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Surgical Capacity Building in Uganda Through Twinning, Technology, and Training Camps

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Abstract
Background Neurosurgical capacity is extremely deficient in East African countries where 27 neurosurgeons serve more than 250 million people. To build capacity, the Duke University Medical Center and New Mulago Hospital in Uganda applied a two-pronged twinning approach that placed usable surplus equipment in a developing country's National Hospital, combined with dedicated comprehensive surgical training camps.
Methods Neurosurgery, anesthesiology, nursing, and clinical engineering personnel supported three training camps. More than 21 tons of essential equipment was delivered to New Mulago Hospital in Uganda. Data was collected during the 2-year period preceding and following the initiation of the program.
Results During the 2 years after the program began, neurosurgery demonstrated a significant increase (180%) in the number and complexity of cases performed ($p < 0.0001$). Multiple cases performed in a single day increased eightfold ($p < 0.0001$), with utilization of elective operating room days improving from 43 to 98%. There was no change in the number of hospital admissions over the 4 years ($p > 0.1$), but there was a dramatic increase in the overall number of procedures performed by all surgical specialties (106%, $p < 0.0001$).
Conclusions Through a twinning program combining delivery of surplus equipment and training camps, capacity building was accomplished and maintained. The program not only built overall surgical capacity, it improved the efficiency and increased the complexity of operative cases performed at the National Hospital in Uganda. This program could serve as a model for twinning, capacity building, and training in other developing countries where surgical disparities are among the greatest.

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Introduction

Disparities in health care are universal but are especially acute in East Africa [1–6]. These disparities are evident in terms of access to surgical care, particularly in the surgical subspecialties [7, 8]. For example, East African neurosurgery lags far behind that of northern African countries and South Africa, where more than 86% of African neurosurgeons practice [9]. In the five countries of northern Africa and South Africa, 486 neurosurgeons serve approximately 174 million people (1:358,000), whereas in the rest of sub-Saharan Africa 27 neurosurgeons serve 250 million people (1:9 million). In Uganda, five neurosurgeons serve 30 million people (1:6 million), and in 11 other East African

countries there is not a single neurosurgeon for 46 million people [9]. For comparison, in the developed world, 4583 North American neurosurgeons serve around 370 million people (1:81,000). Another major factor that hinders the delivery of neurosurgery in East Africa is the lack of technology [6]. Even at the national hospitals, the equipment is so woefully inadequate that even well trained neurosurgeons are unable to deliver what would be considered standard neurosurgical care [10].

In Kampala, Uganda, the New Mulago Hospital is a 1500-bed national referral hospital that houses four of the country's five neurosurgeons. New Mulago Hospital has five elective operating rooms (ORs). Prior to initiation of the program, New Mulago Hospital had only one ventilator, which was reserved for the most critically ill patient in the intensive care unit (ICU). The ORs had no hemodynamic monitoring equipment or ventilators. Patients underwent surgery with general anesthesia using halothane or ether and were manually ventilated up to 8 h for the neurosurgical procedures. The only monitoring available was visual inspection, manual palpation of an arterial pulse, and a manual blood pressure cuff. This resource-poor operating room and intensive care environment is seen too often throughout many national hospitals in East Africa.

The Duke University Medical Center and the Duke Global Health Institute developed a program to provide usable surplus equipment for delivery to developing countries where the technology disparities are greatest. This Duke Global Health PLUS (Placement of Life-changing Usable Surplus) Program was initiated during early 2007 as an initial response to the massive disparities witnessed in Uganda's national hospital. The program was designed to allow Duke's faculty to identify needed surplus equipment and, with the help of bioengineers, determine its functionality for hospitals in developing countries. The first effort in Uganda in August 2007 delivered 1,400 pieces of equipment weighing 9 tons valued at US$1.3 million (approximately 68% refurbished surplus and 32% new). The air shipment included 14 anesthesia machines with complete hemodynamic monitoring equipment and surgical equipment, including operating microscopes (Promedical, Winston Salem, NC, USA), four high-speed drills (Anspach, Palm Beach Gardens, FL, USA), updated and complete surgical equipment trays with microinstruments, intracranial pressure monitoring devices (Integra Neuroscience, Plainsboro, NJ, USA), and cranial plating sets (Biomet, Warsaw, IN, USA). Five elective ORs, the six-bed recovery room, and an eight-bed ICU were all upgraded.

