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Building neurosurgical capacity in low and middle income countries

Anthony Fuller [a,b], Tu Tran [b], Michael Muhumuza [c], Michael M. Haglund [a,b,d,*]

[a] Duke University Medical School, Durham, NC, USA
[b] Duke University Global Health Institute, Durham, NC, USA
[c] Department of Neurosurgery, Mulago Hospital, Kampala, Uganda
[d] Department of Neurosurgery, Duke University Medical Center, Durham, NC, USA

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ABSTRACT

Neurosurgery capacity in low- and middle-income countries is far from adequate; yet burden of neurological diseases, especially neuro-trauma, is projected to increase exponentially. Previous efforts to build neurosurgical capacity have typically been individual projects and short-term missions. Recognizing the dual needs of addressing disease burden and building sustainable, long-term neurosurgical care capacity, we describe in this paper an ongoing collaboration between the Mulago Hospital Department of Neurosurgery (Kampala, Uganda) and Duke University Medical Center (Durham, NC, USA) as a replicable model to meet the dual needs. The collaboration employs a threefold approach to building capacity: technology, twinning, and training performed together in a top-down approach. Also described are lessons learned to date by Duke Global Neurosurgery and Neurosciences (DGNN) and applicability beyond Kampala.

1. Introduction

Building capacity in low- and middle-income countries (LMIC) has proven difficult [1], especially in the more complex subspecialties, such as neurosurgery [2,3]. In Africa, there are approximately 565 neurosurgeons for the entire continent (Fig. 1). The ratio of neurosurgeons to population is complex with a bimodal distribution. The majority of the neurosurgeons are concentrated in just several countries with the remaining neurosurgeons spread out for the majority of the entire continent [4,5]. Of the 565 neurosurgeons in Africa in 2007, 485 were in northern Africa (Egypt, Morocco, Algeria, and Tunisia) and South Africa, which results in a neurosurgeon: inhabitant ratio of 1:358,000. However, in East Africa only 27 neurosurgeons were available to treat 270 million people, a 1:10 million ratio of neurosurgeon to inhabitants. Many countries do not even have one neurosurgeon.

A closer look at two countries of similar size, Uganda and Morocco demonstrates the real dilemma. Morocco with 32 million people has 171 neurosurgeons, a ratio of 1:187,000, which is not vastly different than the United States ratio of approximately 1:65,580 [6]. In Uganda, there are only 6 neurosurgeons for 33 million people, a ratio of 1:5,500,000. This is inadequate to cover the much needed emergency procedures, let alone the necessary elective surgeries to relieve the suffering of the pediatric and adult patients with neurological disorders amenable to surgery. As of 2009 Uganda had no training centers compared with Morocco that had 6 training programs [7]. The real question then centers on how a LMIC with lack of significant resources and a significant health care workforce shortage for routine medical can even attempt to develop more complex surgical capacity. The increases in population, trauma and road traffic accidents in nearly all LMICs [1,5,8,9] leave people in need without any chance of meaningful treatment unless neurosurgical capacity can be increased.

2. Potential solution to building capacity

Over the last eight years, the Duke Neurosurgery Program has taken a threefold approach to developing neurosurgical capacity in Uganda. The approach includes technology, twinning, and training. The technology component is focused on building the technological capabilities to properly perform neurosurgery, provide safe anesthesia, and then recovery room, intensive care unit and general ward care that will allow patients to recover to the best of their ability after their neurosurgical procedure and the biomedical expertise to service and repair the equipment. The twinning relies on developing a collaborative effort between a developed academic medical center, Duke University Health System, and the LMIC Neurosurgery Department at Uganda's national referral hospital, Mulago Hospital [10]. The Training component moves beyond surgical camps to a residency-training program. Training of all health care professionals through surgical camps is inadequate to meet the burden of disease. The shortage can only be met by developing a neurosurgery-training program that trains Ugandan surgeons in the neurosurgical subspecialty. Finally, the overarching theme and backdrop of this threefold approach is the concept of "Together and Top

* Corresponding author at: Department of Neurosurgery, Duke University, 4508 Hospital South, Durham, NC 27710, USA.
E-mail address: michael.haglund@dm.duke.edu (M.M. Haglund).

