

Neurosurgical Needs and Assets Assessment of Public Hospitals in Uganda: An
Evaluation of Mulago Hospital to Inform Neurosurgical Program Planning at Mbarara
and Gulu Hospitals

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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2016

ABSTRACT

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Abstract

Background: Since 2007, there has been an ongoing collaboration between Duke University and Mulago National Referral Hospital (NRH) in Kampala, Uganda to increase neurosurgical capacity. This program is prepared to expand to other sites within Uganda to improve neurosurgery outside of Kampala as well. This study assessed the existing progress at Mulago NRH and the neurosurgical needs and assets at two potential sites for expansion. Methods: Three public hospitals were visited to assess needs and assets: Mulago NRH, Mbarara Regional Referral Hospital (RRH), and Gulu RRH. At each site, a surgical capacity tool was administered and healthcare workers were interviewed about perceived needs and assets. A total of 39 interviews were conducted between the three sites. Thematic analysis of the interviews was conducted to identify the reported needs and assets at each hospital. Results: Some changes should be considered for the Duke-Mulago Collaboration model prior to expansion. These include more training for the neurosurgery residents and making the supply donations sustainable. Neurosurgery can be implemented at Mbarara RRH currently but the hospital needs a biomedical equipment technician on staff immediately. Gulu RRH will not be well positioned for Neurosurgery until there is a CT scanner located in the Northern Region of Uganda. Conclusions: Neurosurgery is already present in Uganda on a small scale and needs rapid expansion to meet patient needs. This progression is

possible with prudent allocation of resources on strategic equipment purchases, human resources including clinical staff and biomedical staff, and changes to the supply chain management system.

Dedication

This work is dedicated to all of the healthcare workers that donated their time to this study; most especially the trailblazers of neurosurgery in Uganda at public hospitals. In 2015, the first two students graduated from the neurosurgery residency program at Mulago National Referral Hospital. Their addition to the workforce increased the number of neurosurgeons devoted to public service in Uganda by 33%.

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1. Introduction

In LMICs, nine out of ten people cannot access basic surgical care (Meara et al., 2015). Universal health coverage and many of the Sustainable Development Goals (SDGs) may remain out of reach as long as surgical and anesthetic care is not universally available (Meara et al., 2015). Continuous improvement is needed in surgical access due to the significant contribution of surgical conditions to the global burden of disease. An estimated 11% of the world's disability adjusted life years (DALYs) are attributed to conditions that require surgical intervention, with a disproportionate amount of DALYs contributed from the African continent (Debas HT, 2006). While 21 per 1,000 DALYs in the America's are attributed to surgical disease, for Africa, the figure is nearly double that at 38 per 1,000 DALYs (Debas HT, 2006). In sub-Saharan Africa, up to 93% of the population do not have access to safe surgery, compared with only 3.6% lacking access in high income regions (Meara et al., 2015).

Currently, the primary barriers to performing surgery in LMICs include human resources, lack of necessary infrastructure, equipment, and supplies (Carlson et al., 2015). These barriers have been demonstrated by studies specific to sub-Saharan Africa, along with additional capacity limitations including lack of adequately trained surgical and anesthesia staff and inconsistent availability of electricity, water, oxygen, blood banking, and fuel (Abdullah et al., 2011; Chao et al., 2012; Choo et al., 2010; Elkheir et al., 2014; Groen et al., 2012; Henry, Windapo, Kushner, Groen, & Nwomeh, 2012; Idriss et

al., 2011; Kingham et al., 2009; Knowlton et al., 2013; Linden et al., 2012; Penoyar et al., 2012; Petroze, Nzayisenga, Rusanganwa, Ntakiyiruta, & Calland, 2012; Sherman et al., 2011).

1.1 State of Surgery in Uganda

Uganda has not been immune to the burden of surgical disease or the regional barriers demonstrated in prior literature. A 2014 sample of households in the Wakiso district in Central Uganda showed a 6.3% prevalence of untreated surgical conditions and a lifetime prevalence of 26% (Butler et al., 2015). Surgical conditions may include infectious diseases, non-infectious diseases, or injuries. Treatments are often a single curative procedure rather than longer term treatment for various medical conditions (Poenaru, Ozgediz, & Gosselin, 2014). Various surgical interventions have been shown to be as cost-effective therapies even when compared to vaccination campaigns or drug treatments (Chao et al., 2014).

Uganda's allocation to the public health sector is dangerously low; between 2010 and 2014, the government health expenditure has ranged between 7.8 and 8.9 percent of the total government expenditure (Anonymous, 2015). This resulted in per capita health spending of between \$9-12 USD during this period. This spending is far below the target of \$17 USD set by the Ugandan government in its Health Sector Strategic and Investment Plan for 2010-2015 (HSSIP) and the WHO recommendation of \$34 USD

(Anonymous, 2015). The lack of funding devoted to public healthcare requires prudent use of resources and proper planning for new programs.

Uganda's financial limitations do not allow for rapid progress on surgical barriers such as human resources. Uganda's Ministry of Health (MOH) has reported significant public health sector staff shortages; only 73% of the approved positions were filled as of April 2015. The most significant human resource shortages have been shown in anesthesia staff and pharmacists; shortages by staff role are shown in Table 1

(Anonymous, 2015).

Table 1: Filled positions by staff role in public health institutions, April 2015

Staff Role	Norm (Approved Positions)	Filled Position	Percent Filled
Doctors	1,296	936	72%
Nurses	19,946	16,584	83%
Midwives	6,061	4,607	76%
Clinical Officers	2,758	2,780	101%
Laboratory Staff	2,737	2,379	87%
Anesthetic cadre	725	215	30%
Pharmacists	370	31	8%
Dispensers	420	232	55%
Other Allied Health Staff	1,177	820	70%
Cold Chain Technicians	284	115	40%
Consultants	305	107	35%
General administrative cadres	1,337	1,356	101%
Health Administrative cadres	374	124	33%
Support Staff	8,622	4,573	53%
Others	6,055	3,330	55%
Total	52,467	38,189	73%

Adapted from (Anonymous, 2015)

Although the number of filled positions has markedly improved from 53% in 2009 to 73% in 2015, Uganda still maintains a critical shortage of healthcare workers

(Anonymous, 2015). The World Health Organization's (WHO) 2006 World Health Report classified 57 countries with less than 2.28 health workers per 1,000 population to have a severe shortage; for Uganda, this ratio was 1.50 in 2013 (Anonymous, 2015). Many of the health workers included in this figure are nurses and technicians while physician numbers are more limited. There is one physician per 20,834 Ugandans (<0.05 per 1000 population) compared to one physician per 460 population in the US (Linden et al., 2012). As of 2012, there were 328 formally trained surgeons and 17 credentialed anesthesiologists available to serve Uganda's population. Of the 328 surgeons, 107 were general surgeons (32.6%), 124 were OB/GYNs (37.8%), and only 97 were subspecialty surgeons (29.6%) including cardiovascular, orthopedic, and plastic surgeons, otolaryngologists, ophthalmologists, and neurosurgeons (Linden et al., 2012).

