Neurosurgical capacity building in the developing world through focused training

Clinical article

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Object. In Tanzania, there are 4 neurosurgeons for a population of 46 million. To address this critical shortage of neurosurgical care, the authors worked with local Tanzanian health care workers, neurosurgeons, the Ministry of Health and Social Welfare, and the Office of the President of Tanzania to develop a train-forward method for sustainable, self-propagating basic and emergency neurosurgery in resource-poor settings. The goal of this study was to assess the safety and effectiveness of this method over a 6-year period.

Methods. The training method utilizes a hands-on bedside teaching technique and was introduced in 2006 at a remote rural hospital in northern Tanzania. Local health care workers were trained to perform basic and emergency neurosurgical procedures independently and then were taught to train others. Outcome information was retrospectively collected from hospital records for the period from 2005 (1 year before method implementation) through 2010. Analysis of de-identified data included descriptive statistics and multivariable assessment of independent predictors of complications following a patient’s first neurosurgical procedure.

Results. By 2010, the initial Tanzanian trainee had trained a second Tanzanian health care worker, who in turn had trained a third. The number of neurosurgical procedures performed increased from 18 in 2005 to an average of 92 per year in the last 3 years of the study period. Additionally, the number of neurosurgical cases performed independently by Tanzanian health care providers increased significantly from 44% in 2005 to 86% in 2010 (p < 0.001), with the number of complex cases independently performed also increasing over the same time period from 34% to 83% (p < 0.001). Multivariable analysis of clinical patient outcome information to assess safety indicated that postoperative complications decreased significantly from 2005 through 2010, with patients who had been admitted as training progressed being 29% less likely to have postoperative complications (OR 0.71, 95% CI 0.52–0.96, p = 0.03).

Conclusions. The Madaktari Africa train-forward method is a reasonable and sustainable approach to improving specialized care in a resource-poor setting. (http://thejns.org/doi/abs/10.3171/2014.7.JNS122153)

KEY WORDS • global neurosurgery • training • self-sufficiency

Abbreviations used in this paper: AMO = assistant medical officer; HLH = Haydom Lutheran Hospital; MD = medical doctor.

In the past, neurosurgery has been considered low priority despite extremely limited options for patients afflicted with disabling and often fatal conditions. Patients younger than 18 years of age, who account for up to half of the population in developing countries, are susceptible to congenital disorders of the brain and spine as well as neurological manifestations of childhood infections. Dangerous road conditions, unsafe environmental factors, accidental falls, military action, and other trauma contribute to a high prevalence of intracranial, spinal, and nerve injuries in developing nations. In 2001 the incidence of neurotrauma was 67–317 cases per 100,000 persons. The prevalence of HIV/AIDS confers increased vulnerability...
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to the neurological complications of tuberculosis and parasitic infections (for example, tuberculoma, Pott’s disease, cysticercosis, and hydatid disease).11,12 Moreover, neurovascular pathology probably occurs with similar frequency in developing and more developed countries.11 In addition to the disease burden attributable to malignancies, even benign CNS tumors, as a consequence of delayed care, frequently result in morbidity and mortality.1 All of these debilitating conditions require prompt and appropriate management. Unfortunately, for most people in the developing world, there is no access to necessary treatment options, forcing them to contend with lifelong disability, social exclusion, and premature death. Some researchers have inferred that by preventing the consequences of delayed neurosurgical care, there will be an amelioration of the public health burden and the cost to individual lives, as well as the expected economic benefits.3 Thus, neurosurgery is not a luxury anywhere. On the contrary, it is a necessity everywhere, and there are distinct advantages to increasing access for underserved populations.19

The ratio of more than 1 neurosurgeon per 100,000 population is not available for 85% of the world’s population.18 The most profound deficiency exists in Sub-Saharan Africa, in which a group of 18 countries has 1 neurosurgeon per 9 million population, and a group of 11 countries has no neurosurgeon at all. Moreover, many of these neurosurgeons are concentrated in urban areas leaving much of the rural population without access. Hence, impediments, such as insufficient funds for traveling and hospital expenses, low levels of education and awareness, and lack of proper transportation infrastructure, amplify the magnitude of the problem.9,10

To address this critical shortage of neurosurgical care, we worked with local Tanzanian health care workers, Tanzanian neurosurgeons, the Tanzanian Ministry of Health and Social Welfare, and the Office of the President of Tanzania to develop a train-forward program in basic and emergency neurosurgery to create a self-perpetuating independent capacity. The method and its 5-year results are presented in this paper.

