million).[5]

NEUROSURGERY IN EAST AFRICA

Kenya

In the late 1940s, the modern era of neurosurgery in Kenya was led by Dr. J.F. Jarvis, who performed the first neurosurgical procedures in the country, such as anterior third ventriculostomies for hydrocephalus and anterior encephalocele repair.[6] In 1967, Dr. Renato Ruberti joined the staff at Kenyatta National Hospital after graduating from the University of Padua, Italy, and he is credited with founding neurosurgery in Kenya. In 1974, the Division of Neurosurgery was created as a separate division of the Department of Surgery by Indian neurosurgeon Dr. Jawahir Dar. Dr. G.M. Sande was the first locally trained surgeon to be selected for neurosurgical training. Among the contemporary neurosurgeons in Kenya, Dr. Mahmood Qureshi was the first one trained. Dr. Qureshi was selected for general surgery training in 1981–1985, and for neurosurgical training in 1986. After a year at the neurosurgical unit in Kenyatta National Hospital, he proceeded to Southampton, England, where he trained from August 1987 to December 1991. He obtained the FRCSEd(SN) as part of this training. Dr. Qureshi returned to Kenya in January as head of the neurosurgical unit at Kenyatta National Hospital in Nairobi, followed by David Oluoch-Olunya in 1999, who also trained in the United Kingdom. In 2007, a second neurosurgical unit was established at Eldoret under Dr. Florentius Koech.

Tanzania

The first step towards modern neurosurgery in Tanzania was the establishment of orthopedic and trauma services in 1971 at the Muhimbili Medical Center (MMC) by Prof. Philemon Sarungi.[7,8] At the time, orthopedic surgeons treated most of the cranial and spinal trauma. Over the next few years, several foreign neurosurgeons from Cuba, China, and the Soviet Union spent short stints practicing neurosurgery at MMC. Dr. H.J. Reulen, a former Professor and Chairman of Neurosurgery at University Hospital in Inselspital, Bern, Switzerland, and later in Munich, Germany, provided the impetus for the establishment of a neurosurgery program at MMC as the teaching hospital of the University of Dar es Salaam, creating a “sandwich” program with training split between national and international centers. He trained Dr. Simpert Kinunda, a plastic surgeon who later became the first Tanzanian with any neurosurgical training. Peter Kadyanji was the first fully trained Tanzanian neurosurgeon, and he joined MMC in 1985 after completing his training in the Soviet Union. Yadon M. Kohi followed in Kadyanji’s footsteps, graduating from Makerere University and Faculty of Medicine at University of Dar es Salaam. He obtained his FRCS in Ireland and Glasgow, and later was appointed as the Director General of the National Commission for Science and Technology. Dr. S.M. Mlay was the third neurosurgeon to join MMC in 1989, with a specialty in pediatric neurosurgery. Prof. Sarungi was instrumental in the subsequent establishment of Muhimbili Orthopedic Institute (MOI), which was opened in 1993 and later combined with MMC to become Muhimbili National Hospital, the national institute for neurosurgery, orthopedics, and traumatology. Several neurosurgeons have practiced at MOI since its founding, including Abednego Kinasha and Joseph Kahamba, who along with Prof. Laurence Museru, the medical director of MOI, played a pivotal role in laying the foundation for the training of the current generation of neurosurgeons in Tanzania. The core of the specialty expertise in the country is formed by the contemporary, locally trained neurosurgeons who provide neurosurgical training at MOI and neurosurgical care at several healthcare institutions around the country. There are currently 11 neurosurgeons in the country, of whom 8 are in public service (1:6 million population) in 3 hospitals. There are 4 neurosurgeons currently in training, and it is estimated that there will be 14 trained neurosurgeons by 2027 (1:5 million population). No dedicated neuroscience nurses or beds are available in the wards; however, there are 8 neurosurgical intensive care unit beds at MOI, and an additional 14 are planned at the proposed new hospital in Dar es Salaam, scheduled to be opened in 2018. There are 5 CT scanners and 3 MRI scanners available across the country, mostly in Dar-es-Salaam, the largest city in Tanzania.

Uganda

The Makerere University School of Medicine (MUSM) was established in 1924, and it is the oldest medical school in East Africa.[8,9] In the 1960s, each class had 100 students, which produced enough doctors to lead to specialization and the formation of new departments. Prof. V. Logue, then the head of the Hospital for Nervous Diseases, Queen Square, London, was invited by the government in 1968 to advise on the establishment of the first neurosurgical unit at Mulago Hospital. Upon Logue’s recommendation, Ian Bailey moved to Uganda and was instrumental in establishing the first neurosurgical unit in Uganda at Mulago Hospital in 1969, equipped with 54 beds for the department of neurosurgery and cardiothoracic surgery. Jovan Kiryabwire became the first indigenous Ugandan neurosurgeon and the first African neurosurgeon in East and Central Africa. He attended medical school at MUSM in Kampala and subsequently completed postgraduate training at the Royal College of Surgeons in Ireland and Scotland; he also trained at Queens Square with Prof. Logue. Dr. Dzintars Svenne and Dr. M. Kahwa both trained in the department, with the latter going on to become the dean of the new medical college of Western Uganda.