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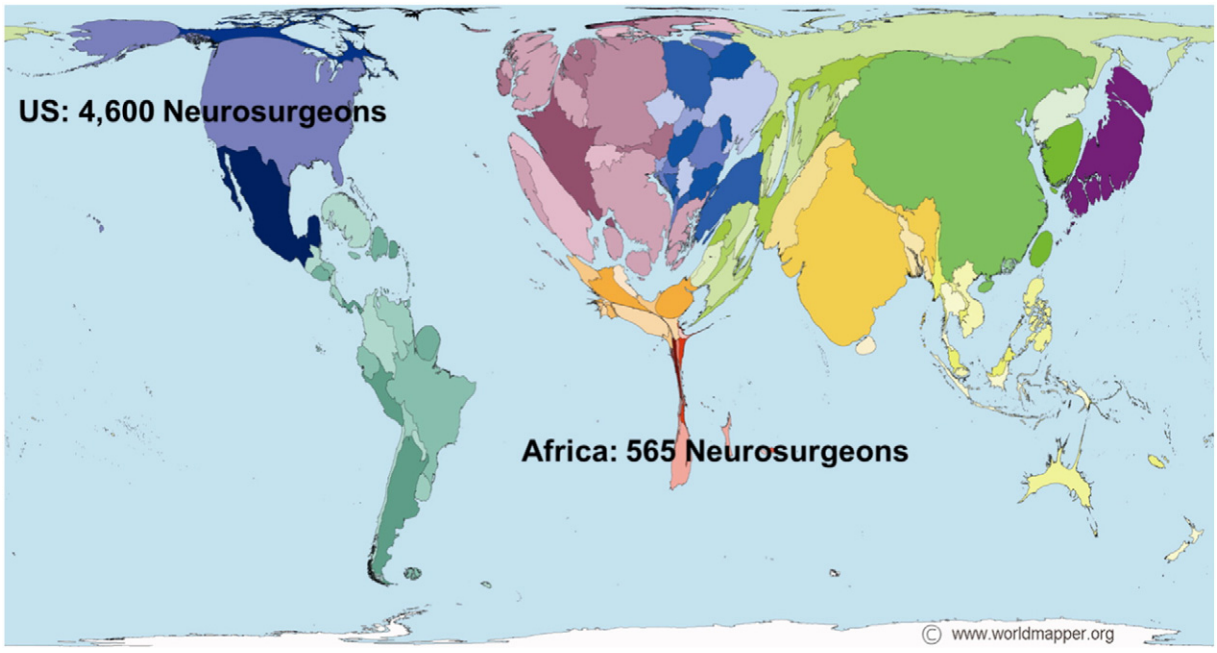

Fig. 1. Global distribution of physicians. [Sourced from World Mapper] Note the significant deficiency in central and eastern Africa, which is reflected in the lack of neurosurgeons in Africa compared to North America.

Down": neurosurgery can be one of the first subspecialties developed not the last and the proof of concept will be that if complex neurosurgical operations can be performed safely then all the other surgical specialties will benefit.

2.1. Technology

Technology available for surgery at most LMIC hospitals, including the larger national referral hospitals, is less than ideal. Other investigators have used just the presence of a pulse oximeter as a proxy measure that the basic needs of an adequate operating room have been met [11,12,13]. Many LMIC hospitals lack fundamental needs like electricity and water, but this was not the case at Mulago Hospital in Kampala [14]. However, Mulago Hospital had serious technology deficits with zero ventilators and no monitoring equipment in their operating rooms. Of their five operating rooms, several were still using ether in 2007. The Duke University Health System developed a program called Duke Global Health PLUS (Placement of Life-giving Useable Surplus). The Duke Global Health PLUS program stopped the previous system of new equipment being depreciated by Duke University and then sent to a surplus warehouse where liquidators would buy the sometimes two- and three-year-old equipment for pennies on the dollar. The liquidators would then typically increase the price dramatically and sell to United States veterinary clinics or to LMIC hospitals. The new program allowed the equipment to be evaluated by biomedical engineers for their worthiness to withstand the rigors of LMIC environments and then the equipment was set aside for Duke faculty projects in LMICs.