Madaktari Africa (Swahili for “Doctors Africa”) and its train-forward neurosurgery method were developed to create an empowering, sustainable, and self-propagating model for neurosurgical care in resource-poor settings. It was introduced at Haydom Lutheran Hospital (HLH), a rural referral hospital in northern Tanzania. This hospital is remote, located 900 kilometers (and in essence, a world) away from Muhimbili Orthopaedic Institute in Dar es Salaam, where, prior to the introduction of the method, Tanzania’s only three formally trained full-time neurosurgeons served a population of 39 million in 2005. In January 2006, an American neurosurgeon began training a Tanzanian assistant medical officer (AMO; that is, a nonmedical doctor) who became the first method-trained surgeon performing neurosurgical procedures. In November 2007, that first method-trained local surgeon began teaching a Tanzanian medical doctor (MD), who became the second method-trained surgeon performing neurosurgical procedures. In December 2009, the second method-trained surgeon began training another Tanzanian MD, who became the third method-trained surgeon performing neurosurgical procedures. All local health care workers were initially trained to perform basic and emergency neurosurgical procedures independently and then were taught to train others in these procedures. As proficiency, as determined by the Western trainer and the hospital medical director, was attained, more complex cases were added to the repertoire of the local trainee.

The goal of the present study was to objectively assess the safety and effectiveness of the Madaktari Africa train-forward neurosurgery method and its ability to increase access to safe neurosurgical care in this resource-poor setting.

Methods

Train-Forward Neurosurgery Method

The Madaktari Africa (501[c][3] nonprofit organization) train-forward neurosurgery method necessitates an initial 6-month time commitment by a formally trained neurosurgeon dedicated to building a training collaboration with an interested MD or paramedical professional. The neurosurgeon lives in the served community while providing focused education, hands-on training, research opportunities, and general advocacy for the interested MD or paramedical professional. This arrangement allows for an increased awareness of local needs and the culture, a deeper understanding of the foundations on which to build, and enhanced mutual trust. Training is intensive, bedside, patient based, and experiential. Traditional classroom-based didactic teaching is minimized or eliminated given that our experience living, working, and training in East Africa has demonstrated very poor transfer of knowledge through didactic methods. Local candidates suitable for training are selected on the basis of general surgical ability, aptitude, interest, and recommendation by the senior medical director of the hospital. It is fundamental to the train-forward model that the neurosurgeon trains this health care professional in how to teach others. Training from the onset is experiential, with the neurological examination, neuroimaging interpretation, surgery, and perioperative management being patient based from the beginning. Following an initial 6-month period, a subsequent 6-month training period in how to teach is imperative to create a sustainable, perpetuating education model. This latter period is enhanced by 1- to 2-week time-focused training at least every 6–12 months to continue working on the aforementioned priorities and assess competency until it is achieved or confirmed. In the interim, communication regarding challenging cases is highly recommended. Once the MD or paramedical professional is adequately competent in neuro-diagnostic, the neurological examination, neurosurgical procedures addressing the most common local pathologies, and didactic skills, he or she may go on to train other MDs and/or paramedical professionals using this same model. The process carries on with limited involvement by the formally trained neurosurgeon as the trainee’s competence increases. The idea of progress assessment in terms of operative competency as opposed to training duration alone has already been introduced in neurosurgery.14
this case, the formally trained neurosurgeon and the medical director of the hospital working with the Ministry of Health and Social Welfare are responsible for ensuring that competency assessment remains an ongoing part of the model for all future trained surgeons.

This apprenticeship model is not based on training hours, case volume per se, classroom hours, or training duration. However, every trainee is required to be involved with every neurosurgical patient cared for at the training hospital unless they are ill and physically unable to be present. Capability and competency are assessed subjectively by the neurosurgeon trainer and the hospital director and objectively by review of the clinical database detailed in this paper.