PROFESSIONAL ORGANIZATIONS OF SURGERY AND NEUROSURGERY IN EAST AFRICA

As surgical expertise and training evolved, the Association of Surgeons of East Africa (ASEA) was founded in 1950 in Nairobi, Kenya. ASEA was founded by member states of Kenya, Uganda, and Tanganyika (later merging with Zanzibar to become Tanzania).[10] The initial moves to form such an association began in 1945 after World War II, and came to fruition on November 9, 1950. Cliff Baimbridge was elected Chair, and Kirkaldy Willis acted as the Honorary Secretary. An annual meeting was held in either Nairobi or Kampala, eventually moving to smaller towns, spreading surgery into the rural areas. During one such meeting, Denis Burkitt presented his paper on “strange lumps he had noticed in African children,” later described as Burkitt lymphoma. In 1961, ASEA became a member of the International Federation of Surgical Colleges. Beginning in 1974, membership was extended to other countries starting with Zambia and subsequently Zimbabwe, Malawi, Mozambique, Ethiopia, and eventually Rwanda in 2008. In 1978, the first edition of the Proceedings of the Society was published, and in 1995 was replaced by the *East and Central African Journal of Surgery*, that is still published today. The Society also focused on the establishment of a second medical school in the region, since MUSM in Kampala was not intended to be able to train enough doctors for the region. ASEA also promoted the establishment of local surgical bodies in each country.

In 1986, plans were initiated to establish a regional College of Surgeons to award postgraduate degrees, to establish standards for postgraduate training, and to accredit new training programs. The college was established in 1999, and named the College of Surgeons of East, Central and Southern Africa (COSECSA) in 2001 with the college secretariat located in Arusha, Tanzania, where it remains today. In addition to the above goals, COSECSA also organizes training programs, examinations in various surgical disciplines, workshops, and local conferences and sets ethical standards for the practice of surgery. There has been extensive collaboration between ASEA, COSECSA, and the Royal College of Surgeons of Edinburgh, Ireland, and Great Britain to establish the college and training and exchange programs. An example of this cooperation is exemplified in the prestigious "Rahima Dawood Traveling Fellowship" that supports surgeons of distinction who are chosen to travel to the member countries of the Association to lecture, teach, and offer advice. Because of duplication of costs in running ASEA and COSECSA in parallel, the bodies were merged in 2007.

In addition, the Pan African Association of Neurological Sciences (PAANS) was established in 1972 and was composed of a neurologic and neurosurgical section. The neurosurgical section joined the World Federation of Neurosurgical Societies (WFNS) in 1973. Osman Sorour from Egypt was the first PAANS president in 1972; he also held office as Second Vice-President of WFNS from 1973 to 1977, and he was subsequently appointed Honorary President of WFNS in 1977. Similarly, Jacquez Charl de Villiers from South Africa and Sayed El Gindi from Egypt also became honorary presidents of WFNS in 1997. In 2005, a world congress of the WFNS was held in Africa, in Morocco for the first time. The *African Journal of Neurological Sciences*, the official journal of the PAANS, was established in 1982. Table 1 summarizes the various neurosurgical societies in East Africa and their goals.

NEUROSURGICAL TRAINING IN EAST AFRICA

Before the mid-1970s, postgraduate training in neurosurgery was mainly obtained in Great Britain and North America, with some local programs in Northern Africa and South Africa. In 1971, the National Postgraduate Medical College of Nigeria was established. In 1998, 13 members from different regions of Africa formed a World Health Organization (WHO) subcommittee under the chairmanship of Dr. Abdelslam El Khamlichi, to advance the development of neurosurgery in Africa. This led to the formation of several local and regional surgical societies around Africa, which routinely organized short educational courses for surgeons. The PAANS also organized several postgraduate educational courses, and it received support from the European Association of Neurosurgeons and the Royal College. With the growth of ASEA and COSECSA, and with the substantial experience of the first 2 generations of foreign-trained neurosurgeons and support from local governments, the education and training in neurosurgery have become organized in a systematic way.

Currently, there are 94 institutions in 10 member countries, and a few nonmember countries are accredited for neurosurgical training. A membership examination (Member of College of Surgery [MCS]) is offered to assess understanding of basic principles of surgery and of broader knowledge in general, which can be taken after 2 years of training. This allows for further specialist training, leading to fellowship status (Fellow of College of Surgery) after passing an accredited examination. Higher surgical training is available in general surgery, plastic surgery, urology, neurosurgery, cardiac surgery, orthopedics, otolaryngology, pediatrics, oral and maxillofacial, obstetrics and gynecology, ophthalmology, and anesthesiology. Neurosurgery requires 2 years of basic training followed by 4 years of dedicated neurosurgical training (Figure 1).

The first local neurosurgical training program, the Regional Neurosurgical Training Program of the East, Central, and Southern Africa (ECSA) region (NSTP-ECSA), was approved as a specialty program of COSECSA in 2005. NSTP-ECSA inducted its first 2 trainees in 2006, and it has become a key neurosurgical training program of the region. The training program has attained recognition as a Reference Training Site by the WFNS, the second such reference site after the Rabat Training Site in Morocco. Since its approval by the COSECSA Board, the program has graduated 10 local neurosurgeons from Kenya (4 neurosurgeons and 2 in training), Uganda (4 neurosurgeons), and Ethiopia (2 neurosurgeons). One Tanzanian trainee has passed the MCS-ECSA in December 2016, and he will commence his neurosurgical training at the Kenyatta National Hospital and the Aga Khan University Hospital in Nairobi, Kenya. The University of Nairobi introduced a second program in 2006, the Master of Medicine (M.Med.) program in neurosurgery and graduated their first 2 candidates in 2011. The M.Med. program is composed of higher surgical training at local institutions, followed by a fixed-term training period in a recognized partner foreign institution. Efforts are underway by COSECSA to standardize all training tracks and bring them under the aegis of one umbrella organization. Several standalone initiatives by various international educational institutions, as well as those sponsored by non-governmental organizations from North America and Europe, also support basic and specialist education and training. Some are limited to one-time "missions," whereas others, including our group from Weill Cornell Medicine and several more, have supported educational exchange and organized annual workshops for several years. These programs have resulted in providing young neurosurgeons with additional training that supplements their existing curricular education. These are detailed further in the article *Neurosurgery in East Africa: Innovations*.[14]

Two agencies have been extremely significant in the realm of outreach training programs for neurosurgeons in East Africa: The Foundation for International Education in Neurological Surgery (FIENS), and the Neurosurgery, Education and Development (NED) Foundation. FIENS and NED have led scores of teaching and surgical missions, and have greatly influenced the development of the NSTP-ECSA region.