In the first year, 2007, the Duke Global Health Program delivered to Mulago Hospital 1400 pieces of equipment worth over 1,200,000 USD. This equipment refurbished the five Mulago operating rooms, a six-bed recovery room, and eight intensive care unit beds. The operating rooms were completely transformed with microscopes, anesthesia machines, monitoring equipment, drills, bipolar cautery, and plating systems for affixing bone flaps to the skull. The recovery room was converted from five trolleys with essentially no medical equipment to a room with proper beds, monitoring equipment and proper transport monitors. The Intensive Care Unit gained proper monitoring equipment, intravenous pumps, and intracranial pressure monitors. Over the last eight years the Duke Global Health PLUS program has now delivered more than 61 t of equipment worth over 8,000,000 USD. However, all the equipment and technology are doomed to failure without proper biomedical maintenance and repair.

From 2007 to 2015, several biomedical engineers have been sent to training courses in Africa and now Mulago's Neurosurgery Department has their own dedicated biomedical engineer. The Duke bioengineers who are critical members of the "twinning" program have worked with the LMIC biomedical engineers to train them in equipment maintenance, repair, and diagnostic problem solving. The relationship between the biomedical engineers from Duke and Uganda allows for constant interaction to keep the equipment maintained and in proper working order to allow the neurosurgeons and anesthesiology teams to work together to build capacity.

2.2. Twinning

Two common approaches to twinning have included a single surgeon visiting a facility and teaching and working with local surgeons or a surgical camp being performed but not providing in-depth training to be left for the local surgeons to perform once the developed country surgeons leave [15]. Single surgeon visit can have great benefit at times [16]. Surgical camps with multidisciplinary teams on the other hand can benefit those receiving the critical care at the camp; however, capacity building is limited and there is an increased dependence of the LMIC to wait for the surgical team to return [15,17]. The twinning concept emphasizes training not only the surgeons but also everyone in the health care delivery and maintenance of the technology. Twinning applies to working with the LMIC neurosurgeons, anesthesiologists, nurse anesthetists, operating room, recovery room, intensive care unit and general ward nurses, and biomedical engineers during the week long surgical camps. The goal is to work side by side throughout the week, "Together," with educational and training courses at the beginning of the camp and gradual transition of care during the surgeries and pre- and post-operative care from the developed country health care workers to the LMIC surgeons, nurses, and biomedical engineers.

During a two-year period before the Duke Program was initiated the Uganda neurosurgeons performed 125 cases (57 cases in FY06 and 68 cases in FY07). After the program was instituted the Ugandan neurosurgeons accomplished 392 procedures in two years (187 cases in FY08