Limitations in infrastructure and equipment have also been documented in Uganda. The existing number of health centers is not adequate for the population as capacity is frequently up to twice the number of beds (Linden et al., 2012). Operating theaters also are not adequate, as there are only 0.2 major theaters per 100,000 population (Linden et al., 2012). This is less than the west and sub-Saharan regional average of 1.0 theaters per 100,000 population and drastically less than the 25.1 per 100,000 regional average in eastern Europe (Funk et al., 2010).

Although hospitals generally have access to water, the supply is somewhat unreliable and backup supplies are not always available. Power outages are frequent as

electricity is usually supplied from a national grid. Back-up power generators tend to be available at most hospitals and are used to run essential services such as the operating theaters until power is restored; however high fuel costs limit the use of generators (Linden et al., 2012). Reports from 2008 through 2009 showed a mere 40% of available equipment was in good condition (Anonymous, 2010a). Significant deficits also exist in vital monitoring equipment; a 2012 survey of 14 public hospitals revealed not one available pulse oximeter (Linden et al., 2012).

1.2 Neurosurgery in Uganda

There is sparse information on surgical barriers in LMICs for subspecialties like neurosurgery which require complex infrastructure, equipment, and human resources beyond that of general surgery. A 2005 study revealed that Uganda had only five neurosurgeons to meet the needs of the then 30 million population, a ratio of just one neurosurgeon to meet the needs of the then 30 million population, a ratio of just one neurosurgeon per six million people (El Khamlichi, 2005). By contrast, the United States has a ratio of one neurosurgeon per 65,580 population (Rosman et al., 2013).

Neurosurgery comprises a smaller subset of surgical need, but it includes both acute and chronic debilitating conditions that contribute high morbidity and mortality to the surgical burden of disease. Imperative neurosurgeries include interventions for stroke, aneurysms, brain tumors, traumatic brain injury (TBI), hydrocephalus, and spinal disorders.

In Uganda, the burden of TBI is high; at Mulago National Referral Hospital (NRH) in the capital city of Kampala, road traffic injuries (RTIs) were the most common cause of injury admitted to the hospital and the leading cause of mortality in trauma patients (Hsia et al., 2010). Among all injury-related mortality at Mulago NRH, 65% were due to a head or neck injury (Jayaraman et al., 2011).

In order to fill a critical gap in service delivery for neurosurgery in Uganda, a collaboration between Duke University School of Medicine and Mulago NRH began in 2008. This program will be referred to as the Duke-Mulago Collaboration throughout this document. The partnership has focused on training, equipment, and supplies. The training component aims to credential new neurosurgeons within Uganda with a residency program at Makerere University Medical School. Biannual neurosurgical camps occur in-country to train clinical support staff and introduce cases of increasing complexity to the hospital. Another component to the program is equipment; there have been regular donations of devices and supplies from Duke University Medical Center to Mulago NRH to outfit a neurosurgical operating suite, intensive care unit, and recovery area with capacity to accommodate neurosurgical patients. Within the first two years of the program establishment, neurosurgical capacity at Mulago Hospital had increased 106% (Haglund et al., 2011).

The initial success of this partnership and continued increase in neurosurgical demand has motivated the expansion of this program to additional public hospital sites.

This emphasis on public rather than private facilities is in an effort to reach all Ugandans, regardless of socioeconomic status. All health services at public facilities have been free since 2001, yet utilization is poor based on public perception of the substandard infrastructure, medicine and supply stock-outs, and staff shortages (*Health Sector Strategic & Investment Plan 2010/11-2014/15*, 2010).

The call for program expansion has also been echoed by the Uganda Health Sector Strategic & Investment Plan (2010-2015). One of the key goals in this plan was to prevent, manage, and control non-communicable diseases - including injury. The strategic plan discussed the increasing burdens from cancer, injuries, and disabilities; a subset of each which require neurosurgical care (Anonymous, 2010a). The MOH's suggestion for addressing their key goals is a good reflection of the goals of this program as well:

A comprehensive approach to addressing health services is needed.

Focus only on a small set of interventions will not deliver the results required in a cost efficient, and sustainable manner. Investments made in health are not done by program, but rather by required inputs. These inputs are Human Resources, Infrastructure (including equipment transport and ICT), Medical Products, vaccines and technologies, and operational financing. (Anonymous, 2010a)

Since its inception in 2008, the program has continued to grow and plans to expand its partnerships to other public hospitals in Uganda. The purpose of this study is to evaluate the strengths of the Duke-Mulago Collaboration from the service provider perspective and to assess the neurosurgical needs and assets at two future program sites for feasibility and planning for program implementation.

2. Methods

This mixed methods study documents both assets and perceived needs for a neurosurgical program at three Ugandan public hospital sites. Both quantitative and qualitative tools will be used to evaluate the Duke-Mulago Collaboration at Mulago NRH in Kampala, and to plan for the establishment of neurosurgical programs at the Regional Referral Hospitals at Mbarara and Gulu.

2.1 Setting

Uganda is located on the equator in East Africa, bordering South Sudan, Kenya, Democratic Republic of Congo, Rwanda, and Tanzania. As of 2014, Uganda's population was 34.9 million with an annual growth rate of 3.03%; bringing the population to an estimated 42.4 million by 2020 (Anonymous, 2014). Life expectancy at birth in Uganda is 57 years for men and 61 years for women (WHO, 2013).

The health system of Uganda is comprised of both public and private facilities; although for the purpose of this study, research was focused on the public hospitals where patients have not been required to pay their providers since 2001 (Anonymous, 2010a). The National Health System's public sector is structured into National Referral Hospitals (NRHs), Regional Referral Hospitals (RRHs), General Hospitals, Health Centers IV, III, and II, and Village Health Teams (Anonymous, 2010a). At a minimum, general hospitals provide preventative and curative care, maternity and surgical care, blood transfusions, laboratory, and medical imaging services. Operational research, in-

service training, and consultation services are also available at general hospitals. Regional Referral Hospitals (RRH) are able to offer the same services as the general hospitals but in addition have some specialist clinical services available such as psychiatry, ear/nose/throat, ophthalmology, and specialty surgery. Research and teaching are also present at RRHs. At the highest level, National Referral Hospitals (NRH) should provide all of the RRH services in addition to comprehensive specialist care (Anonymous, 2010a).

2.2 Study Sites

The selected study sites include the cities of Kampala, Mbarara, and Gulu. Kampala, with a population of 1.5 million (Anonymous, 2014), was selected in order to evaluate the neurosurgical program at Mulago NRH; which serves as the teaching hospital associated with the medical school at Makerere University.