Table 1. African Neurosurgical Societies

Name and Status of the Society	Description
Pan African Association of Neurological Science (PAANS): initial continental representative to WFNS	Founded in 1972, with the objectives of advancing neurologic sciences, promoting friendship, and exchanging ideas among practitioners of and people interested in neurologic sciences in Africa in particular and the world at large. Its official journal is the *African Journal of Neurological Sciences*.[11]
Continental Association of African Neurosurgical Societies (CAANS): current continental representative to WFNS	Founded in 2012 and recognized in 2013, when it replaced PAANS as the continent's representative at WFNS.[12]
Association of Neurosurgical Societies of Africa (ANSA): regional neurosurgical society	Founded in 2008 with the aim of training young African neurosurgeons, sustaining high standards in neurosurgery in Africa, and encouraging African research.[13]
AFNS African Federation of Neurosurgical Societies	Has several member countries in various regions of Africa: North Africa—Morocco, Egypt, and Tunisia West Africa—Nigeria and Ghana East Africa—Ethiopia, Kenya, Uganda, and Tanzania Southern Africa—Zambia and Rwanda

WFNS, World Federation of Neurosurgical Societies.

The overarching aim of the organizations, training programs, and missions is to develop neurosurgery as an independent field by training an adequate number of neurosurgeons who are evenly distributed in the region, and to address the growing burden of neurosurgical disease. At the same time, resource management is equally crucial in directing precious money into developing the necessary physical infrastructure, allied professions, and social resources. Ensuring that resources are properly attributed requires an estimation of the burden of disease faced by the neurosurgical profession in the region.

JUDGING THE BURDEN OF NEUROSURGICAL DISEASE IN EAST AFRICA

The global burden of disease is generally difficult to assess, which is particularly true for LMICs because of the lack of specific health data.[15-17] As a result, burden of disease estimates are often not based on gold-standard clinical diagnoses, but are extrapolated from less concrete methods, including modeling approaches with questionable reliability, applicability, and consistency.[15,16,18] The Global Burden of Disease Study 2015 provided by the Institute for

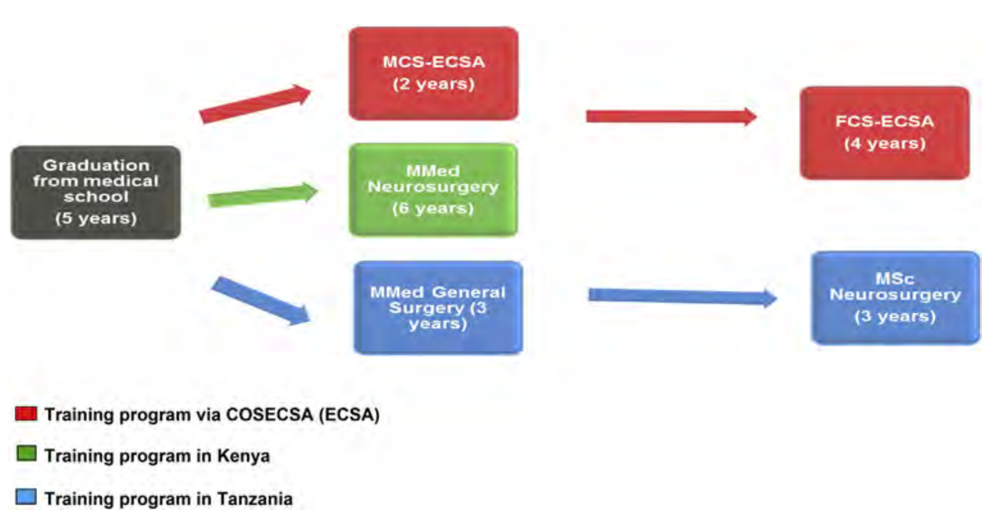

Figure 1. Educational pathways to becoming a neurosurgeon offered by different training programs in East Africa. MCS-ECSA, Member of College of Surgeons; FCS-ECSA, Fellowship of the College of Surgeons; M.Med, Master of medicine; MSc, Master of Science.

Health Metrics and Evaluation is a reliable source of the burden of neurosurgical disease. This study maps country-specific death or disability-adjusted life years (DALYs) data to International Classification of Disease categories.[19] Not surprisingly, according to this study injuries, —particularly transport injuries—have an enormous influence on the disease burden in East Africa, followed by neural tube defects.

A 2013 review of the Ministry of Health and Social Welfare in Tanzania emphasized the epidemiologic importance of road traffic injuries as a major cause of death and disability in East Africa.[20] The review noted that 10,162 road traffic accident-related deaths were reported, of which pedestrians accounted for one third. The most alarming observation was that since 2007, the number of road traffic injury−related deaths has been increasing by an average of 10% per year, and the number of road traffic injury−related injuries has been increasing by approximately 7% per year since 2007. A 2012 WHO report (country health statistics and global health estimates by WHO and United Nations partners) showed that road traffic injuries ranked ninth in the causes of death (2.7% of deaths) in Tanzania, just behind ischemic heart disease (also 2.7% of deaths). However, data from the 2012 SAVVY (SAmple Vital Registration with Verbal AutopsY) project, which were assumed to be more accurate, reported that injuries were associated with 4% of deaths in children younger than 5 years, and 9% of deaths in individuals 5 years of age and older in Tanzania.