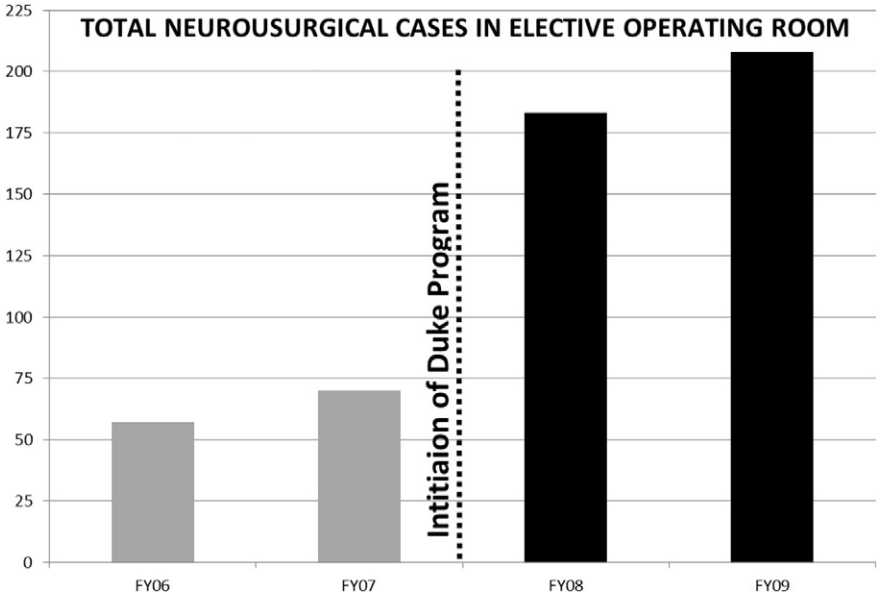

Fig. 2. Number of neurosurgery cases performed at Mulago Hospital (2006–2009). Number of cases performed by the Ugandan neurosurgeons before and after the Duke Neurosurgery Program was initiated. There was a 313% increase.

and 205 cases in FY09), a 313% increase in capacity (Fig. 2) [10]. The neurosurgeons not only did 3 times the number of cases but with the training by the Duke team, the Ugandan neurosurgeons were able to increase their complexity of cases dramatically from 2807 Relative Value Units (RVUs), a standardized measure to allow for comparison of the surgical skill needed and difficulty of various surgical procedures, before the program began to 8597 RVUs in the following two years [10].

The first two years of the Duke Program along with the already established Global Partners in Anesthesia and Surgery (GPAS) program [18,19] led to a rapid increase in capacity for the Uganda Neurosurgery program. Neurosurgeons are highly dependent on the anesthesia care during the long hours of complex neurosurgical cases. The GPAS program in coordination with the Makerere and Mulago Anesthesiology Department had only three residents in the training program when the Duke Program was initiated. The combination of the technology provided by the Duke Global Health PLUS program and the twinning of the GPAS program with the anesthesia training led to an increase from 3 to over 18 residents in a little over two years [20,21].

The capacity building included an increase in efficiency in the operating room utilization for elective cases. In two years, the Ugandan team increased their operating room utilization for at least one elective case on a given operating room day from approximately 40% to 98%. The proof of concept that "twinning" works was demonstrated at its most basic level in examining how many times if the neurosurgical team did one elective case they could do a second case on the same day. Prior to the collaboration with Duke, the Ugandans were able to do a second case less than 9 times per year out of 100 potential opportunities. After the program began in less than two years they were able to do a second case 68 times with many days with three or four cases. This would only be possible if the operating room nurses were able to clean and re-sterilize equipment and the anesthesiologists were committed to providing proper anesthesia for multiple cases, and the recovery room and intensive care unit nurses were capable of covering and treating the increased patient load.

At each subsequent neurosurgical camp over the seven years, the Ugandan neurosurgeons were performing more and more of the cases. In the second of two camps during 2013, there were 38 cases performed during the one-week camp, of which the Ugandan neurosurgery teams performed 30. The cases that used to be the "training cases" of large complex brain and spinal cord tumors combining the Duke and Ugandan neurosurgeons were now being performed entirely by the Ugandan neurosurgeons.

2.3. Training

Training beyond the surgical camps is critical if the shortage of neurosurgeons is to be reduced. Morocco as previously mentioned had six training centers, whereas Uganda had zero in 2007. In an effort to reduce this disparity, the Duke Neurosurgery Training Program and its Program Training Director combined with the faculty at Mulago, including the Chief of Neurosurgery formed the Ugandan East African Training Program. The curriculum was based on the East African Neurosurgery Training Program developed by the Executive Board at the Foundation for International Education in Neurological Surgery (FIENS) and the leaders of the College of Surgeons of Eastern, Central, and Southern Africa (COSECSA). The COSECSA program, championed by Dr. Moody Qureshi, brought five East Africa countries together (Kenya, Tanzania, Uganda, Ethiopia, and Rwanda) to provide a formal fellowship program for training local neurosurgeons. The Duke Program Director, Dr. Michael Haglund, and the Head of Neurosurgery at Mulago, Dr. Michael Muhumuza, became Co-Directors of the Uganda program and the first two residents were admitted in 2009.