Mbarara was selected in order to study Mbarara RRH; which also serves as the teaching hospital for the medical school at Mbarara University School of Medicine. Mbarara RRH has one neurosurgeon and thus an existing small-scale neurosurgical program. Mbarara is located in southwest Uganda with a population of nearly 200,000 (Anonymous, 2014).

The third site, Gulu, was selected because of the medical school that is also located in the city; Gulu University School of Medicine. It is located in the northern region of the country with a population just over 150,000 (Anonymous, 2014).

Table 2: Demographic Characteristics of Study Sites

Study Site	District	Region	Number of Beds
Mulago NRH	Kampala	Central	1609
Mbarara RRH	Mbarara	Western	250
Gulu RRH	Gulu	Northern	335

Adapted from (Anonymous, December 2009)

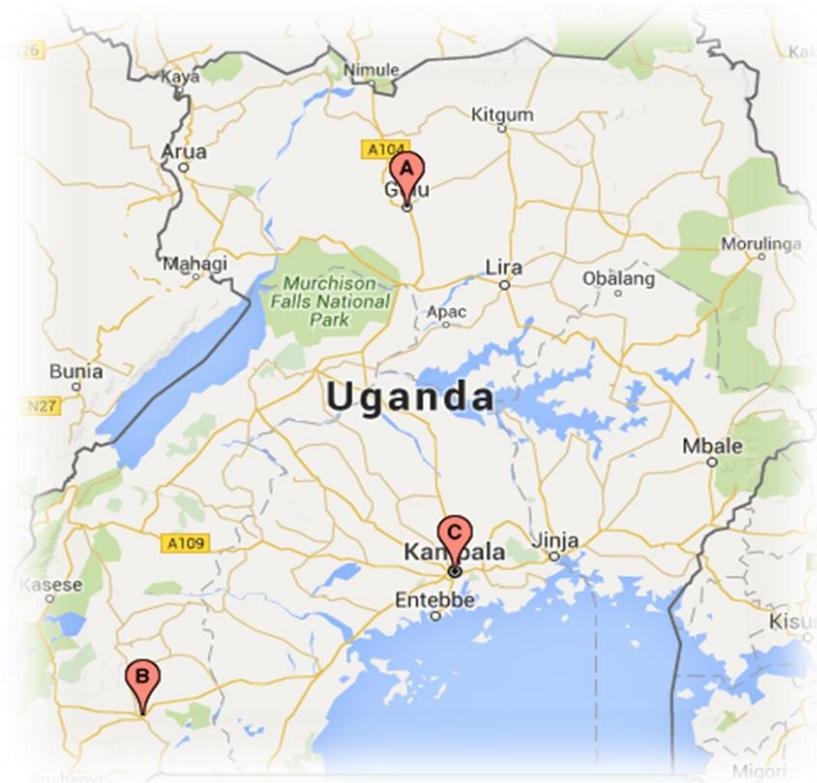


Figure 1: Study Sites (A: Gulu, B: Mbarara, C: Kampala)

The close association with the Medical schools is of importance for program planning since these sites have the potential to produce future surgeons, neurosurgeons, nurses, and anesthesia professionals that could be a part of a neurosurgical program, combating the human resource deficit. In addition, the three cities are located in different geographical regions; likely to meet a larger proportion of need. Kampala,

Mbarara, and Gulu are all in the top five most populous urban centers in Uganda (Anonymous, 2014).

2.3 Participants: Healthcare Workers

Study participants were recruited with cooperation from hospital administration. A total of 39 participants were interviewed; 18 from Mulago NRH, 13 from Mbarara RRH, and 8 from Gulu RRH. All three sites included participants from neurosurgery (if applicable), general surgery, trauma, intensive care, anesthesia, maintenance, and administration. Healthcare workers at the hospitals were eligible to participate if they were currently employed at the study site (at least part time) and worked in a relevant department to surgery, while workers were excluded if they preferred not to participate or did not have free time during the data collection period.

2.4 Procedures

Each site visit began with the completion of the quantitative surgical capacity assessment. The researcher conducted an adapted version of the Personnel, Infrastructure, Personnel, Equipment, and Supplies (PIPES) assessment with a staff member with substantial knowledge of the surgical operations at the hospital such as the nurse in charge of the operating theater, or the chief of surgery.

After completion of the surgical capacity assessment, interviews with medical staff members were conducted. Participants were approached in person by the study director and the research assistant at the hospital and asked if they had 30-60 minutes

free to discuss daily hospital needs with regard to neurosurgery. Upon request, they were also shown the Administrative Clearance granted from the hospital in order to conduct the study. Informed consent was provided to the participants, which explained the goals of the study. Many interviews occurred during tea breaks and lunch hours, so participants were offered snacks and beverages at the interview in appreciation of their time.

All staff members were individually interviewed by the study director in English (national language of Uganda). A local research assistant was present in all interviews to take notes as well as help with translation or pronunciation when required. Translation was not needed in any of the interviews, although occasional clarifications were requested due to the accents of the interviewer and respondents. Interviews were conducted with an interview guide (Appendices B and C) created for this study and audio-recorded. The recordings were stored on an encrypted hard drive and transcribed by local research assistants. During interviews, no protected health information was collected. In cases where names were included on the recordings, this information was de-identified in the transcripts. Original recordings on an SD-card and informed consent forms were kept in a locked cabinet for the duration of data collection in Uganda and analysis in the US. Once analysis is complete, all copies of the recordings will be destroyed. This study received ethical approval from the Institutional Review Board at

Duke University Medical Center and Makerere University in Kampala, Uganda.

Administrative Clearance was also granted by each hospital visited during the study.

2.5 Measures

Needs and assets were measured using a combination of the qualitative and quantitative tools attached in Appendices A, B, and C.

2.5.1 Surgical Capacity PIPES Assessment

The PIPES tool, adapted from Surgeons OverSeas, gives each hospital a score that signifies surgical capacity. PIPES was originally adapted from the World Health Organization's (WHO) Tool for the Situational Analysis of Emergency and Essential Surgical Care (Kwon et al., 2012). There are five subsections; one each for: personnel, infrastructure, procedures, equipment, and supplies. In the personnel section, the respondent would say how many staff members of a particular type work at the institution (for example, how many surgeons are employed at this hospital). This subsection is then given a score by adding up the numbers of staff that are included in the assessment. This subsection therefore does not have a maximum score; as it is dependent on how many staff are employed. The infrastructure subsection has 13 items, but also adds the number of functional operating rooms to this score, thus it also has no maximum. The remaining three sections of procedures, equipment, and supplies have a maximum possible score. Within the infrastructure, equipment, and supplies subsections, the respondent would answer whether the item was *always available*, for

which the hospital would receive a point, or *not always available*, for which the hospital would receive zero points. In the procedure subsection, the respondent would answer if a particular procedure was *done*, for which the hospital received one point or *not done*, for which the hospital would receive zero points. The scores from each subsection would then be added for a total, divided by 105, and multiplied by 10 to get a standard PIPES Assessment score.

