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Title Using Google Glass to reduce a blind spot in task-shifting for extension of safe surgery and anaesthesia care in Uganda

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Abstract
Globally, 2 billion people don't have access to surgery. In Uganda, task-shifting is proposed to address human resources shortage and is already practiced to varying degrees of regulation. We propose applying Google Glass to aid supervision in delivery of surgical care, which may improve feasibility of a national policy on task-shifting basic surgical care.

Development Challenge: expanding basic surgery as part of Universal Health Coverage
The rising incidence of noncommunicable diseases (NCDs) and injuries has been well documented in recent years. The Global Burden of Disease 2010, the largest study of its kind, has demonstrated this trend [1, 2]. Twenty one percent of injury burden can be averted by surgical intervention [3]. NCDs often require surgical intervention in managing sequelae: ischaemic heart disease (1^{st} – leading cause of global mortality), stroke (2^{nd}), chronic obstructive pulmonary disorder (3^{rd}), lung cancer (5^{th}), and diabetes (9^{th}). Obstetrical emergencies, perinatal conditions, congenital anomalies, acquired deformities, such as cataracts, also require surgical intervention.

Yet, about 2 billion people worldwide have no access to any surgical care [4]. The world's poorest 1/3 receive only 3.5% of all operations performed annually [5]. High-income countries have as much as 100 times the number of surgeons as do low-income countries [6]. In Uganda, there is one neurosurgeon per 6,000,000 whereas in the United States there is one per 81,000. This problem was identified over 30 years ago by WHO Director General Dr. Halfdan Mahler [7]. Among the global health community and some policy makers, the past decade has seen increased traction for extending access to surgical and anaesthesia care in developing countries [8, 9]. In May 2015, the World Health Assembly will consider, for the first time, a resolution to incorporate surgical care into member states' minimum healthcare package [7].

Gaps in human resources for health have been well documented with a current shortage of 7.2 million and up to 12.9 million by 2035 [10, 11]. In low-income countries, these gaps are amplified for surgical workforce thus some countries have long shifted high-need procedures to non-physician clinicians (herein: NPCs). In District Hospitals of Malawi, Mozambique, and Tanzania, up to 90% of obstetrical operations are performed by NPCs [12, 13]. These countries have formally adopted such systems so patient outcomes do not suffer; a comparison of over 1,000 major obstetric operations over a 4 month period in 14 Tanzanian hospitals showed no significant differences in outcomes, risk indicators, or quality between NPCs and physicians [14]. In perioperative care, anaesthesia officers/nurse anaesthetists have been widely integrated in most low-income countries.

This paper builds upon a neurosurgery collaboration between Makerere University-Mulago Hospital and Duke University; the collaboration has strengthened clinical capacity and will graduate the first class of Uganda-trained neurosurgeons by end of year 2014 [15]. Two neurosurgeons will be placed in Regional Referral Hospitals (RRH) where they will also transfer neurotrauma skills to general surgeons and medical officers (recent graduates from medical school). Uganda only has 200 surgeons for a country that now has 37 million people and one of the highest fertility rates in the world (5.96%) [16, 17]. The high need for surgical care, cesareans being an urgent priority, means that task-shifting is already in practice without a set of national regulations to assure quality and optimize the potential to extend care. One form of task-shifting occurs with non-surgeon medical officers who operate without regular supervision for an average of 3 years prior to entering surgery residency; a survey of Mulago Hospital general surgery residents showed that each performed on average 2,000 operations during their pre-residency years, which is double what American and Canadian general surgery residents perform in 5

years of supervised training [18]. About 60% worked without supervision. The second most common form of task-shifting trains NPCs to perform cesareans, but this varies District to District (110 total Districts). A review of district hospital records suggest as much as 36% of major and minor surgeries are provided by NPCs, which is likely underreported due to fear of litigation [19]. Galukande and colleagues have concluded that the surgical care community cautiously accepts task-shifting as a necessary measure; regardless of professional disposition, task-shifting is practiced widely, even unregulated [20].

Task-shifting can be made safer, more efficacious, and more abundant with quality controls. Thirty years since the WHO Director General pronounced surgery as an integral component of the primary care, the semiconductor/technology revolution has enabled practical, inexpensive usage of wearable technology to soon change surgical care delivery [21].

Barriers: Human resources for surgery and anaesthesia care

Uganda's shortage of surgery and anaesthesia providers is due to less individuals choosing such career path for reasons of inadequate remuneration and low work satisfaction, limited but burgeoning training capacity, and reluctance to work in rural and remote areas where needs are often greatest.