Over the last five years, the resident total has reached five, which will nearly double the number of neurosurgeons for the entire country. The goal is to increase the number of trainees in the Uganda Neurosurgery Program to two residents in each year of the four-year program. The training program includes twice a month teleconferences with presentations on fundamentals of neurosurgery by the Uganda trainees, case presentations, and oral examinations twice per year by the co-directors and the rest of the faculty in neurosurgery at Mulago. The applicants have become stronger and the competition is high for the two spots per year. The goal for 2022 is to have 20 trained neurosurgeons spread out over the entire country (Fig. 3A). The other goal, building on the success of Madaktari Africa, is for each of the fellowship-trained neurosurgeons from the Uganda program to train six general surgeons from the local district hospitals. The training of other surgeons to deal with minor neurosurgical procedures that encompass traumatic brain injuries (burr holes, elevation of depressed skull fractures) or congenital neurological disorders (small encephaloceles or myelomenigoceles) will further increase capacity. These general

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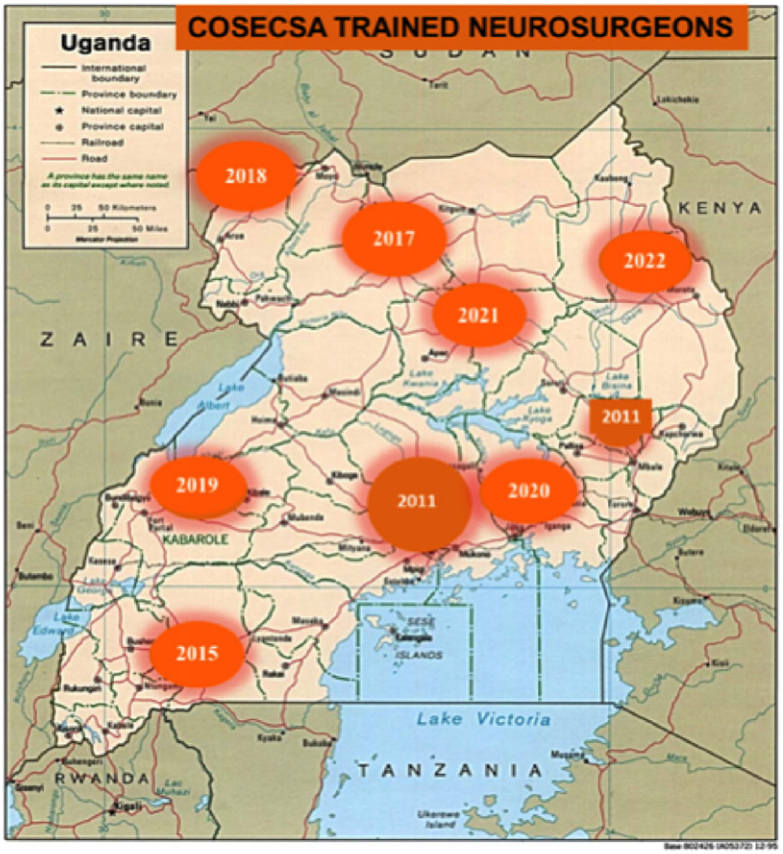