Because there is overlap in surgical disease that is not accounted for in the classification by surgical subspecialty, the measured incidence may still be understated.[20] The 2015 *Lancet* Commission report estimated that surgical conditions account for 28%−32% of the overall global burden of disease.[21] The necessity for surgery, however, varies between regions depending on disease patterns, social determinants, and the availability and usage of medical care.[22] In a well-resourced health system, operations are conducted for more than 80% of musculoskeletal disorders, approximately 60% of neoplasms, 45% of transport injuries, and approximately 10% of neurologic disorders in patients admitted to a hospital.[23] For instance, a disease that might not require surgical treatment in a country with a strong primary healthcare system might not receive the same quality care in an LMIC because of the lack of medical resources, and therefore progress to a stage at which surgical intervention is required.

Rose et al[23] reported data on the minimum total need and the unmet need for surgery in an epidemiologic region defined by the Global Burden of Disease study. The estimated total need for the eastern sub-Saharan Africa region with a population of 356 million was 6145 surgeries per 100,000 population, and the estimated unmet need was 4935 per 100,000 population, which is the second highest unmet need worldwide behind western sub-Saharan Africa. According to a recently published report, an estimated 16.9 million lives (i.e., 32.9% of all deaths worldwide) were lost from conditions that required surgical treatment in the year 2010.[21] Thus, annual death rates owing to lack of surgical care far exceed annual death rates owing to HIV/AIDS, tuberculosis, and malaria together (1.46 million, 1.20 million, and 1.17 million, respectively).[24]

Another way to exemplify the burden of neurosurgical disease in a certain region is by a structured literature review. Therefore, the authors conducted a literature search on the National Center for Biotechnology Information Database (Pubmed/MEDLINE) on October 7, 2016, using the keywords "prevalence," "neurosurgery," and "East Africa." Of the resulting 64 hits, 35 publications were reviewed after the exclusion of articles that did not investigate neurosurgical conditions or include any helpful epidemiologic information, and after inclusion of articles that were extracted from citations in the primary articles (**Table 2**).

All the articles were published between 1993 and 2016, but most were published in the last 10 years. The country of origin of the articles was Uganda, Kenya, Tanzania, or Ethiopia, plus one article based in Rwanda. Most of the studies had a retrospective study design, and 7 studies included prospective cohorts. The number of patients per investigated cohort ranged from 30 to 9991. Studies were then divided into 4 groups:

- Studies with an epidemiologic study design (n = 5 studies)
- Studies that focused on neurosurgical conditions (n = 10)
- Surgical series with mixed neurosurgical conditions (n = 4)
- Surgical series with only 1 neurosurgical condition (n = 16)

In decreasing frequency, neurosurgical conditions that were investigated by the studies included hydrocephalus, neural tube defects (NTDs), traumatic brain injury (TBI), spine or spinal cord injury, brain and spine tumors, and degenerative conditions.

The studies provided epidemiologic information on the overall neurosurgical disease burden in East Africa and the burden of individual neurosurgical conditions. **Figures 2** and **3** show different patients being treated for TBI and spine injury in a rural Tanzanian hospital setting.

OVERALL EPIDEMIOLOGY OF NEUROSURGICAL CONDITIONS IN EAST AFRICA

The studies by Maier and coworkers investigated the prevalence of neurological and neurosurgical conditions in cohorts of patients that received a cranial CT or MRI scan in rural or urban areas in Tanzania.[25,27] In their first study, the authors found the most common reasons to undergo cranial CT or MRI in the urban setting were stroke (there was no differentiation between ischemic and hemorrhagic stroke), extracranial infection, cerebral atrophy, and brain tumors, whereas the most common diagnoses in the rural setting were neurotrauma, stroke, and cerebral infections or infestations.[27] The most striking difference was in the higher frequency of cerebral infections and hydrocephalus in rural areas. One explanation for this difference could be the higher rate of HIV positive patients in rural areas who were predisposed to cerebral infection because of their condition. In addition, cerebral infections are known to be associated with the development of hydrocephalus.[22] The second study by Maier emphasized the effects of TBI on the overall burden of neurosurgical disease in East Africa, particularly in rural areas.[25] The authors found the prevalence of TBI to be 34.2% and 21.9% in the cohort of patients who underwent cranial CT in rural and