For the purpose of this study, items were added to the PIPES assessment that are specific to neurosurgery such that neurosurgical capacity could be evaluated; for example, several standard neurosurgical procedures were added to the “Procedure” section within the tool. These items are shown in Table 3.

Table 3: Additions to PIPES Subsections

NeuroPIPES Item
Infrastructure
Dedicated Neuro Operating Room
MRI
Procedures
VP Shunt, ETV and EVD
Spina Bifida Repair
Myelomeningocele/Encephalocele Repair
Craniotomy/Craniectomy for Tumor
Craniotomy/Craniectomy for Fracture
Cyst Drainage and Abscess Removal
Evacuation of Bleeds
Spinal Surgery (laminectomy)
Neuro Flap/Skin Grafting
Equipment
Ventilator
Cardiac/O2 Monitors
EKG

NeuroPIPES Item
Drills
Retractors
Forceps
Rongeurs
Hooks
Dissectors
Distractors

In addition, the tool was modified to add space for notes and whether or not the element was available prior to 2008 when the Duke-Mulago Collaboration was established at Mulago NRH. This column (“Available prior to 2008”) is not relevant for the assessments at Gulu and Mbarara. The assessment was conducted on paper and the data was subsequently stored in electronic format in Microsoft Excel.

2.5.2 Perceived Needs and Assets

The in-depth interviews were conducted according to an interview guide created for this project. There were two unique interview guides to fit the needs of the evaluation of the Duke-Mulago Collaboration at Mulago NRH (Appendix B) and the needs assessment at Mbarara and Gulu RRHs (Appendix C). In addition, each interview guide was adjusted based upon the job role of each respondent. For example, although only one interview guide was initially created for Mulago NRH, in the field, for ease of the interview and flow, the guide was further divided into questions that were more appropriate to ask administrators, biomedical technicians, neurosurgeons, etc. Questions in these interviews revolved around perceived needs and barriers to a neurosurgical program with positive patient outcomes. Topics of discussion in the interviews

included: infrastructure such as water and electricity, human resources, training, equipment, supplies, and patient needs. The in-depth interviews were audio recorded and saved on SD Cards. The discussions were transcribed in English and these transcriptions were saved into Microsoft Word files, imported into NVivo 11 and backed up on an external hard drive.

2.6 Analysis

The study followed the layout in Figure 2. At all three sites, NeuroPIPES Assessments were completed. At Mulago NRH, 18 interviews were conducted representing administration, anesthesia, general surgery, intensive care, maintenance, neurosurgery, and trauma departments. At Mbarara RRH, 13 staff interviews were conducted representing administration, anesthesia, emergency, general surgery, intensive care, maintenance, neurosurgery, and oncology departments. At Gulu RRH, eight staff interviews were conducted among administration, anesthesia, emergency, general surgery, and maintenance departments.

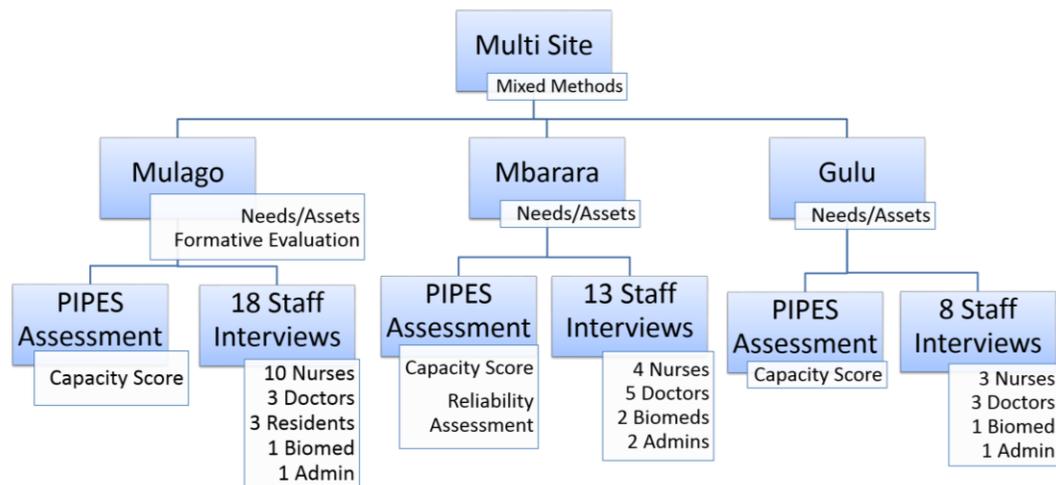


Figure 2: Study Flow Diagram and Sample Composition

Each hospital site was scored according to the Surgeon’s Overseas PIPES guidelines. The scores were tabulated and compared between sites to qualify the different levels of surgical readiness. Scores were computed for both the unmodified PIPES assessment and for the adapted NeuroPIPES assessment. The NeuroPIPES assessment was scored according to the additional items added for neurosurgery. Each subscale of the PIPES tool was updated to reflect additional items. The changes in scoring are shown in the Table 4.

Table 4: PIPES and NeuroPIPES Scoring Details

Subscale Maximum	PIPES	NeuroPIPES
Personnel	No maximum	No maximum
Infrastructure	13 + # Operating Rooms	15 + # Operating Rooms
Procedures	40	49
Equipment	22	32
Supplies	25	25
Total number of items used to compute score	105	126

To analyze the qualitative data, a thematic analysis approach was used. This analysis was conducted with the pre-identified themes of: needs, assets, personnel, infrastructure, equipment, and supplies. These themes were not mutually exclusive. Line by line micro-analysis was subsequently used for open coding to identify further themes. A thematic chart was developed with all identified themes and narrative text and quotes applied around these themes.

3. Results

The NeuroPIPES assessment contained all items previously in the PIPES assessment, thus results of this assessment are presented in two parts: PIPES scores, followed by NeuroPIPES scores.

3.1 Surgical Capacity: PIPES Assessment

The PIPES assessment was administered to one surgical staff member at each of the three hospital sites. At Mulago NRH and Mbarara RRH, the survey was taken by a surgical administrator and at Gulu RRH, the survey was taken by a surgeon.