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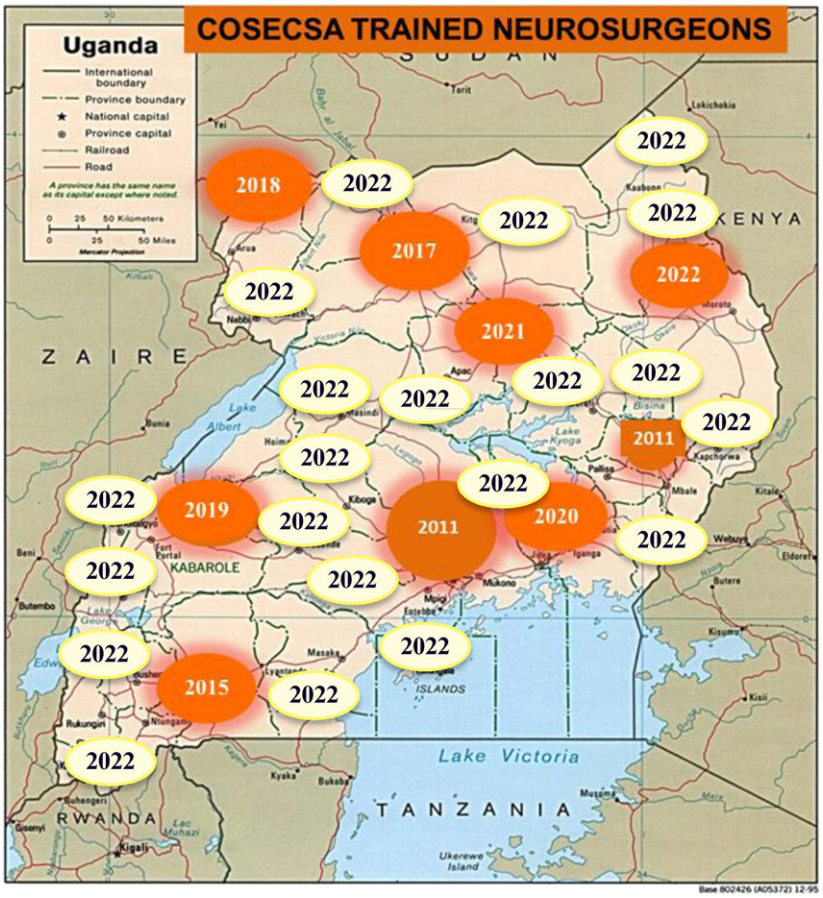

Fig. 3. A. Projected distribution of fellowship-trained neurosurgeons. B. Projected distribution of NSU-capable general surgeons and fellowship-trained neurosurgeons.

surgeons will spend a three-month period of time at the home hospital of the newly trained neurosurgeons for three months learning diagnosis, operative procedures, and proper postoperative neurosurgical care.

Studies of task shifting in surgery show potential practicality and willingness of stakeholders [22,23]. By task shifting the simple neurosurgical procedures from the fellowship trained neurosurgeons to local district hospitals, the neurosurgeons that are spread out throughout the country will be able to proceed with operating on the more complex and difficult neurosurgical cases. If the training goes as planned, by 2022 there will be over 120 neurosurgeons or their counterparts to deal with neurosurgical disorders (Fig. 3B). The 2022 plan for training will reduce the neurosurgeon/trainee: inhabitant ratio to 1:250,000. This ratio is at least within the range of the capacity necessary to take care of the burden of neurosurgical disease in a LMIC such as Uganda. Similar efforts are being made in support of neuro-critical care nursing, anesthesiology, and as mentioned, biomedical engineers.

2.4. Top-down approach

With the increased capacity of the neurosurgical care as evidenced by the increased number of cases, increase in operating room utilization, and multiple cases being performed each day, there remained to be answered whether or not overall capacity had increased in the entire operating theater in the other specialties. The five operating rooms were shared by nine surgical services (Cardiothoracic, Neurosurgery, Pediatrics, General Surgery, Oral Surgery, Urology, Trauma, Ophthalmology, and Burns). In the two years after the Duke Program was initiated, even though the number of overall and new admissions had not changed at Mulago, the surgeons were able to double the number of cases from just fewer than 1200 per year before the program to over 2400 cases per year [10]. The consensus from the Head of the Operating Theater, a general surgeon specializing in colon surgery, was that the anesthesia machines and monitoring equipment along with the large increase in anesthesia providers had dramatically increased the safety of the surgeries, allowing many more surgeries to be performed.

2.5. Lessons learned for broader applicability

The technology, twinning and training approach described could be expanded, enhanced, or newly developed by any university or health care system that wanted to devote similar resources and expertise. Other programs, such as the Madaktari Africa project in Tanzania exist which utilize an approach that is focused on the nearly complete utilization of the local resources [3]. Madaktari Africa is currently in the process of establishing a holistic training approach similar to the one described above, so that all necessary neurosurgical personnel receive training.