Table 2. Literature Review

References	Location	Type of Study	Number of Patients per Cohort	Neurosurgical Condition and Prevalence	Supplemental Epidemiologic Information	Observed Period	Percentage of Surgical Patients	Mortality
Epidemiologic study								
Maier D 2014[25]	Tanzania (Manyara and Dar es Salaam)	Retrospective	680 with cCT	TBI prevalence: 21.9% in urban setting and 34.2% in rural	Male:Female ratio: 2.21:1 urban, 5.68:1 rural Mean age: 40.5 urban, 33.7 rural	Rural: 4 years; Urban: 3 years	N/A	N/A
Kiboi JG 2011[26]	Nairobi, Kenya	Retrospective	608 with traumatic intracranial hematoma	Traumatic intracranial hematoma	89.3% male, 10.7% female patients 49% age 26–45 years; causes of injury: predominantly assault (48%) Mean age: 35.55 years	10 years	73.5%	N/A
Winkler AS 2010[22]	Northern Tanzania	Prospective	151 (neurosurgical)	TBI>spine TB>NTD>cerebral lesion>hydrocephalus	1.7% of overall admissions for neurosurgical conditions	8 months	100%	10.6% overall neurosurgery; 54% cerebral lesion
Maier D 2010[27]	Tanzania (Manyara and Dar es Salaam)	Retrospective	3238 with cCT/ cMRI	Urban setting: primarily stroke or extracranial infection; Rural setting: primarily trauma or stroke	Median age: 32 years rural and 48 years urban Rural: 7.0% HIV positive; Urban: 2.9% HIV positive	Rural: 3 years for cCT Urban: 4 years for cCT, 3 years for MRI;	N/A	N/A
Zellner H 2010[28]	Tanzania (Manyara and Dar es Salaam)	Retrospective	1268 with spinal CT/MRI	30% of patients in rural area: changes consistent with infections 3 radiological classifications: extradural-extramedullary pathologies; intradural-extramedullary pathologies; intramedullary pathologies	Mean age 39.8–46.6 years (rural vs. urban setting)	Rural: 3 years; Urban: 4 years.	N/A	N/A
Study focused on neurosurgical conditions								
Nkusi AE, 2016[29]	Kigali, Rwanda	Prospective	4	Cervical spine, spinal cord injury; delayed treatment	4 patients with missed/delayed diagnosis - 3 male, 1 female; age range 23–46 years	12 months	100%	0%
Biluts H 2015[30]	Addis Ababa, Ethiopia	Cross-sectional study	385	Spine or spinal cord injury	Mean age: 32.8 years; mean duration for presentation: 4.3 days; causes of injury: Fall>RTI; predominantly (33%) cervical injuries; predominantly ASIA A	4 years	80%	8.3%
Tran TM 2015[31]	Kampala, Uganda	Retrospective	120	Severe TBI; incidence: 89/ 100,000	Motorcycle accident leading cause of severe TBI; males 15–29 years old comprised the predominant demographic (42.5%)	12 months	N/A	25.8%
Ochieng N 2015[32]	Nairobi, Kenya	Retrospective	53 with positive CSF culture	VP-shunt infection	68% of infections in patients < 6 months old; 79% within 2 months after surgery; 40% gram-negative bacteria; Patient ages ranged 1 month to 20 years; 81% of the cases were in < 1 year old	1.8 years	42% (had new VPS inserted after the infection cleared)	4%

ASIA, American Spinal Injury Association; CBR, community based rehabilitation; cCT, cranial computed tomography; cMRI, cranial magnetic resonance imaging; CSF, cerebrospinal fluid; DALY, disability-adjusted life year; EC, encephalocele; ETV, endoscopic third ventriculostomy; HIV, human immune deficiency; MMC, myelomeningocele; MVC, motor vehicle crash; NTD, neural tube defect; PIH, post-infectious hydrocephalus; RTI, road traffic injury; TB, tuberculosis; TBI, traumatic brain injury; VP, ventriculo-periotoneal.

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Table 2. Continued

References	Location	Type of Study	Number of Patients per Cohort	Neurosurgical Condition and Prevalence	Supplemental Epidemiologic Information	Observed Period	Percentage of Surgical Patients	Mortality
Chalya PL 2012[33]	Tanzania	Prospective	1678 road traffic crash victims	52.1% TBI	Mean age: 29.45 years Modal age group 21–30 years old (52.1%); majority of victims were students (58.8%) and businessmen (35.9%)	12 months	80.3%	17.5%
Biluts H 2012[34]	Addis Ababa, Ethiopia	Retrospective	364	Lumbar disc disease	Median age: 44 years, 92.5% of patients presenting with pain	12 months	29.4%	0%
Warf BC 2010[35]	Uganda	N/A	3684	Pediatric hydrocephalus	Burden of infant hydrocephalus in East Africa >6000 new cases/year, majority owing to neonatal infection; 1000–2000 new cases per year in Uganda	8 years	N/A	N/A
Mwachaka PM 2010[36]	Nairobi, Kenya	Retrospective	117	VP-shunt complications	Complications: Obstruction (53.8%), migration (21.4%), infection (19.7%); almost 50% in patients <6 months old; 62.4% congenital hydrocephalus, 37.6% acquired	3 years	100%	0%
Biluts H 2009[37]	Addis Ababa, Ethiopia	Retrospective	9991 hospital admissions; 694 deaths	Neurosurgical patients	Mean age: 41 years; 34.4% of in-hospital deaths: neurosurgical patients; 59.2% of in-hospital trauma deaths owing to isolated head injury	5 years	100%	6.9% mortality overall with 4.5% postoperative mortality rate; 34.4% of deaths were in neurosurgery unit
Mlay SM 1993[38]	Dar es Salaam, Tanzania	Retrospective	38	Depressed skull fracture	Age range 0–10 years; 21% patients falling from trees	6.5 years	57.9%	N/A
Surgical series (mixed)								
Coburger J 2014[39]	Mwanza, Tanzania	Prospective	62 neurosurgical	52% hydrocephalus, 17% NTD, 15% severe TBI, 10% spine injury, 6% degenerative spine disease	46 cases were pediatric, 32 of whom were treated for hydrocephalus; 16 patients were adults, 12 of whom were treated for a trauma-related condition	3 months	100%	1.6%
Wilson DA 2012[40]	Tanzania	Retrospective	41	Hydrocephalus 22%, NTD 22%, TBI 17%, brain tumor 12%, spine tumor 7%, spine trauma 7%	Age 4–58 years	15 weeks	100%	5% perioperative deaths
Cadotte DW 2010[41]	Addis Ababa, Ethiopia	Retrospective	172 neurosurgical	51 trauma or emergency cases	Median time from symptom onset or trauma to consultation: 3 days; median time from consultation to operation: 1 day	6 months	100%	N/A
Attebery 2010[42]	Tanzania	Retrospective	51 neurosurgical	Procedures: VP-shunts, MMC repair, trauma surgery, biopsies	36% with craniocerebral trauma diagnosed, 64% with nontraumatic diagnoses	6 months	100%	27%