The goal of this study was to determine if the capacity and efficiency of neurosurgical services in an East African country's national referral hospital could be improved and sustained by "twinning" of disparate health care systems. Our hypothesis centered on a top-down approach. Specifically, if complex neurosurgical procedures could be performed safely in a developing country with access to improved surgical, anesthetic, and monitoring equipment combined with the twinning of training camps, it would result in an increase in the overall caseload and complexity of cases the Ugandan neurosurgeons could perform, thereby building capacity and benefiting all other surgical specialties.

Methods

The official New Mulago Hospital operative logbooks were reviewed and the following data collected for the neurosurgical cases: date of surgery, hospital number, primary surgeon(s), preoperative diagnosis, and operative procedure. Hospital numbers were sequential, and all personal identifiers were removed. The overall number of individual surgical cases performed in the five elective operating rooms before and after the initiation of the program was recorded. All cases were performed in the elective operating rooms that are in operation mainly during daytime hours. The overall number of surgical cases applies to all the surgical specialties using the five elective operating rooms; it does not include the two casualty operating rooms or the orthopedic trauma and spine operating rooms located at another site on the Mulago Hospital grounds. The number of new hospital admissions was determined. The total number of surgical and neurosurgical cases were tabulated, and cases performed during the neurosurgical training camps were identified. The number of new admissions for each year was compared between New Mulago Hospital records and the operative logbook hospital numbers (<1% difference/year, range 0.2–0.8%).

Operative cases for the three neurosurgical camps were chosen by reviewing more than 100 patients per camp. For the first, second, and third camps, Duke and Ugandan neurosurgeons and anesthesiologists selected 14, 15, and 12 index cases, respectively, that would be optimal for demonstration and for skills transfer. The four Ugandan neurosurgeons had either completed an MMed in General Surgery or spent time training in general surgery before receiving their neurosurgery training in Australia (J.K.), China (M.M., John Mukasa), or Germany (Hussein Ssenyonjo). Training was provided by the Duke teams at the three training camps by groups of neurosurgeons, anesthesia personnel, surgical OR nurses and technicians, ICU specialists, recovery and floor nurses, and clinical engineers. In addition, 1 day of continuing medical education (CME) courses were conducted for the surgeons, nurses, and anesthesia providers during the second and third camps. The CME courses for the neurosurgeons consisted of "Surgical Anatomy and Approaches" and

"Treatment of Traumatic Brain Injury." The anesthesiologists focused on the "Use of Monitoring During General Anesthesia" and "Modern Approaches to General Anesthesia." The nursing CME highlighted "Proper Sterile Technique and Surgical Equipment Preparation and Sterilization" and "Evaluation of the Neurosurgical Patient during the Postoperative Period." A dedicated effort was made by the Duke clinical engineers to train the New Mulago engineers in appropriate maintenance and repair of the equipment. In addition, the Mulago Chief Clinical Engineer was sent to a 2-month training school in Ghana on equipment repair and proper maintenance.

As a measure of the complexity and difficulty of each neurosurgical case, relative value unit totals (RVUs) were determined using the Common Procedure Terminology (CPT) Coding Book (2008). These values were then used to calculate totals for each quarter of the fiscal year. Overall changes in surgical workload are represented by case totals within each fiscal year (e.g., FY06, meaning fiscal year 2006) quarter for FY06 to FY09. Case totals for FY06/FY07 were compared to FY08/FY09 independently. Those quarters in FY08 and FY09 that included Duke neurosurgical camp cases were identified. Data were analyzed without the Duke neurosurgical camp cases, which were done during the first and fourth quarters of FY08 and the fourth quarter of FY09 (represented graphically in Figs. 1, 2, 3, 4, and 5).