Table 5: Cross-site PIPES Score Comparison

	Mulago NRH	Mbarara RRH	Gulu RRH
P-Score (no max)	133	29	10
I-Score (no max)	19	13	12
Pr-Score (40 max)	39	39	34
E-Score (22 max)	22	21	21
S-Score (25 max)	4	13	24
PIPES Index	20.67	10.95	9.62

According to the PIPES Assessment, Mulago NRH had the highest score for surgical capacity (Table 5). The Mulago score of 20.67 is nearly double that of Mbarara RRH (10.95) and more than double that of Gulu RRH (9.62). However, this score difference does not indicate that Mulago NRH has double the surgical capacity of Gulu RRH, but rather indicates a greater number of staff, reflective in the P-score, and surgical operating theaters, reflected in the I-score, at Mulago NRH.

Personnel (P-score)

The P-score is comprised of the numbers of staff that are present at the hospital in the surgical area including: anesthesiologists, nurse anesthetists, surgeons, and medical doctors performing surgery (Table 6). Due to Mulago’s National Referral status, the hospital has much larger numbers of staff than Mbarara or Gulu RRHs and this greatly inflated the Mulago score.

Table 6: Cross-site P-Score Comparison

Personnel	Mulago NRH	Mbarara RRH	Gulu RRH
General Surgeon	42	12	1
Anesthesiologists (MD)	11	4	0
Medical Doctors (doing surgery)	50	9	6
Nurse anesthetists	30	4	3
Total P-score:	133	29	10

*In the above table, numbers are total staff in each role. There is no maximum.

Infrastructure (I-score)

The I-score includes the number of operating rooms at the hospital without a maximum (Table 7). The number of operating rooms is added to the 13 items listed in the Infrastructure subsection. In the case of Mulago NRH, there are seven operating rooms while at Mbarara and Gulu RRHs there are four. The only infrastructure item missing at Mulago NRH was the functional CT scanner, which was also not present at Mbarara or Gulu RRHs.

Table 7: Cross-site I-Score Comparison

Infrastructure	Mulago NRH	Mbarara RRH	Gulu RRH
Running Water	1	1	0
External Electricity	1	1	0
Functioning Back-Up Generator	1	1	1
Incinerator	1	1	1

Infrastructure	Mulago NRH	Mbarara RRH	Gulu RRH
Medical Records	1	1	1
Emergency Department	1	1	1
Postoperative Care Area	1	1	1
Intensive Care Unit	1	1	0
Pretested Blood Available (blood bank)	1	1	1
Lab to test blood and urine	1	0	1
Functioning X-ray Machine	1	0	0
Functioning Ultrasound Machine	1	0	1
Functioning CT Scan	0	0	0
Subtotal I-Score	12	9	8
Number of Functioning Operating Rooms	7	4	4
Total I-score: (Subtotal + Operating Rooms)	19	13	12

*In the above table, each 1 represents an answer that the item was “always available” and each 0 was “not always available.” There is no maximum; there are 13 items plus the number of operating rooms.

Procedures (Pr-score)

In contrast with the large variety in P- and I-scores, The Pr-scores for the hospitals were somewhat similar; Gulu RRH scored 34 (out of 40) while Mulago NRH and Mbarara RRH scored 39 (Table 8). Mulago NRH and Mbarara RRH had identical answers in this section. None of the sites performed laparoscopic surgery.

Table 8: Cross-site Pr-Score Comparison

Procedures	Mulago NRH	Mbarara RRH	Gulu RRH
Cricothyroidotomy	1	1	0
Obstetric Fistula Repair	1	1	0
Cholecystectomy	1	1	0
Splinting	1	1	0
Cleft Lip Repair	1	1	0
Laparoscopic Surgery	0	0	0
Resuscitation, Suturing, Wound Debridement, Incision & Drainage of Abscess, Laparotomy,	1 (x34)	1 (x34)	1 (x34)

Procedures	Mulago NRH	Mbarara RRH	Gulu RRH
Tracheostomy, Chest Tube Insertion, Burn Management, Cesarean Section, Dilation & Curettage, Tubal Ligation, Hysterectomy, Appendectomy, Hernia Repair – elective, Hernia Repair – strangulated, Hydrocele, Bowel Resection and Anastomosis, Male Circumcision, Biopsy, Skin Grafting, Pediatric Hernia Repair, Pediatric Abdominal Wall Defects, Repair Imperforate Anus, Casting, Traction (Closed Fracture), Open Treatment of Fracture, Management of Osteomyelitis, Amputation, Clubfoot Repair, Contracture Release, Regional Anesthesia Blocks, Spinal Anesthesia, Ketamine Anesthesia, General Anesthesia			
Total Pr-score:	39	39	34

*In the above table, each 1 represents a procedure that was “done” and each 0 was “not done.” The maximum is 40. Procedures which were done at all three sites were represented in the same row of the table.

Equipment (E-score)

Scores were also nearly identical for the E-score (Equipment) between sites (Table 9). Differences were recorded in availability of oxygen concentrators and suction pumps. Mulago NRH scored a perfect 22 on equipment; stating that all listed equipment was available.

Table 9: Cross-site E-Score Comparison

Equipment	Mulago NRH	Mbarara RRH	Gulu RRH
Oxygen: Concentrator	1	0	1
Suction Pump (Manual or Electric)	1	1	0
Oxygen: Compressed (cylinder), Resuscitator bag valve & mask (adult), Resuscitator bag valve & mask (pediatric), Oropharyngeal	1 (x20)	1 (x20)	1 (x20)

Equipment	Mulago NRH	Mbarara RRH	Gulu RRH
airway (adult), Oropharyngeal airway (pediatric), Endotracheal tubes (adult), Endotracheal tubes (pediatric), Anesthesia machine, Pulse Oximeter, Oxygen Mask & Tubing, Stethoscope, Blood Pressure Measuring Equipment, Thermometer, Instrument Sets (abdominal, C-section), Kidney Dish Stainless Steel, Sterilizer, Electrocautery Machine, Vaginal Speculum, Endoscopes (gastro, colon, bronch), Operating Room Lights			
Total E-score:	22	21	21

*In the above table, each 1 represents an answer that the item was “always available” and each 0 was “not always available.” The maximum is 22. Equipment which was available at all three sites was represented in the same row of the table.

Supplies (S-score)

There was a large range of scores in the supplies section. Mulago NRH scored only 4/25 while Mbarara RRH scored 13/25 and Gulu RRH scored the highest reporting always having a sufficient supply of 24/25 items. Gulu RRH was only lacking absorbable sutures, Mbarara RRH was missing these and other standard items such as gloves, sterile gauze, and bandages, and Mulago NRH was missing the overwhelming majority of their supplies in sufficient quantity.