Surgical series — One condition								
Lehre MA 2015[43]	Addis Ababa, Ethiopia	Retrospective	146	Spine injury	Causes of injury: MVC more than falls, predominantly (41.1%) lumbar injuries; 32% ASIA A	4.75 years	100%	17.1%
Biluts H 2014[44]	Addis Ababa, Ethiopia	Retrospective	30	Pituitary tumor	Mean age: 34 years	4 years	100%	6.7%
Lane JD 2014[45]	Uganda	Retrospective	80	Pediatric hydrocephalus	Mean age at VPS placement ± SD: 11.3 ± 17.7	Mean follow up: 7.6 months	100%	9.4%: 11.2% of children with BUS, 7.5% of children given Chhabra Shunt
Stagno V 2014[46]	Uganda	Retrospective	172	Pediatric brain tumors	Mean age: 6.5 years, predominantly (23.2%) pilocytic astrocytoma	10 years	100%	40% 5-year mortality
Warf BC 2011[47]	Uganda	Retrospective	297	Pediatric hydrocephalus	Costs/DALY range $59—126, estimated 82,000 infant hydrocephalus cases in SSA	12 months	100%	1.3% operative mortality rate for patients who underwent ETV, 4% for patients who underwent shunt placement
Warf BC 2012[48]	Uganda	Retrospective	2329; 900 received initial VP shunt placement	Pediatric hydrocephalus	255 primary nonselective VP shunt placement with no endoscopy 370 VP shunt at the time of abandoned ETV attempt 275 VP shunt placement after a completed but failed ETV	6.4 years	100%	1.4% within 30 days postoperatively (13 deaths; 3 occurring in context of shunt failure) 99 total deaths (0.04%); 6 directly related to shunt failure
Warf BC 2011[49]	Uganda	Retrospective	149	Pediatric postinfectious hydrocephalus	Mean age: 9.4 months	4 years	100%	27.2%—32.4% 5-year mortality
Warf BC 2011[50]	Uganda	Retrospective	2780	Pediatric hydrocephalus with NTD 12.3% of all hydrocephalus	Etiological trends: 62.7% were PIH, 11.8% associated with MM, 10.4% primary aqueduct stenosis	9.25 years	100%	4% operative mortality
Warf BC 2011[51]	Uganda	Retrospective	140	Myelomeningocele	Mortality for children in districts with CBR programs had an under-5 mortality rate ∼16%; those in districts without CBR had mortality ∼50%	4 years	100%	37% 5-year mortality; 6.4% operative mortality
Warf BC 2011[52]	Uganda	Retrospective	110	Encephalocele	EC location: 30% sincipital; 48% occipital; 22% parietal	9 years	100%	39% 5-year mortality
Gathura E 2010[53]	Kenya	Retrospective	574	Hydrocephalus	Mean age: 8.5 months, 43.4% spina bifida assoc. hydrocephalus, 27.7% postinfectious hydrocephalus	2.3 years	100%	7.1%
Kulkarni AV 2010[54]	Uganda	Retrospective	1597 (979 in Uganda; 618 in Canada, Israel, United Kingdom)	Pediatric hydrocephalus: risk-adjusted survival of ETV	Mode age in Uganda = 1—6 months Mode age in developed nations = 1—10 years (difference was considered in risk adjustment)	95.4% of cases for 1995—2006	100%	Number of ETV failures: 62.1% in Uganda; 42.6% in developed nations

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Continues

Table 2. Continued

References	Location	Type of Study	Number of Patients per Cohort	Neurosurgical Condition and Prevalence	Supplemental Epidemiologic Information	Observed Period	Percentage of Surgical Patients	Mortality
Warf BC 2008[55]	Uganda	Prospective	93	Pediatric hydrocephalus with myelomeningocele	Mean age: 3.0 months Median age: 2.0 months	5.5 years	100%	Surgical mortality: 1.1%
Warf BC 2005[56]	Uganda	Prospective	710 underwent ventriculoscopy; 550 received ETV	Pediatric hydrocephalus	Mean age: 14 months Median age: 5 months	3.5 years	100%	Surgical mortality: 1.3%
Warf BC 2005[57]	Uganda	Prospective	300	Pediatric hydrocephalus	81.3% younger than 1 year; 60% of hydrocephalus caused by infection	1.75 years	100%	2.1%
Wanyoike PK 2004[58]	Nairobi, Kenya	Retrospective	37	Pediatric posterior fossa tumors	Mean age 6.7 years; 20% blind on admission; 8 weeks from diagnosis-treatment; >90% of medulloblastomas in females	6 years	100%	40% died at various times after surgery

ASIA, American Spinal Injury Association; CBR, community based rehabilitation; cCT, cranial computed tomography; cMRI, cranial magnetic resonance imaging; CSF, cerebrospinal fluid; DALY, disability-adjusted life year; EC, encephalocele; ETV, endoscopic third ventriculostomy; HIV, human immune deficiency; MMC, myelomeningocele; MVC, motor vehicle crash; NTD, neural tube defect; PIH, post-infectious hydrocephalus; RTI, road traffic injury; TB, tuberculosis; TBI, traumatic brain injury; VP, ventriculo-periotoneal.

urban Tanzania, respectively. Zellner et al[28] used a similar study approach to assess the epidemiology of spinal pathologies in EA. In a cohort of patients that received either a spinal CT or MRI, the 2 major findings were 1) the majority of lesions were extradural pathologies in both urban and rural regions and 2) almost 30% of patients had radiologic signs of spinal infection in the rural area, whereas the predominant condition in the urban area was disc herniation or protrusion. An overview of the burden of neurosurgical disease in rural Tanzania was also provided by Winkler et al from our workgroup, who conducted a prospective hospital-based study in rural Tanzania.[22] The authors found neurosurgical diseases to have a prevalence of 1.7% in the 8676 patients admitted to the hospital over an 8-month study period. Predominant conditions were TBI (60% of all neurosurgical patients, primarily because of assault), Pott's disease (15%), spina bifida (9%), space-occupying cerebral lesions (9%), and hydrocephalus (8%; congenital more than acquired).