Statistical comparisons

Variable means for the 2 years preceding initiation of the Duke program (August 1, 2005 to July 31, 2007: FY06/FY07) were compared with those for the subsequent 2 years (August 1, 2007 to July 31, 2009: FY08/FY09) using independent-samples *t*-tests. The statistical results are reported as t(degrees of freedom) = *t*-statistic, *p* value. For all but two of the comparisons, the variances were equal. For the other two reported comparisons with unequal variances (total number of neurosurgery cases and complexity of neurosurgical cases), Levene's test for equality of variances was performed and the degrees of freedom adjusted accordingly.

Results

Changes in the number of neurosurgical procedures performed

For neurosurgical cases, a significant increase was seen from FY06/FY07 to FY08/FY09 [$t(8) = 8.34$, $p < 0.0001$]. The increase in capacity was clearly maintained during intervening quarters when there was no Duke presence at New Mulago. During those times when no visiting neurosurgeons were present, the Ugandan neurosurgeons were able to more than double their case numbers during FY08 and more than triple them in FY09, which was a significant increase from FY06/FY07 [$t(9) = 8.69$, $p < 0.0001$] (Fig. 1).

Changes in the complexity and types of neurosurgical procedures performed

During the 2 years preceding initiation of the program, more than half of the elective cases performed by the Ugandan neurosurgeons were pediatric ventriculoperitoneal (VP) shunts for hydrocephalus and spina bifida repairs for myelomeningocele. During the 2 years following the

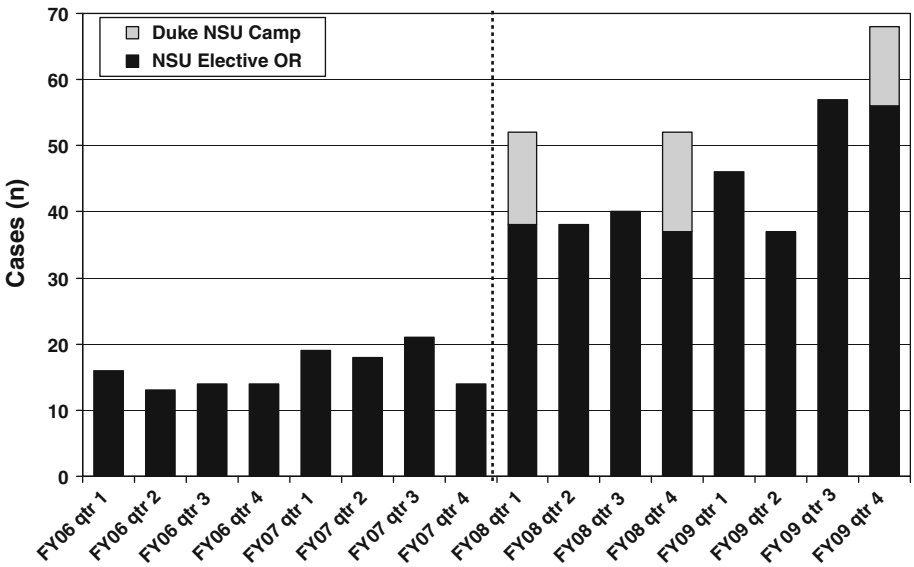

Fig. 1 Neurosurgery cases performed in the elective operating room (OR) for each fiscal year quarter (e.g., fiscal year 2006 quarter 1: *FY06 qtr 1*) of the 4-year study. *Vertical dotted line* divides the time before and after initiation of the Duke program. There is a clear increase during the last 2 years, which was maintained during the quarters when the Duke training camps were not being conducted in FY08 and FY09