Remuneration has varied in Uganda due to donor funding, providing financial incentives for human resources to pursue fields with greater number of high-paying positions; in FY 2009/10, donor funding was almost on par with government funding. The trend is a positive increase in Government of Uganda funding, albeit private expenditure is on the rise as well (Figure 1) [22]. Of the 200 residency-trained surgeons, 90% are based in the Kampala metropolitan area, leaving the remaining 10% to serve 85% of the Ugandan population [23]. Reluctance to work in rural and remote areas is experienced globally. Even in Brazil, the federal government's Mais Medicos program depends on bringing in 4,500 Cuban physicians to serve in remote areas of the country [24]. A Makerere University-led study elucidated a few other factors demotivating physicians including quality of management, availability of equipment and supplies, quality of facility and infrastructure, staffing and workload, political influence (as in other jobs with influence vs. being healthworker), community location, and professional development [25]. Providing the right working environment, especially for surgery and anaesthesia which depend more heavily on material resources, is critical for motivation; if a surgeon or anaesthetist is dealing with a high perioperative mortality or complication, he/she will become demoralized quickly and they are specialties prone to such eventualities.

The experience of Makerere University/Mulago Hospital-Duke University's neurosurgery program and Global Partners for Anaesthesia and Surgery (GPAS) show that scholarships, push incentives to lower educational costs attracted more trainees into surgery and anaesthesia programs [15, 26]. This has been coupled to parallel support of faculty mentors and reinforcement of clinical capacity. When the newly graduated neurosurgeons take their posts at RRHs, they will begin an experiment that can be enhanced by real-time supervision. Ideally, the long-term solution is training more neurosurgeons as in high-income countries, but it requires the Government to address macro issues of compensation, health sector infrastructure, and formal regulations for task-shifting [27]. The scale requires significant expansion of fiscal space and political reforms.

In the immediate term, more and more Ugandans need access to surgical care. Every year, a new cadre of 220 physicians and over 600 nurses are deployed to their posts, up to 150 new surgical and anaesthesia NPCs are deployed, and 10-15 surgeon and anaesthesists graduate from residency programs. All are expected to participate in thousands of operations at the 136 hospitals across the country [22, 28]. Various forms of task-sharing and task-shifting must be arranged to meet the population's needs, provide

adequate supervision and management for quality, and a working environment that empowers each and every surgery and anaesthesia provider of all levels.

Blind Spot: a view inside the operating theatre

The College of Surgeons of Eastern, Central, and Southern Africa (COSECSA) has maintained a stance of promoting usage of NPCs in provision of surgical care: "Where NPC programmes are not established or are resisted, COSECSA must use evidence based best practice to influence policy makers and map out clear career paths for NPCs to ensure they continue to provide surgical care" [27]. In Uganda, Galukande and colleagues have determined 11 barriers to task shifting (Table 1). One of the main concerns is fear of increased morbidity and mortality from having less skilled personnel take on more operations. The blind spot is not having a specialist trained surgeon's view in remote, rural operating theatres of District Hospitals. However, wearable technology may finally provide a viable, scalable solution. Google Glass is a full-fledged smartphone-like device projecting an optical display that accepts commands by the user vocalizations (Figure 2). One of the world's first deployments of Google Glass enabled a UK surgeon to communicate in real-time with students all over the world [21]. Academic medical centers in the USA have begun using it for keeping track of vital signs and accessing diagnostic images, while enabling collaborators from multiple sites to view the operation from point-of-view of the onsite surgeon in real-time. This technology can be applied in the same manner to enable real-time communication between a general surgeon, Ugandan medical officer, or NPC performing an operation and a specialist providing mentorship (eg. asynchronous video reviews and feedback) or formal supervision from Kampala (if synchronous connection can be maintained). Emergent conditions may require immediate intervention and a medical officer can benefit from using Google Glass to connect and attempt the procedure with video-enhanced decision support. Internet connectivity may affect video quality and communication effectiveness, but the competition between the two major carriers, Orange and MTN, has led to ever-increasing coverage of 3G and since 2011 even 4G speeds. Never has there been affordable technology that enables an onsite provider ability to provide in real-time such perspectival vantage point. High-risk emergency operations are best candidates for this technology.