Epidemiology of Hydrocephalus and Neural Tube Defects in East Africa

In our search of mixed surgical series, operations to treat hydrocephalus or to repair NTDs were the most common neurosurgical procedures conducted in rural Tanzania.[39,40,42] Warf et al[47] assessed the burden of infant hydrocephalus in sub-Saharan Africa using a modeling approach, and used a conservative estimate of 82,000 new cases annually. The model includes patients with congenital hydrocephalus (the rate was adopted from known numbers in developed countries) and patients with postinfectious hydrocephalus. Postinfectious hydrocephalus accounts for 60% of infant hydrocephalus cases in Uganda, mostly because of ventriculitis from neonatal sepsis in the first month of life.[47,57] Furthermore, Warf et al calculated infant hydrocephalus DALYs for sub-Saharan Africa, and estimated 895,000 for the year 2005, which is comparable with DALYs for all malignancies (2 million), perinatal conditions (2 million), congenital anomalies (2 million), and cataracts and glaucoma (1 million) in Africa. Regarding the combination of hydrocephalus and NTD, Warf et al[50] found an association with meningomyelocele in 11.8% of the overall hydrocephalus cohort, and with encephalocele in 0.5%. Conversely, Gathura et al from Kenya found that spina bifida was the most common cause of hydrocephalus in their cohort (43.4%), followed by postinfectious hydrocephalus (27.7%).[53]

Epidemiology of Traumatic Brain and Spine Injury in East Africa

Head and spine injuries clearly have extraordinary relevance in the burden of neurosurgical disease in East Africa, and TBI was consistently reported as one of the most common admission diagnoses in our literature appraisal.[22,25,27,31,39,40,42] Rural regions are primarily affected, but TBI is also an urban problem.[22,39,42] Recently, Tran et al[31] found that 89 of 100,000 patients admitted to a referral hospital in Uganda received a diagnosis of severe TBI. However, this statistic is likely underestimated because of the typically nascent or nonexistent trauma care infrastructure in Uganda, which results in many late admissions at referral hospitals.[31] Therefore, for all of sub-Saharan Africa, the incidence of TBI is likely as much as 3.5 times that of the global incidence, and it is predicted to reach 14 million cases per year by

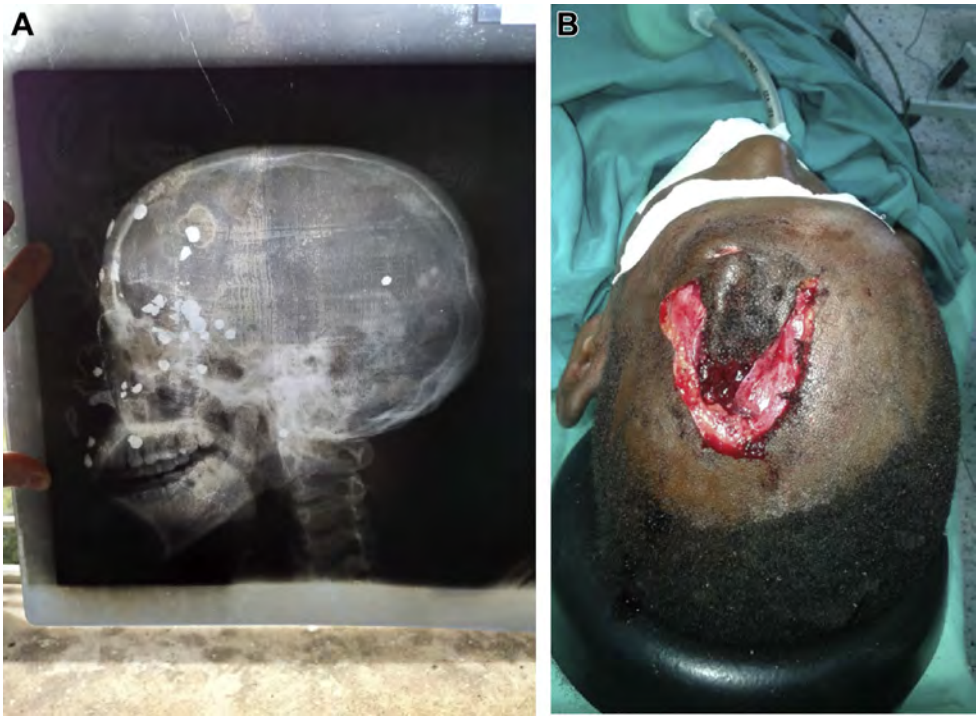

Figure 2. Traumatic brain injury (TBI) victims in Tanzania. (**A**) Radiograph of the skull of a patient who sustained a TBI after a gunshot assault in rural Tanzania. (**B**) A 7-year old patient being prepared for surgery with open, depressed skull fracture and cerebrospinal fluid leak after a motorcycle crash. Photo credits: André Liohn.

2050, primarily because of rapid infrastructure growth and motorization.[59] A prospective registry study recently conducted by our workgroup (submitted, unpublished results) in rural Tanzania demonstrated the effects of road traffic injuries on the rate of TBIs, with 66.1% of severe TBI being traffic-related, which is also supported by data from other East Africa regions.[31] Not surprisingly, young males were primarily affected, and referrals were usually delayed. Furthermore, Chalya et al[33] found that more than half of road traffic injury victims who were admitted to a hospital also had TBI.