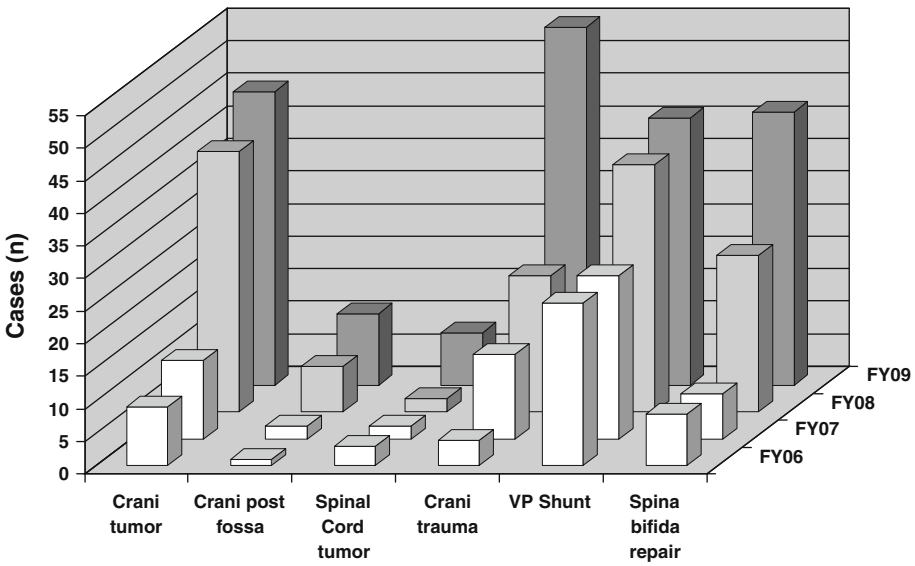

Fig. 2 Neurosurgery cases performed in the elective OR before (FY06/FY07) and after initiation of the Duke program (FY08/FY09). There is a significant increase in the number of craniotomies (*Crani*) for tumor and posterior fossa tumors after the program began. Spinal cord tumor and spina bifida repair cases significantly increased owing to the availability of operating microscopes and microsurgical equipment. *VP* Ventriculoperitoneal

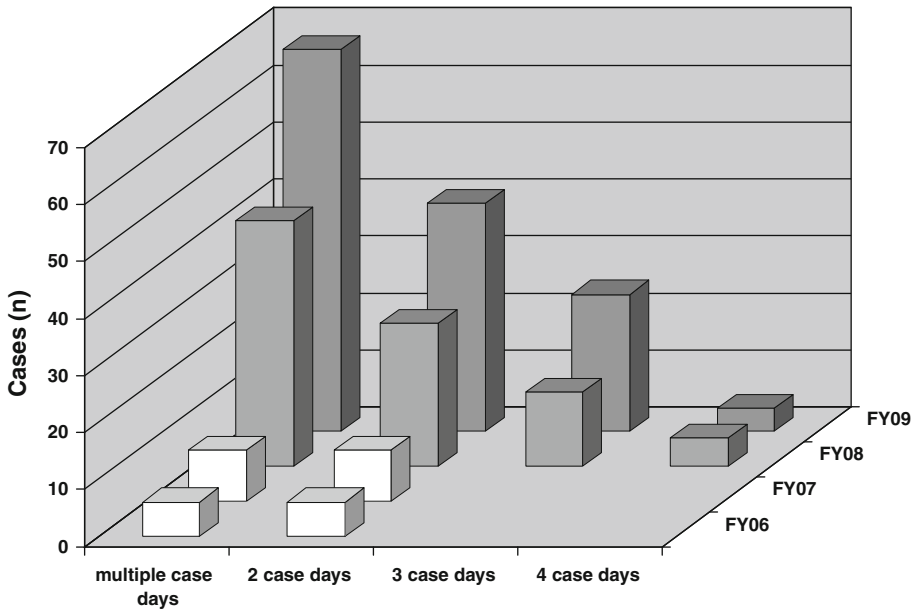

Fig. 3 Number of multiple cases for individual elective OR days. Before the Duke program, there were fewer than 10 two-case days in each of FY06 and FY07. After the Duke program was initiated, the number of multiple-case days increased to 46 and 67 in FY08 and FY09, respectively, adding three- and four-case days for the first time in the hospital's history