Table 10: Cross-site S-Score Comparison

Supplies	Mulago NRH	Mbarara RRH	Gulu RRH
Gloves (Sterile)	0	0	1
Gloves (Examination)	0	0	1
Nasogastric Tubes	0	1	1
Intravenous Fluid Infusion Sets	0	1	1

Supplies	Mulago NRH	Mbarara RRH	Gulu RRH
IV Cannulas	0	1	1
Syringes	0	1	1
Disposable Needles	0	1	1
Tourniquet	0	1	1
Sterile Gauze	0	0	1
Bandages Sterile	0	0	1
Adhesive Tape	0	0	1
Suture (absorbable)	0	0	0
Suture (non-absorbable)	0	0	1
Urinary Catheters	0	1	1
Sharps Disposable Container	0	0	1
Scalpel Blades	0	1	1
Face Masks	0	1	1
Eye Protection (goggles, safety glasses)	0	1	1
Gowns (for surgeon/scrub nurse)	0	0	1
Drapes (for operations)	0	0	1
Laparoscopic Supplies	0	0	1
Apron, Boots (theater shoes), Chest Tubes, Trach Tubes	1 (x4)	1 (x4)	1 (x4)
Total S-score:	4	13	24

*In the above table, each 1 represents an answer that the item was “always available/sufficient” and each 0 was “not always available/sufficient.” The maximum is 25. Supplies which were available at all three sites were represented in the same row of the table.

3.2 Neurosurgical Capacity: NeuroPIPES Assessment

Upon scoring the hospitals for neurosurgical capacity using the NeuroPIPES metric rather than the Surgical PIPES scores (Table 11), Mulago NRH scored somewhat lower than their prior score on the PIPES Index: 18.73 on NeuroPIPES and 20.67 on PIPES. This lower score shows a somewhat lesser capacity to perform neurosurgeries than general surgeries.

Table 11: Cross-site NeuroPIPES Score Comparison

	Mulago NRH	Mbarara RRH	Gulu RRH
P-Score (no max)	133	29	10
I-Score (no max)	20	13	12
Pr-Score (49 max)	48	48	38
E-Score (32 max)	31	26	31
S-Score (25 max)	4	13	24
NeuroPIPES Index	18.73	10.24	9.13
PIPES Index	20.67	10.95	9.62

Table 12 shows all items specific to Neurosurgery added to the Pr-score of the PIPES tool. Of the nine procedures in total for NeuroPIPES, all were performed by Mulago and Mbarara. Gulu RRH's Pr-score increased from 34 to 38 when the additional procedures were added; able to perform only four of the nine additions.

Table 12: Cross-site Neurosurgery Items Comparison

NeuroPIPES Item	Mulago NRH	Mbarara RRH	Gulu RRH
Infrastructure			
Intensive Care Unit*	1	1	0
Functioning CT Scanner*	0	0	0
Dedicated Neuro Operating Room	1	0	0
MRI	0	0	0
Procedures			
VP Shunt, ETV and EVD	1	1	1
Spina Bifida Repair	1	1	0
Myelomeningocele/Encephalocele Repair	1	1	0
Craniotomy/Craniectomy for Tumor	1	1	0
Craniotomy/Craniectomy for Fracture	1	1	1
Cyst Drainage and Abscess Removal	1	1	1
Evacuation of Bleeds	1	1	1
Spinal Surgery (laminectomy)	1	1	0
Neuro Flap/Skin Grafting	1	1	0
Equipment			
Oxygen: Compressed (cylinder)*	1	1	1
Anesthesia Machine*	1	1	1

NeuroPIPES Item	Mulago NRH	Mbarara RRH	Gulu RRH
Sterilizer (autoclave)*	1	1	1
Suction Machine (Manual or Electric)*	1	1	0
Electrocautery Machine*	1	1	1
Ventilator	0	1	1
Cardiac/O2 Monitors	1	1	1
EKG	1	1	1
Drills	1	0	1
Retractors	1	0	1
Forceps	1	1	1
Rongeurs	1	0	1
Hooks	1	1	1
Dissectors	1	0	1
Distractors	1	0	1

Also included in this table are items specific for Neurosurgery that appeared on the unmodified PIPES tool; these items are marked with an “” (for example, the Intensive Care Unit).

In the Equipment subsection, the E-score could have increased by a maximum of ten. Mulago NRH E-score increased by 9, having most of the specified equipment items. Mbarara RRH increased by 5, scoring 26/32; possessing half of the necessary neurosurgical equipment, and Gulu RRH increased by ten.

3.3 PIPES Inter-Rater Reliability Assessment

At Mbarara RRH, only one staff member initially completed the NeuroPIPES assessment as outlined in 3.1 (surgical administrator). Five months after the initial survey, two additional surgical staff members completed the assessment at Mbarara; an anesthesiologist and a specialty surgeon. The results of all three Mbarara respondents

were then compared to examine inter-rater reliability of the PIPES Assessment (Table 13).

Table 13: Mbarara PIPES Comparison for Reliability

	Respondent 1 Surgical Administrator	Respondent 2 Surgical Staff	Respondent 3 Anesthesia Staff
P-Score (no max)	29	21	31
I-Score (no max)	13	11	12
Pr-Score (40 max)	39	38	39
E-Score (22 max)	21	18	19
S-Score (25 max)	13	9	9
PIPES Index	10.95	9.24	10.48

There were large discrepancies in the P-scores between respondents, ranging anywhere from 21-31. The largest disagreements were seen for “Anesthesiologists”, with answers of 4, 5, and 9; and “Medical Doctors (doing surgery)” with answers of 9, 0, and 8 between the three respondents. For the I-scores, disagreements were observed on items such as external electricity, post-operative care area, intensive care unit, functioning ultrasound machine, and number of functioning operating rooms. In the Procedures Section, nearly all answers matched among respondents, with only one disagreement over whether or not clubfoot repair is done. The E-scores showed respondent disagreements over the availability of oxygen concentrators, stethoscopes, blood pressure measuring equipment, thermometers, instrument sets, suction pumps, and electrocautery machines. The last subsection, Supplies, showed the most disagreement over availability. Respondents disagreed on availability of IV cannulas,

tourniquets, adhesive tape, urinary catheters, sharps disposal containers, scalpel blades, eye protection, aprons, and chest tubes.

Although the three PIPES scores are not drastically different, it should be noted that Respondent 2 answered the assessment with a resulting score of 9.24. This score is lower than the score at Gulu RRH (Table 5). During the five months between conducting the assessments between the first respondent and the second/third respondents, two changes occurred at Mbarara RRH. First, the hospital purchased several ventilators for the ICU. Although ventilators are not included in the PIPES score, this could have changed the answer to whether the ICU was available (in the I-score). Secondly, Mbarara RRH built an oxygen plant on-site, which affected their supply of compressed oxygen. This change did not affect the respondent's answers; all three respondents reported adequate supplies of compressed oxygen.