In contrast to TBI, data regarding the epidemiologic relevance of spine and spinal cord injury in East Africa are almost nonexistent. We retrieved 3 studies that focused on spine injury—2 from Ethiopia and 1 from Rwanda—that presented some epidemiologic information. Common features among the studies were the majority of patients being young, delayed hospitalization, and a high proportion of complete American Spinal Injury Association (ASIA) A spinal cord injury classification.[29,30,43] Predominant injury mechanisms were road traffic injuries or falls.[30,43]

Epidemiology of Brain and Spine Tumors in East Africa

The overall burden of brain and spine tumors in East Africa is difficult to assess, and epidemiologic data for incidence or prevalence do not exist. In neurosurgical series with different conditions, brain tumors were often mixed with other space-occupying lesions, including those with infectious origin, and the exact histology was not always reported even if the patient received an operation.[22,40] Only a few surgical series have focused exclusively on brain tumors and provided a good histologic workup.[44,46,58] However, these series were likely affected by selection bias by including, in most of the cases, patients with a "visible diagnosis."[46] Thus, it appears that the majority of brain tumors were not recognized, which clearly had implications for the epidemiologic analysis.[46] Epidemiologic information on spinal tumors is even more scarce, and surgical reports with available histology are almost nonexistent.[28,40]

CONCLUSION

Neurosurgery as a specialty in East Africa is still at an early stage. Main challenges include the difficulties with hospital and operating room infrastructure, lack of emergency services, intensive care medicine, and imaging modalities. The establishment of national training programs is helping to kick-start the practice of neurosurgery in several regional centers. However, systematic data on neurosurgical disease burden remain somewhat scarce and indirectly obtained. Establishing national registries to record disease burden will be extremely effective in helping direct financial resources appropriately. As the global epidemic of injuries grows,

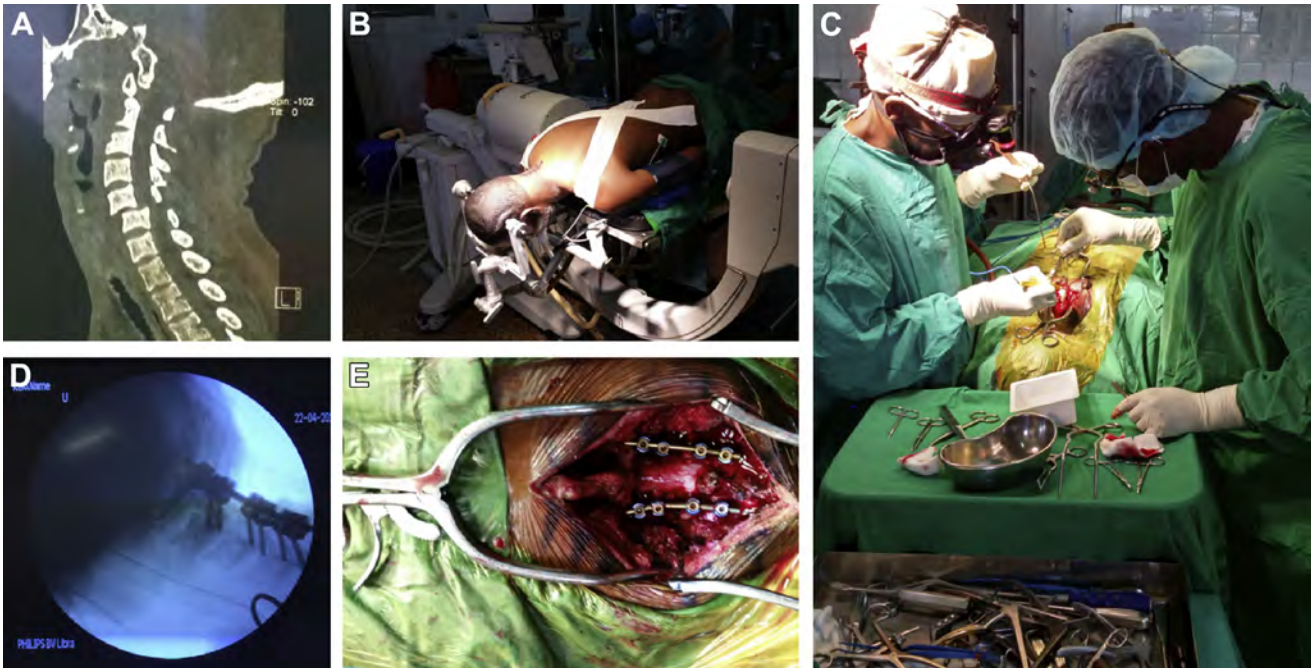

Figure 3. Patient with traumatic spondylolisthesis and incomplete spinal cord injury at C5-C6 after a motor vehicle crash in rural Tanzania. (**A**) Preoperative computed tomography. (**B**) Patient in prone position with head fixed in a Mayfield clamp for planned posterior decompression and instrumented fusion. (**C**) Intraoperative situation with 2 local surgeons (supported by a multinational team, not shown here) conducting the operation. (**D**) Intraoperative control image radiograph showing correct placement of posterior instrumentation at C4-C7 and reduction of spondylolisthesis. (**E**) Intraoperative view of the posterior instrumentation and the decompressed thecal sac. Photo credits: André Liohn.

East Africa must be prepared to handle this, as well as other widely prevalent neurosurgical diseases that are now being more frequently recognized. The future of neurosurgery can only be brighter as the region strives for self-reliance in the field.

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