The Madaktari training method is conducted under a memorandum of understanding with the Tanzanian Ministry of Health and Social Welfare, acting on behalf of the government of the United Republic of Tanzania. A clinical database (health care operations) exists as part of the method’s efforts in good clinical practice. This database is housed on a secure server with limited access and password protection. Institutional review board approval was obtained and abstracted for information on demographics, comorbidities, diagnoses, procedure types, complications, and so forth, as well as information on the surgeon, assistant, and anesthetist. Ambiguous outcomes were determined by clinician consensus after review of all abstracted data for the patient in question. Study data were collected and managed using REDCap electronic data capture tools. Analysis of de-identified data involved descriptive statistics, including the number and complexity of neurosurgical procedures independently performed over time by Tanzanian health care providers. “Independent” surgery was defined as that performed by a Tanzanian alone or a Tanzanian with a Tanzanian trainer. In assessing complexity, procedures were categorized as simple, moderate, or complex: Simple cases included ventricular drain placement, exploratory bur holes or bur holes for evacuation of epidural or subdural hemorrhage, and traumatic head wound repair without skull fractures. Complex cases were defined as those involving shunt placement or revision, bur holes for tumor biopsy, craniotomies for any reason, myelomeningocele or encephalocele repair, spinal decompressions, discectomy, fusions, or tumor excision. Additionally, independent predictors of complications following a patient’s first neurosurgical procedure were analyzed using multivariable logistic regression. Predictors of postoperative complications (yes/no) with $p \leq 0.10$ in a univariate analysis were entered into the multivariable model. Multivariable odds ratios and 95% confidence intervals were calculated, with $p \leq 0.05$ considered significant in the final model. All analyses were done using SPSS (IBM) or SAS/STAT (SAS Institute Inc.) software. Regional neurosurgery leaders from Nairobi, Kenya, and Dar es Salaam, along with US neurosurgeons, and the vice president of Tanzania conducted on-site evaluations and reviews of the method.

**Results**

Over the time period from 2005 through 2010, the initial Tanzanian trainee was trained and then learned to teach others. He went on to train a second Tanzanian health care worker, who in turn trained a third. Three hundred seventy-two neurosurgeries were performed (basically demographics and length of stay appear in Table 1), with some surgeries requiring multiple procedures, for a total of 418 procedures. An analysis of the number of procedures by year indicated an increase from 18 in 2005 to an average of 92 per year in the last 3 years of the study period. Approximately half of the patients were pediatric (age $\leq 17$ years).
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The most common procedures performed (number of procedures > 10 of the total 418) were shunt related (107), bur hole drilling and evacuation (68), spina bifida repair (57), bone elevation (34), craniotomy and evacuation (33), laminectomy (26), craniotomy (24), bur hole biopsy (20), and tumor excision (19). Remaining procedures included blood transfusion, discectomy, encephalocele repair, and external ventricular drain placement. The most common procedures are shown by year in Fig. 1 (note that some of the more complex procedures, such as craniotomies and tumor excision, were not done until after training began). Additionally, the number of cases performed independently by Tanzanian health care providers increased significantly from 44% in 2005 to 86% in 2010 (p < 0.001), with the number of complex cases performed independently also increasing over the same time period from 34% to 83% (p < 0.001; Fig. 2). Multivariable analysis of clinical patient outcome information to assess safety indicated that postoperative complications decreased significantly from 2005 through 2010, with patients who had been admitted as training progressed being 29% less likely to have postoperative complications (OR 0.71, 95% CI 0.52–0.96, p = 0.03), when controlled for patient age group (age ≤ 17 vs > 17 years), functional status prior to surgery, and postoperative status. Other variables tested but not significant predictors in the final model were trauma (head trauma vs all other diagnoses), sex, complications during surgery, and intraoperative antibiotic use. Specific complications reported at least once in any year include bleeding, cardiac complications, CSF leakage, death, hydrocephalus, hypothermia, hypoxemia, infection, and pneumonia. An example of the complexity of cases performed at this hospital (tumor removal) by independent Tanzanian surgeons is demonstrated in Fig. 3.