3.4 Perceived Needs and Assets: In-Depth Interviews

Field interviews were conducted across all three sites among 39 respondents. The main codes of "Needs" and "Assets" and sub-codes of "Personnel," "Infrastructure," "Equipment," and "Supplies," were predetermined from the literature prior to analysis. Additional sub-codes were determined by reading the interviews and these codes were segregated into "what" and "why" categories that appear in Table 14. To note, the code for the CT scanner was grouped into Infrastructure rather than Equipment in order to reflect similar coding by the authors of the PIPES Assessment.

Table 14: Thematic Coding Map

Code	Sub-code	What are the Needs/Assets	Why are there Needs/Assets
Needs	Personnel	Anesthesia, Biomedical Engineer/Technician, Doctors/Medical Officers, Neuro-Specialists, Nurses-General, Nurses-ICU, Nurses-Theater, Nurses-Ward, Surgeons, Staff Training	Motivation, RRH Limitation
	Infrastructure	Ambulance, Blood Bank, Communication, CT Scanner, ICU, Laboratory, Medical Records, Oxygen Supply, Physical Space, Procurement System, Sterilization Department, Transportation Inside Hospital, Trauma Department, Unstable Electricity, Water/Sewage System	Budget Limitation, Night/Weekend Service, RRH Limitation
	Equipment	Biomedical Engineer/Technician, Drills, Monitors, Suction, Ventilator	Budget Limitation, Cannot Get Spares, Maintenance, Missing Parts, Night/Weekend Services, Over-Use, Service Contracts, Software Updates, Staff Training, Uninformed Equipment Purchases, Unstable Electricity/Power Damage
	Supplies	Basic Supplies, Drugs, Equipment Consumables	Budget Limitation, Delays in Reporting, Personal Supplies, RRH Limitation, Stock outs from NMS

Code	Sub-code	What are the Needs/Assets	Why are there Needs/Assets
Assets	Personnel	Biomedical Engineer/Technician, Interns/Residents, Maintenance Department, Surgeon, University Staff	Neuro-Camp Training, Dedicated Neuro-Department Staff
	Infrastructure	Blood Bank, CT Scanner, Oxygen Supply, Physical Space, Power Protection, Private/Neighboring Facilities, Sterilization Department, Water Supply	New Construction
	Equipment	Back-up Machines, Donations, Hospital Purchased Equipment	Use of non-protocol Equipment, Biomedical Technician/Engineer, Personal Equipment, Preventative Maintenance
	Supplies	Adequate Supplies, Private/Neighboring Facilities	Given from Camp, Reuse of Disposables

3.4.1 Personnel Needs

Gulu RRH

At Gulu RRH, there were no staff available with neuro-specialized training; including surgeons, anesthesia staff, and nurses. The lack of a qualified neurosurgeon was repeatedly mentioned by respondents as a barrier to neurosurgery as their general surgeon on staff had limited neurosurgical experience and there was no neurosurgeon in all of the Northern Region of Uganda (both public and private facilities). Although there was a general surgeon at Gulu RRH, it was mentioned as a limitation that there was only one on staff and very few doctors or medical officers to supplement. The anesthesia staff

consisted of three or four nurse anesthetists and there were no anesthesiologists. The hospital has just one biomedical technician to service the needs of the entire region and this staff member is on a short-term contract from a non-governmental organization to improve HIV/AIDS diagnostics.

Respondents speculated that there is little motivation to work as a doctor or surgeon in Gulu as there is little to no private practice in the region; thus medical professionals have preferred to stay in other urban areas. Doctors reportedly use private practice to supplement their salaries as they are paid low wages in the public sector.

“Private practice is not very good here in Gulu, I think the economy of the area is still low after the war. Actually the reason they don’t want to come to Gulu-- especially the doctors is because there is no private practice in Gulu. They would not get that money so they prefer to stay in Kampala [...] Where they are not going to do private practice what are you going to do? You have to pay them well to keep them here.”

~Administrator at Gulu RRH

Mbarara RRH

At Mbarara there were limited staff trained to deal with neurosurgical patients; only two nurses and one neurosurgeon had specialized training. Inside the operating theater, there was a severe staff shortage including nurses, anesthesia, and surgeons. The operating theater has four unused operating rooms despite high patient demand due to inadequate staff. This shortage is also reflected in the lack of use of the recovery area. Post-surgical patients recover and wake from anesthesia in the theater corridors so they

may be monitored by the staff as they walk past; there is not enough staff to be stationed separately in the recovery area. There is no biomedical technician at Mbarara RRH.

Staff members at Mbarara RRH felt that some positions such as biomedical technicians or specialty doctors were not being filled at the hospital because the staff numbers were limited by their Regional Referral status.

“It’s not only here but a political policy. For several years there has been a freeze on expanding new posts. Like I was talking about, upgrading this to a national referral hospital, that would have more staff. It’s about allowing the hospital to employ more people...”

~ Doctor at Mbarara RRH

Mulago NRH

Staff members at Mulago NRH reported a shortage of nurses in the intensive care unit (ICU). Nearly all services in the hospital were reported to be substandard during nights, weekends, and holidays due to staff shortages. This led to examples of inability to conduct diagnostic labs when a patient is deteriorating overnight, the ambulance having to pick up the radiographer at home to conduct or interpret a CT scan, and neurosurgeons or residents being unavailable while on-call.

At Mulago, many staff expressed frustration on being trained only on-the-job and not receiving specialized training for their department or area. In addition, staff mentioned that they are frequently rotated from one department to another such that once they have adequately learned a skill, they start over in another department. This

lack of training along with low salaries compared to their workload has left the nurses lacking motivation.

“People have been talking about motivation, motivation. Someone is working and gets salary but you need to put someone in the mood of working at least appreciate them like give allowances in some areas and motivate them. [...] We used to get cost sharing sometime back but it is no longer there. No allowance there, we are like other people who are working in other wards and those people you tell them to come and work in ICU but they don't want. It is terrible.”

~ ICU Nurse at Mulago NRH

Across All Sites

The severe nursing shortage was discussed by respondents at all sites, specifically for the wards where patients stay pre- and post-operatively. In Gulu RRH, there may be times where one nurse is looking after up to 80 patients in the surgical ward. At Mbarara RRH, the surgical ward can hold up to 100 patients which may be staffed by only one or two nurses.

“Staffing is generally a problem everywhere [...] for night even if you have a major post-operative day you have four or seven (patients), still it will be that person in the night for monitoring [...] by the time somebody realizes that maybe somebody is getting hypertension it may be late [...] she is alone you cannot blame her, she is running up and down others are calling wanting her help may be transfers from emergency to the main ward they want to be admitted so you realize that man power is generally not adequate.”

~ Doctor at Gulu RRH

3.4.2 Personnel Assets

Gulu RRH

The personnel assets at Gulu RRH were limited to the biomedical engineer under contract with an NGO, and the general surgeon.