Intraoperative details should be constantly accessible and viewable to the on-site and remote site providers. These include vitals (temperature, pulse, blood pressure, respiratory rate, oxygen saturation), additional, customizable measures such as urine output, blood lost volume, diagnostic imaging, and summary of patient medical records. For these enhancements to be captured digitally, an open-sourced electronic medical record software can be used where voice commands complete data points and access data specific to the patient. Quality checks in task-shifting or normal surgical care delivery can yield better outcomes. The WHO Safe Surgery Checklist is a basic set of safety measures pre-op and post-op which can be programmed to take input for specific case and shared with the supervisor viewing remotely (Figure 3) [29]. An on-site medical officer might list non-routine steps he/she plans and the supervising surgeon could review prior to incision. If the patient will be referred for follow-up care, the eventual receiving surgeon based in Kampala may also choose to view the operation live or review video. A summary of benefits and direct impact of barriers to task-shifting is presented in Table 1.

Population affected and possible impact

Surgical conditions affect all members of the population so the anticipated impact should be broad. Infants born with anomalies need surgery. Woman of child bearing age are at risk of complications during labor. Rising incidents of cancer inevitably increases operative need as first-line treatment consideration. Injuries affect those of all ages and are most deleterious for victims during economically productive stage of life, for example motorcycle injuries in built-up areas. Surgery is also needed for preventive measures such as male circumcision, in which 400,000 was provided in Uganda during FY2012-13. Because surgery and anaesthesia care requires higher absolute costs, often the socioeconomically-disadvantaged,

indigenous, and rural residents are worse off which is generally true in study of health disparities even in high-income countries [30, 31].

To estimate impact, we make major assumptions about volume and surgical need. A population-based study has recently been performed and currently in analysis (also part of Makerere-Duke collaboration); therefore we are using older, limited hospital based data. Thus, estimates miss up to 50% of the population who do not access the formal healthcare system. We assume the Google Glass platform can work with asynchronous or synchronous applications at all health facilities providing surgical interventions. We are interested in Health Centre IV's (HC IVs) and all hospitals minus the 13 Regional Referral Hospitals and Mulago Hospital. We should also exclude all Kampala-area hospitals (n = 29) and HC IVs (n = 11) [32]. This brings the total HC IV count to 179 and hospital count to 87 for a total of 266 health facilities. The most common operations are caesareans, uterine evacuations, wound care (fracture manipulation included), and herniorrhaphies [33]. The Uganda National Minimum Health Care Package (UNMHCP) includes cesareans and they should be available at HC IVs, but only 28% of the 190 HC IVs offer cesareans [34]. Absenteeism, private sector incentives for dual practice, and reluctance to work in remote, rural areas are cited as factors limiting availability. The 2011 Uganda Demographic and Health Survey established 5% of births are delivered by cesareans; because HC IVs are underperforming, some District Hospitals, such as Iganga, are operating at rates of 22.5% of deliveries [33, 35]. The mal-distribution of providers overburdens a select few facilities and renders others incapable of providing surgical interventions, which ultimately places at risk up to 80,000 cesarean births per year (derived from UNICEF's 2012 total births estimate of 1.59 million births). Other common procedures and operations such as wound care, herniorrhaphies, uterine evacuations, laparotomies, open fracture reduction, and circumcision will also be impacted. Extrapolation from a small subset of hospital analysis has its limitations. The 80,000 deliveries per year number is a reasonable number to estimate cesarean need. Other procedures would increase in volume if the trained providers are on site. A Google Glass-based supervision platform could help address this problem. In Table 2, we estimate total population served by health facilities that would benefit from placement of Google Glass per standard catchment area estimates. We have proposed a secondary analysis of operating theatres to know better national statistics, but for argument sake, if we average major non-obstetric operations rate from Galukande et al 2010, we have a rate of 21.5/10,000 at general hospitals. If there are 29,750,500 served, then up to 64,000 people could benefit annually from extending basic surgery and anaesthesia care capacity. Thus, our total population affected estimate is 144,000 per year (80,000 + 64,000). Any fraction of this could be considered "high-risk". This does not take into account the potential volume increase in operations with extended capacity.