Duke project, an increase in the number of the more complex case types was seen, including surgery for brain, posterior fossa, and spinal cord tumors (Fig. 2). From FY06/FY07 to FY08/FY09, there was a significant increase in the number of craniotomies for tumors [$t(2) = 4.85$, $p < 0.05$] and VP shunts [$t(2) = 9.67$, $p < 0.05$], and a trend toward an increase was seen in craniotomies for posterior fossa tumors [$t(2) = 3.64$, $p = 0.068$]. In FY09, there was a significant increase in spina bifida repairs [$t(1) = 39.84$, $p < 0.05$] and the total number of cases over all six types [$t(1) = 15.94$, $p < 0.05$] compared to FY06/FY07. Compared to FY06/FY07/FY08, there was a significant increase in FY09 for spinal cord tumors [$t(2) = 8.5$, $p < 0.05$]. In addition to increases in the various case types, the complexity of those cases increased as indicated by the fact that total RVUs of FY08/FY09 (3772/4825) were significantly higher than those for FY06/FY07(1163/1707) [$t(9) = 5.99$, $p < 0.0001$].

Changes in neurosurgery operating room efficiency and utilization

Operating room efficiency and utilization were compared to determine if capacity building was accomplished. Efficiency was assessed by the number of days when at least one elective case was performed. This measure of efficiency takes into account complexity of cases, difficulty of providing general anesthesia for multiple cases, and the capability of the OR staff to turnover equipment for multiple cases on the same day. In light of the fact that the complexity

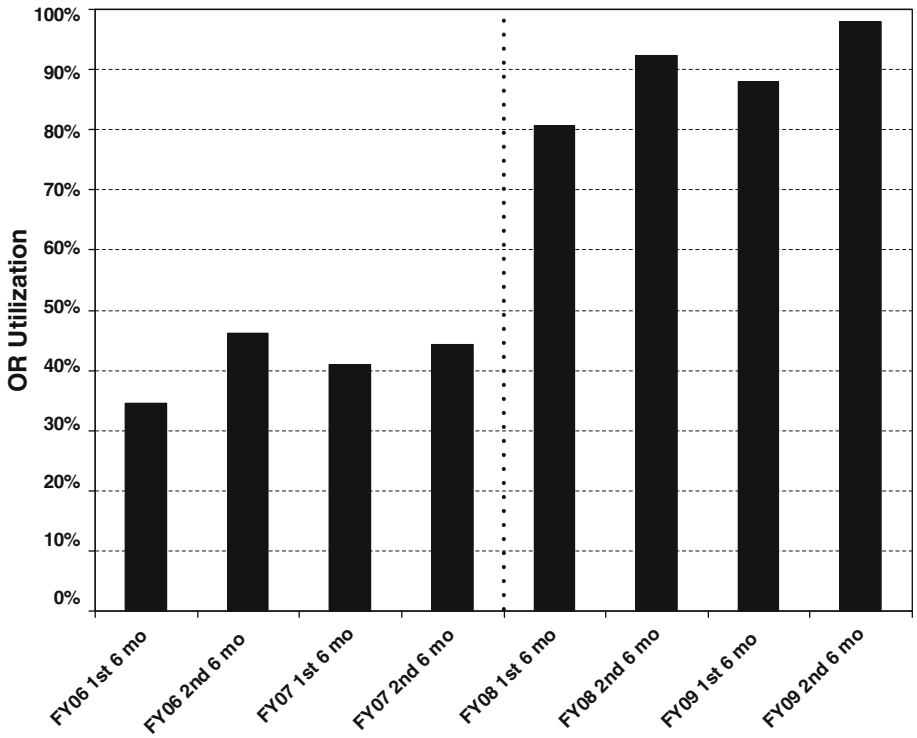

Fig. 4 Elective OR utilization for 6-month periods based on the percentage of time when at least one elective case was performed on an elective OR assigned day. *Dotted vertical line* divides the time before and after initiation of the Duke program. The utilization hovered around 35–46% prior to the program's first year but has reached 98% during the last 6 months of the study