Although the approach for twinning, technology, and training has many advantages, several challenges have been noted and bear mentioning for consideration in future planning and implementation. There is still minimal government support for neurosurgery within Uganda. The Ministers of Health over the last several years have been very supportive, as has the President of Uganda; however, the complexities of providing health care in a country with a high burden of communicable diseases has led to a lack of funds to support a specialty department like neurosurgery. Currently, the developed country subsidizes the surgical camps and portions of the Uganda Neurosurgery Training program and private funds pay for equipment repair, additional trainee salaries, and purchasing key disposable components and equipment. However, the government in 2015–2016 was renovating the National referral hospital at Mulago, and is supportive of an overarching neurosurgical effort. A Uganda Neuroscience Institute will be developed to follow on the successful Uganda Heart Institute. The expected growth of the program is likely to bring anticipated stressors in other areas.

At the local level, several issues arose over the last several years and should be considered and planned for in advance. For example, the neurosurgery operating room staff was unable to do more than two cases per day on many occasions due to a lack of sterile reusable surgical gowns. Many of the gowns were quite worn and unsatisfactory and could only be sterilized overnight. Although donations are helpful as was secured from a supplier and delivered to Mulago Hospital, a more sustainable plan is needed. There was also a lack of functioning large sterilization machines. There was only one large capacity sterilization machine located in the main operating theater. This sterilization was frequently not working due to its increased use and the inability to obtain parts. Having a complete assessment of equipment and need for onsite support is needed in order to build capacity for that part of the health care team also.

Neurosurgeons were faced with a difficult dilemma of whether to do multiple trauma cases per day to clear out the overwhelming number of cases building up on the neurosurgery ward or operate on a single complex case of a large brain tumor or complex spinal case. Up through the end of 2012, the Neurosurgery service at Mulago Hospital split one operating room 50/50 with the Cardiothoracic service, two elective operating days one week and three the next week. The main pressure on the Neurosurgery Department's choices for the operating room focused on the ever-increasing trauma cases building up. Seeing the dilemma, private funds were raised and with the help of the Executive Director of Mulago, a tearoom, two washrooms, and a storage area were converted into a dedicated Neurosurgical Operating Theater. Beginning in 2013, the neurosurgeons now had their own operating room five days per week and increased the number of cases they performed from 216 in 2012 (similar to the 208 performed in 2010) to 524 cases in 2013. Data are still being analyzed but there has not only been an increase in cases, but a decrease in waiting time for surgeries both urgent and elective. To allow the neurosurgeons and the operating room staff to increase the surgical capacity, a large (75 l) and smaller (21 l) sterilization machines were bought, using private funds, for dedicated use by the neurosurgery nurses. Nurse training in the use of new equipment, care for new neurosurgical cases, and management of an increased surgical patient caseload are needed investments to more fully support increased neurosurgical capacity. The Executive Director of Mulago and the Neurosurgery Department developed a High Dependency Unit on the Neurosurgical Ward and Duke through the Duke Global Health PLUS program provided the monitoring equipment for six beds to care for the intermediate complex cases. The development of a dedicated Neurosurgical Unit will complete the patient care flow and allow even a further increase in the number of cases performed safely with improved post-operative management.

Many other resources and the shift in day-to-day processes need to be considered with increased neurosurgical capacity in a hospital or region. A formal assessment of outcomes of this approach is underway.

3. Conclusion

Although neurosurgical capacity is increasing, sustainability is still at risk. The government must spend at least minimal resources on the sundries utilized by subspecialties to provide a complete patient care scenario for their country. There are still many lessons to be learned from these endeavors but many of the basics that involved the technology, twinning, and training have had at least a proof of concept successfully completed by this collaborative effort. This Duke initiated collaboration would not be possible without other interventions such as in the GPAS anesthesiology program and help from the Dean of the Makerere School of Medicine, the Executive Director of Mulago Hospital Complex, and the Ministry of Health.

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