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Tables and Figures

Table 1: Barriers to surgical task-shifting

Barrier	Google Glass
1. Possible increase in morbidity and mortality	• Real-time mentoring and supervision by surgeons in major Ugandan cities, Kampala, or abroad. • Potential for consulting surgeon to consult in real-time, which should improve on outcomes and knowledge of the operation for follow-up care • Asynchronous video reviews to provide feedback for lower experience surgery providers • Implementation of safety checklists programs, such as the WHO Safe Surgery Checklist
2. Low staff motivation to take on extra load	• Google Glass helps with redistribution of caseload
3. Lack of facilitation, equipment and space	No impact; health system cross-cutting issue
4. Medical- legal responsibility for mishaps	• Google Glass may provide supervision where there would be none so that an onsite provider would be more willing to perform emergency operations vs. sending a patient away.
5. Lack of public acceptance for the concept	• Google Glass can be used to robustly collect data for monitoring and evaluation, build evidence-base for comparable outcomes in basic, high-need operations
6. Staff over stepping their boundaries	• A real-time feed will likely prevent this from occurring, which is already occurring in lower level health facilities
7. Lack of support supervision	• Beyond real-time supervision, it can be used for training as well where the specialist surgeon performs cases and clinical officers, medical officers, general surgeon view procedure in real-time. The reverse is possible where mentors can review operations of trainees and surgery providers in lower-level facilities.
8. Cost of training and support supervision	• One pitfall is the MOH may decide to spend less by de-emphasizing onsite supervision, which should continue to be gold standard. However, given the sheer number of operations that must be performed, supervision at distance is necessary in the medium term until newly trained specialist accumulate more experience.
9. Risk of impersonation (fraud)	No impact on risk of impersonation
10.Disincentive for appropriately trained personnel to accept deployment in rural settings	• A new generation of trainees would also prefer to be in major cities; they can help supervise clinical and medical officers in more remote sites
11.Cost of compensation for extra load	• Redistribution should lead to less perception of the caseload being "extra" if more providers are engaged and managed through task-shifting

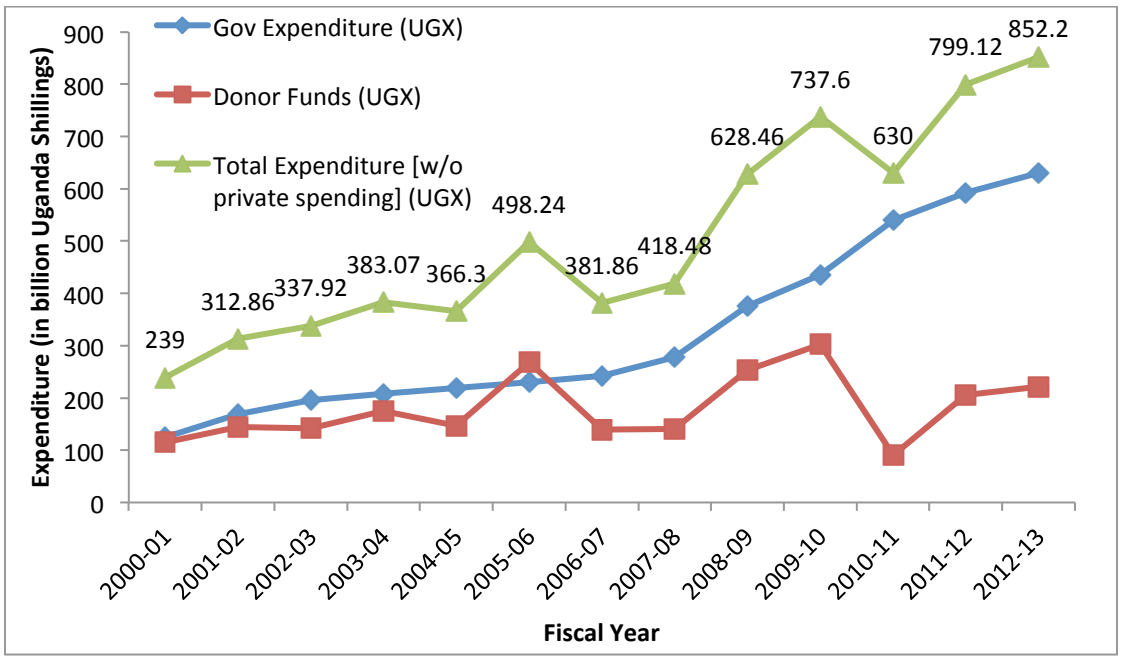
Adapted from [20]

Table 2: HC IVs and General Hospitals

	Total National	Number Excluded (Kampala-based mainly)	Population Served/Facility (average)	Estimated Population Served
Health Centre IV (lowest level facility that has Operating Theatre)	190	11	194,700	34,858,000
General Hospitals	115	28	258,700	29,750,500
Regional Referral Hospitals	13	13	-	-
Mulago National Referral Hospital	1	1	-	-

Adapted from [34], revised from population estimate of 35.7 million to 37.0 million