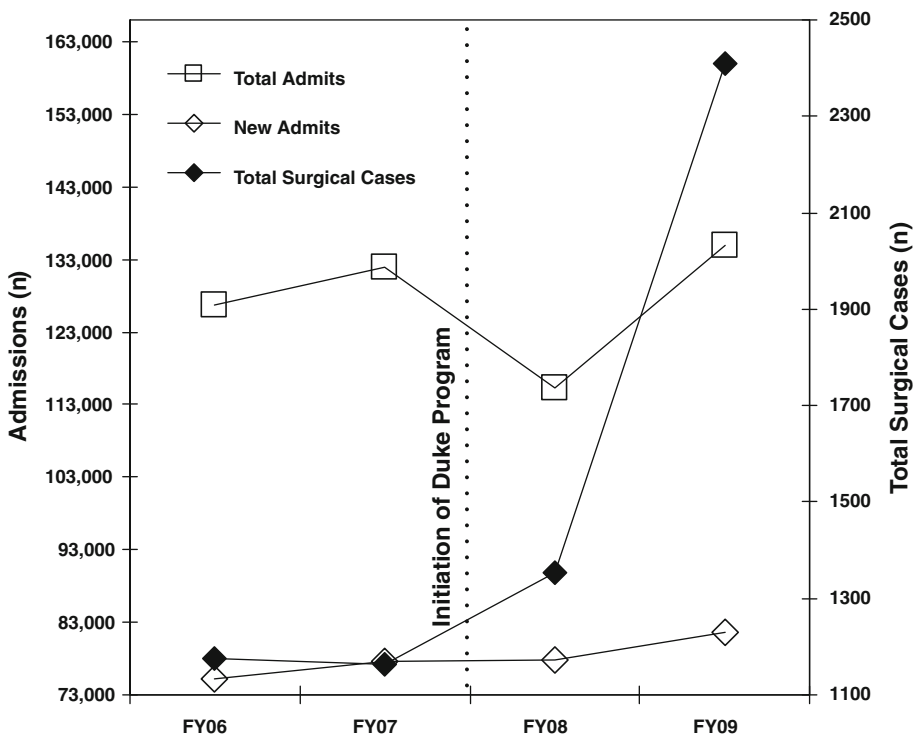

Fig. 5 Data for total admissions (*Admits*), total new admissions, and total surgical cases before (FY06/FY07) and after (FY08/FY09) initiation of the Duke program. Left-side *y*-axis shows the number of total and new admissions. This is equivalent in proportion (2.23×) to the right-side *y*-axis, which shows the number of surgical cases. There is no significant change in the admission numbers, but there was a significant increase in the number of surgical cases by FY09

of cases had tripled after the program began, one might assume there would be no significant difference in efficiency as the Ugandan neurosurgeons were performing more complex, time-consuming cases; however, this was not the case. During the 2 years preceding the program compared to the following two years, the number of two-, three-, and four-case days all increased in number, although just short of a statistically significant level. In FY09, however, the

increase in multiple-case days is significant compared to FY06/FY07 [$t(1) = 22.9$, $p < 0.05$] (Fig. 3).

Operating room utilization was determined by the number of elective OR days assigned to the neurosurgeons and how many times the neurosurgeons utilized the OR for an elective case on those days (trauma cases were eliminated from the calculations). Prior to initiation of the program, the OR was utilized 41% in FY06 and 48% in FY07. This usage increased to 87% in FY08 and 93% in FY09, which was a significant increase over FY06/FY07 [$t(6) = 11.22$, $p < 0.0001$]. OR room utilization for neurosurgery peaked during the last 6 months of FY09, at 98% (Fig. 4).