Discussion

Results indicate that this train-forward method is a reasonable and sustainable approach to improving specialized care in this resource-poor setting. By 2010, 3 Tanzanian health care workers had been trained; that is, the initial Tanzanian trainee had trained a second, who in turn had trained a third. Increases were seen in the total number of procedures performed, the number of cases performed independently by Tanzanian health care providers, and the number of complex cases performed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2005</th>
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<th>2008</th>
<th>2009</th>
<th>2010</th>
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<td>no. surgery patients</td>
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<td>64</td>
<td>82</td>
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<td>75</td>
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<tr>
<td>median</td>
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<td>34.0</td>
<td>30.5</td>
<td>28.0</td>
<td>19.0</td>
<td>20.0</td>
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Fig. 1. Most common procedures by year, beginning the year before program implementation.
independently by Tanzanian health care providers. All increases occurred safely, as evidenced by a simultaneous decrease in postoperative surgical complications.

Interventions to reduce the rate of complications were instituted during this method and were specifically tailored to address the unique environment and conditions. For example, one of the more common complications was local wound infection. To reduce the rate of infections, the doors to the operating suite were closed, and an individual kept them closed after the entry or exit of personnel (this was not normally done). Operating staff for neurosurgical procedures were required to wash their hands with soap and water (instead of water alone, which was the norm in 2006) and to do a final rinse with alcohol when it was available. Patients were prepared with betadine or alcohol when available (instead of sterile water, as was routinely used in 2006). In the ensuing years, a preoperative antibiotic dosage was used when antibiotics were in supply. During the postoperative period, we instituted a culture of surgeon rounding on postoperative patients (prior to 2006, postoperative rounds were often done by a clinician other than the operating surgeon). Unlike in a Western hospital setting, some of the interventions necessary to reduce operative and postoperative complications had not been considered fundamentals of care and hygiene; however, the implementation of a neurosurgical specialty allowed these changes to be made and accepted in this hospital without resistance. Many of these changes are now enforced in all cases throughout the operating suites at this hospital.

For the past decade, African neurosurgeons and medical trainees have been calling for methods that increase access to neurosurgical training. Many of the efforts to provide neurosurgical care in the past, while well intentioned, encompass a form of “humanitarian colonialism” involving neurosurgery teams equipped with imported specialists and supplies. They often provide care despite limited medical knowledge regarding the local disease pattern, a dearth of experience with local pathology, and significantly inadequate inclusion of local health care providers. Moreover, they often have limited knowledge regarding local customs, local medical mores, and the economic impact of treatment. Although beneficial in the short term, these intermittent and temporary medical missions have an unfortunate tendency to perpetuate medical and psychological dependency on foreign aid. It is being recognized that the solution to sustainability lies in a transfer of knowledge through increasing accessibility to educational courses and training methods. Accordingly, the World Federation of Neurosurgical Societies (WFNS), which has maintained official relations with the WHO since 1972, offers educational courses all around the world. Furthermore, the Foundation for International Education in Neurological Surgery (FIENS) sends volunteering neurosurgeons to spend several weeks to months providing hands-on training and education to local health care workers in developing nations. Additionally, count-
less commendable humanitarian endeavors have been made by individual or groups of neurosurgeons, which have been anecdotally described. Alternatively, a few recent analytical data-driven studies have been devoted to increasing access to neurosurgical services through training methods. While these training methods have proved effective, they require the pairing of training with the importation of heavy and/or expensive neurosurgical equipment and tend to be carried out in major cities of developing countries with the infrastructural capacity for the desirable type of growth.12,13,16 Thus, the Madaktari Africa train-forward neurosurgery method is distinctive in that it fulfills a niche for need in extreme resource-poor settings, and its requirements are time, patience, and a focus on training rather than direct patient care. Note that our experience demonstrates that continuous (minimum of 6 months at a time) intensive one-to-one experiential training is needed rather than shorter-term training episodes or didactic classroom teaching alone.