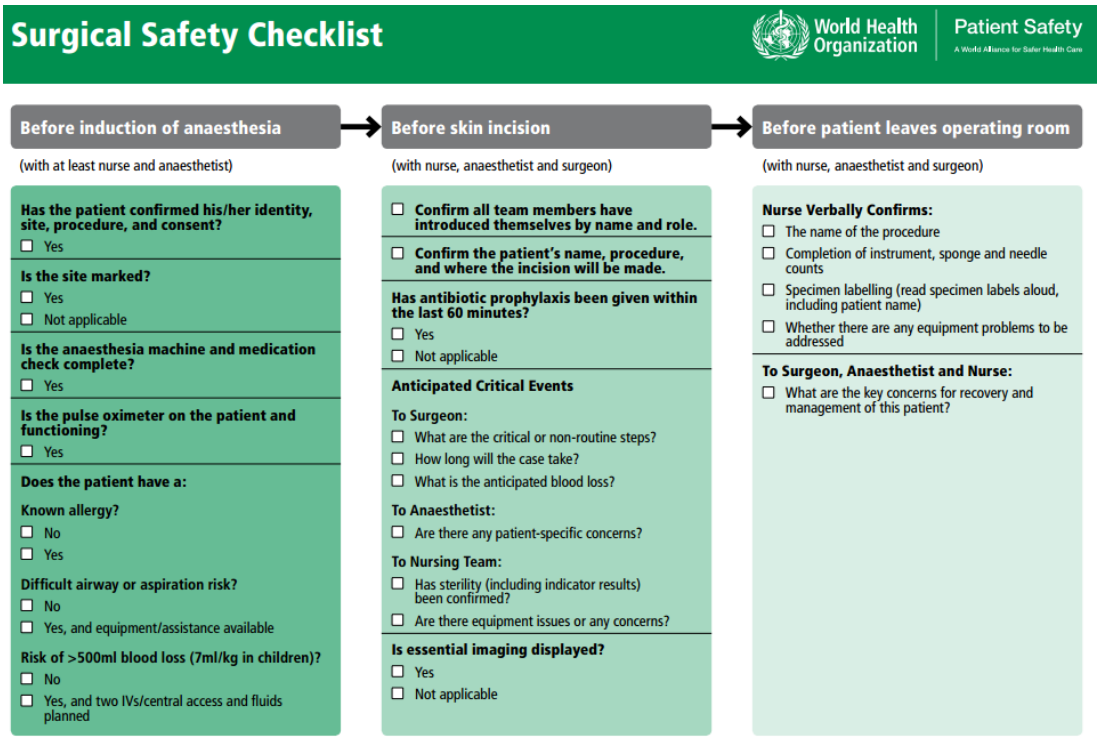
Figure 1: Government of Uganda and Donor Funding to Health Sector FY 2000/01 to 2012/13



Created with data from Annual Health Sector Performance 2012/13 FY Report [22]

Figure 2: Google Glass optical screen deployed in point-of-view surgery

Figure 3: WHO Surgical Safety Checklist



Surgical Safety Checklist

World Health Organization | Patient Safety
A World Alliance for Safer Health Care

Before induction of anaesthesia → **Before skin incision** → **Before patient leaves operating room**

(with at least nurse and anaesthetist)

Has the patient confirmed his/her identity, site, procedure, and consent?
- ☐ Yes

Is the site marked?
- ☐ Yes
- ☐ Not applicable

Is the anaesthesia machine and medication check complete?
- ☐ Yes

Is the pulse oximeter on the patient and functioning?
- ☐ Yes

Does the patient have a:

Known allergy?
- ☐ No
- ☐ Yes

Difficult airway or aspiration risk?
- ☐ No
- ☐ Yes, and equipment/assistance available

Risk of >500ml blood loss (7ml/kg in children)?
- ☐ No
- ☐ Yes, and two IVs/central access and fluids planned

(with nurse, anaesthetist and surgeon)

- ☐ **Confirm all team members have introduced themselves by name and role.**
- ☐ **Confirm the patient's name, procedure, and where the incision will be made.**

Has antibiotic prophylaxis been given within the last 60 minutes?
- ☐ Yes
- ☐ Not applicable

Anticipated Critical Events

To Surgeon:
- ☐ What are the critical or non-routine steps?
- ☐ How long will the case take?
- ☐ What is the anticipated blood loss?

To Anaesthetist:
- ☐ Are there any patient-specific concerns?

To Nursing Team:
- ☐ Has sterility (including indicator results) been confirmed?
- ☐ Are there equipment issues or any concerns?

Is essential imaging displayed?
- ☐ Yes
- ☐ Not applicable

(with nurse, anaesthetist and surgeon)

Nurse Verbally Confirms:
- ☐ The name of the procedure
- ☐ Completion of instrument, sponge and needle counts
- ☐ Specimen labelling (read specimen labels aloud, including patient name)
- ☐ Whether there are any equipment problems to be addressed

To Surgeon, Anaesthetist and Nurse:
- ☐ What are the key concerns for recovery and management of this patient?