Changes in admissions and total surgical procedures

During the 2 years following initiation of the program, although the number of total admissions (TA) and new admissions (NA) remained stable [TA $t(2) = -0.41$, $p > 0.1$; NA $t(2) = 1.53$, $p > 0.1$], the number of total surgical cases performed moderately increased in FY08 from less than 1200 cases per year to 1394 cases (16% increase) and increased 106% by the end of FY09 to more than 2405 cases [$t(2) = 9.65$, $p < 0.01$] (Fig. 5).

Discussion

The Duke Global Health PLUS program in combination with the twinning of the neurosurgical, anesthesiology, nursing, and clinical engineering training camps dramatically changed the way neurosurgery and, more generally, how anesthesiology and other surgical specialties were being performed at New Mulago Hospital in the elective operating rooms. The twinning program combined human and technical components to allow Ugandan surgical teams to reach higher levels of productivity and efficiency. This is the first time, to our knowledge, that data regarding the sustained value of this type of program are available. Surgical camps are conducted throughout East Africa [11–17], but until now no data have been published assessing the lasting value of these short-term programs when combined with a significant technology influx. Some have argued that these camps are actually a negative influence and encourage dependence on the visiting surgical teams performing complex surgeries that may leave behind satisfied patients but do nothing to build independence or skills of the local surgical teams [18]. Our results show the lasting value of twinning two health systems with the successful transfer of skills and technology.

Two major points can be emphasized regarding our program. First, it can serve as a model as to how a twinning program involving a developed and developing health system partnership can affect a developing country's health system with few resources and minimal manpower. Second, rather than using a bottom-up approach—slowly building the capacity of the hospital and staff capabilities and teaching simple surgical procedures leading to more highly specialized surgical subspecialties—we followed a top-down approach that was based on the concept that delivering highly complex neurosurgery by local providers would provide a "collateral benefit" to a number of surgical and anesthesiology specialties using the elective operating rooms. The goal was that if complex neurosurgery could be performed safely by the neurosurgeons and anesthesiologists, more routine surgical procedures would reap the benefit. This goal was accomplished with a more than doubling of the surgical cases performed in the elective operating rooms—from nearly 1200 cases before the program to more than 2400 two years later.

Role of the twinning the health care systems

In our program, the Duke University Medical Center provided substantial manpower and technology. Specifically, the Duke University Chancellor of Health Affairs committed resources to help begin the Duke Global Health PLUS program. Through this program, the Chancellor's office, Duke Global Health Institute, and the Departments of Surgery, Anesthesiology, Nursing, and Clinical Engineering were committed to using surplus equipment (that would normally be sold to liquidators) for Duke Faculty projects in developing countries where large health disparities existed. Modern health systems routinely swap out older equipment for newer even though the older equipment typically has many years of life left if properly maintained. Clinical engineers were critical to this effort by screening and refurbishing equipment as well as deciding which equipment was suitable for the challenging East African environment. Most of the equipment was found to be in complete working order on subsequent visits. The engineers also worked at the surgical camps to train Ugandan clinical engineers in necessary maintenance and repair, providing an additional level of continuity and independence for the local engineers. These same Duke biomedical engineers then kept in close contact with their Ugandan biomedical engineers throughout the year to order small parts, provide advice, or supply critical manuals needed for repairs.

Prior to initiation of the Global Health PLUS program, the New Mulago National Hospital had only one functioning ventilator, which was not in the OR. The surgical patients were hand-ventilated with an Ambu-bag. Also, there was no monitoring or surgical equipment, except for a manual blood pressure cuff, hand drill, and bovie cautery. This OR setting is, unfortunately, the reality at many

national hospitals and almost all district hospitals throughout East Africa [6, 19–21]. To address this massive need, a proportional approach was necessary. During a 2-year period, three shipments of equipment weighing 21 tons and worth almost US$4 million were sent to Uganda. Through the continuous process of twinning, equipment and spare parts were shipped or brought with subsequent teams to repair equipment that would otherwise become a burden to the Ugandan hospital system. Critical parts that are of low cost or obtainable from other surplus equipment in developed countries are not readily available in East Africa. Therefore, the twinning of two health systems must be an ongoing partnership to sustain the project. Twinning involves not just health systems but all the dedicated individuals who partner in an ongoing way with their specific counterparts to make the program function at a high level.