This method can be justifiably criticized for training para-medical professionals to perform neurosurgical procedures. An AMO has a high-school-level diploma and 3 years of medical technical school training. In Tanzania, however, these AMOs provide general surgery care, obstetrical care including deliveries and cesarean sections, and intensive care unit and general medical care without the supervision of an MD. The government of Tanzania has recognized that these paraprofessionals will be providing medical care for the majority of the population until adequate MDs can be trained, which could take decades. The Madaktari Africa train-forward method describes using the best available medical personnel to provide care and does not necessarily argue for or against paraprofessionals in general. The method can be further criticized for training outside a formal neurosurgery residency program. Excellent ethical arguments can be made both for and against this practice. Nevertheless, we posit that the method is a reasonable option in a setting without neurosurgical care now or in the near future and with certain death as the most likely outcome in many cases. Formal neurosurgery residency programs in Sub-Saharan Africa have been slow in developing, and none existed in 2006 in East Africa. Additionally, the training of non-MDs in subspecialty care in Sub-Saharan Africa is a policy decision that is made at the country level with local neurosurgeons and the local Ministries of Health, with wide variability among countries. For example, the Ministry of Health in Kenya has mandated that non-MDs cannot perform neurosurgical procedures, while in neighboring Tanzania it is encouraged as an interim step in providing country-wide access to neurosurgical care. Further, until a formal training program is begun, the Tanzanian government has promoted the Madaktari Africa method to train local MDs to perform neurosurgical procedures. Even if a neurosurgical residency is begun, it would take many years to provide adequate neurosurgeons to a country the size of Tanzania (Fig. 4). Specifically, based on data from the WHO, the US has more than 1 neurosurgeon per 100,000 population, while Africa has 0.1 per 100,000.18 For a Tanzanian population of over 46 million (http://data.worldbank.org/indicator/SP.POP.TOTL?cid=GPD_1), a traditional 7-year US neurosurgery training program producing 2 neurosurgeons per year would require 234 years to bring Tanzania to the level of 1 neurosurgeon per 100,000 population. The Madaktari training method or the like may provide a bridge from now until then.

Beginning July 2013, in partnership with the Congress of Neurological Surgeons and Centra Neuroscience Institute, 2 US neurosurgeons, recruited through the newly established Global and Rural Neurosurgery Fellowship, will spend 1 year in Tanzania training local partners at HLH and the National Hospital in Dar es Salaam. Curriculum and competency benchmarking will be developed for this next phase of the program.

Undoubtedly, by itself, an intervention of this nature is not going to ameliorate all of the neurosurgical disparities between developing and more developed nations. And since many regions within and across different developing nations are at different stages in their neurosurgical capacity, the needs vary significantly. Organizationally, basic neurosurgical training programs for resource-poor settings such as the one presented are equally important to more formal training programs, such as the Neurosurgery Training Program of East Central and Southern Africa. The need for these training programs to be local is emphasized because foreign training has the potential to generate maladaptation, incomplete training, and in some cases non-return to the home country. Another priority is the acquisition of biomedical equipment ranging from basic craniotomy sets to CT scanners to more modern neurosurgical technology to ensure continual development for the field. However, for the group of 43 countries in the world that have a neurosurgeon/population ratio of 1:1 million, the train-forward neurosurgery method providing local doctors with the ability to perform lifesaving interventions is perhaps the highest priority.10

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Fig. 4. Overlay of Tanzania on the eastern United States. Figure created with permission using IfItWereMyHome.com.
Conclusions

This study documents an experiential, patient-based training method that seeks to create self-perpetuating neurosurgical care in a profoundly underserved area of the world. We have termed this method the “Madaktari Africa train-forward method.” By integrating neuro-diagnostic and neurosurgical skill competence with the inherently empowering properties of knowledge acquisition and propagation, the method has proved effective in producing 3 local neurosurgery-capable health care workers, has increased the number of neurosurgeries performed, and has increased the amount of local participation in neurosurgeries while reducing postoperative complications over the training period. Significantly, it has shown sustainability over 5 years and is the longest independently audited method of its kind in the developing world and reported in the neurosurgical literature. Expansion of this method to involve other specialties of need at the behest of the US and Tanzanian governments is ongoing.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Nicholas, Ellegala. Acquisition of data: Nicholas, Ellegala, Simpson. Analysis and interpretation of data: Nicholas, Ellegala. Drafting the article: Nicholas, Ellegala, Simpson. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Nicholas. Statistical analysis: Nicholas. Administrative/technical/material support: Nicholas, Ellegala. Study supervision: Nicholas, Ellegala.

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