Increase in productivity of the surgical program in Uganda

The neurosurgical program at Mulago Hospital showed a dramatic increase in clinical efficiency and capability after this program was initiated. The number of neurosurgical cases almost tripled in just 2 years. This increase is even more impressive considering there was a significant increase in the complexity of cases done during the later portion of the study period. The Ugandan neurosurgeons credited this to several factors: (1) the training and teaching by the Duke neurosurgeons on how to perform more difficult and complex cases; (2) the enhanced ability of the anesthesiologists with improved training and use of the monitors and ventilators; and (3) the new surgical equipment—specifically, power drills, operating microscope, bipolar cautery, microinstruments, and microplates. All of these changes contributed to a substantial decrease in their OR time for complex cases. Important gains were made by the nursing staff, especially in the preparation of instruments and in case turnover. Also, the upgraded equipment made available for the anesthesia personnel improved the safety of anesthetic care to the point that they were willing to take on more challenging cases with greater confidence, not to mention the ability to concentrate on caring for their patients rather than performing the arduous task of hand-ventilating their patient during the entire procedure. While factors such as confidence and comparisons of room turnover are difficult to analyze statistically, it was the opinion of the local surgeons and support staff that these factors contributed to the documented and statistically significant gains in the overall number of surgical and neurosurgical cases, the complexity of cases, the number of multiple cases per day, and the increase in OR utilization.

An unexpected beneficial effect of the top-down approach and the neurosurgical success was that the entire Department of Surgery at New Mulago Hospital increased their overall number of cases in their five elective operating rooms. At our initial evaluation of the first year after the Duke program [22], it was evident that the newly renovated and equipped ORs had led to a small but clear increase in the overall number of all surgical cases (16%). The surprising result came during the second year when there was a doubling of the overall surgical volume. In fact, the chief surgeon in the OR stated that the anesthesia machines and monitors had "completely transformed the attitudes and practices of both the surgery and anesthesiology teams." Of note, the Global Program in Anesthesiology and Surgery (Director, Gerald Dubowitz, M.D.) has spent many years funding residency training positions and interacting on multiple occasions with the Mulago anesthesiologists and surgeons [23, 24]. The Duke program built on this experience by combining advanced training and technology, which quickly led to a large increase in overall surgical productivity.

The future of neurosurgery in Uganda depends not just on providing a sustainable increase in the complexity and number of neurosurgery cases performed by Ugandan neurosurgeons but in training new Ugandan neurosurgeons. The East African Neurosurgery Training Program that has been accredited by the College of Surgeons in East, Central, and Southern Africa has two trainees currently, and two more are to be added in the summer of 2011. The program is led by two of the authors of this article (M.M., MH). The goal is by 2020 to have 12 newly trained neurosurgeons in Uganda, bringing the total to 17 neurosurgeons spread out across the country.

Conclusions

We have shown that it is possible for a developed health system to twin with a large national hospital in a developing country if the administration and medical professionals are dedicated to maintaining a large, sustained effort. We have been fortunate to have the support in our efforts from the Duke University Health System, Duke Global Health Institute, and the faculty in the Duke Department of Surgery, Division of Neurosurgery, and Department of Anesthesiology, along with the senior leadership of the Ugandan government, Dean of Makerere Medical School, Executive Director of Mulago National Hospital, and the faculty of the Surgery and Anesthesia Departments at Mulago Hospitals. The Duke Global Health PLUS program's technology played a vital part in the initial and ongoing success of this program, as did the dedication of many medical professionals, clinical

engineers, and volunteers. We are optimistic that this process can be replicated in other developing countries where the disparities in surgical subspecialties are greatest.

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