Mbarara RRH

Mbarara does not have a biomedical technician or engineer on staff, however, the hospital benefits from a self-trained volunteer that troubleshoots equipment when time allows. In addition, the hospital has a maintenance staff available with a few electricians and a plumber for infrastructure needs.

Mulago NRH

Mulago staff members discussed several human resource assets resulting from a dedicated neurosurgery staff; including neuro-theater nurses that keep items well stocked, neuro-residents, and a neuro-biomedical technician. Operating Theater staff can easily access the dedicated biomedical technician as his workshop is located within the theater. Staff expressed a perceived benefit from training received during neurosurgery camps in conjunction with the Duke-Mulago Collaboration.

Across All Sites

Respondents at all sites mentioned the advantage of having access to interns and residents from their associated medical schools to assist with patient care. There is also

benefit from the University faculty at these schools which would assist in the hospitals occasionally.

“Those days they were not training residents. But these days there are trainings [...] they can handle the emergencies while the seniors are doing other long cases.”

~ Theater Nurse at Mulago NRH

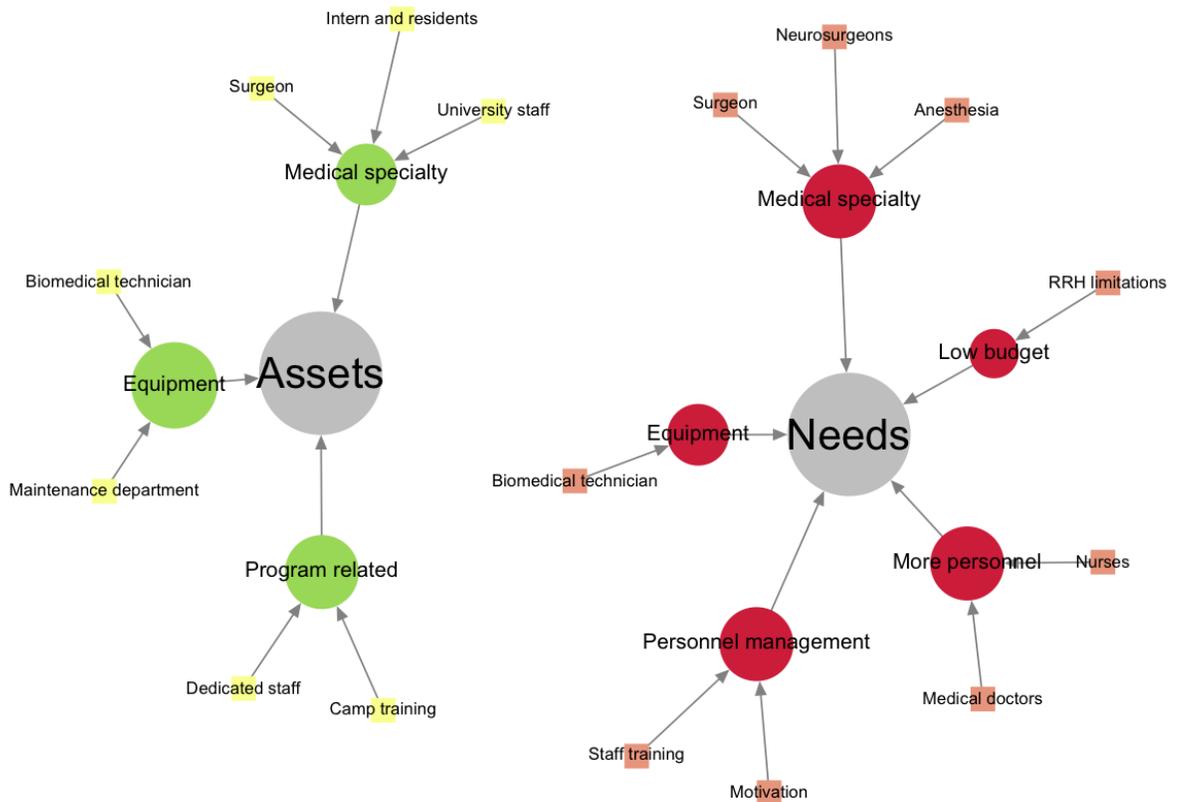


Figure 3: Concept Map Across Sites for Personnel

A concept map for the Personnel related themes across all sites is shown in figure 3. The concept bubbles are shown with larger diameters based on frequency of their mention.

3.4.3 Infrastructure Needs

Gulu RRH

There is no ICU or Trauma Unit at Gulu RRH. The staff expressed limitations to their daily activities due to sewage system disruptions such as long term toilet blockages for up to five months. During the dry season, the water supply will occasionally run dry and nurses fill large drums from the bore-hole on site. Electricity sometimes fails and although there is a back-up generator, it is not directly linked to the operating theater and thus sometimes fails to supply them with backup power.

There is not an adequate system for communicating between departments; there is no intercom or landline telephones. Staff must use their personal mobile phones for which they pay their own airtime to contact fellow staff. The referral system to get to Gulu RRH is lacking as there is only one ambulance. This ambulance will take patients to Mulago NRH when specialized care is needed. Problems arise when more than one patient needs to be referred to Mulago in the same day. Blood is difficult to procure from the blood bank during night and weekend hours because the bank is off-site. Gulu also lacks a CT scanner to diagnose neurosurgical conditions. Staff speculated that some infrastructure issues may be due to Gulu RRH's old physical structure. A limited budget inhibits proper maintenance and updating of the infrastructure. The significant infrastructure limitations cause frequent referrals from Gulu RRH to other hospitals with improved surgical capacity.

“CT scan, we don’t have it and it’s not in whole region, so there is no short cut you don’t know what is happening [...] so you have to refer the patient. Sometimes you realize that for a long time you don’t have power; if it is a rainy season sometimes we have spent a whole week without power [...] you do not want to risk the life of that patient to die there because if there is no power it means the autoclaving ability is slow the generator is run for few hours and you cannot do much you just have to refer the patient.”

~ Doctor at Gulu RRH

Mbarara RRH

Staff reported several limitations with regard to water; it occasionally fails completely and they have sinks (taps) that are non-functional. At the time of the interviews, the CT scanner at Mbarara had been out-of-service for at least four months. The ICU was also out-of-service during the study as all ventilators were out-of-service. This resulted in post-operative patients being discharged to the emergency ward where patient monitoring might be slightly improved over the surgical ward. Staff noted limitations with regard to the ambulance system and the lack of training of those bringing in trauma patients. Since ambulances are not in abundance, it is police and bystanders that frequently bring patients to the hospital and they sometimes cause secondary injury. The infrastructure for sterilization often impeded surgeries; both for sterile linen and for instruments. Mbarara also has limited supply of oxygen to sustain their patient demand.

The hospital's infrastructure progress is thought to be limited by their Regional Referral status. Since they are not designed to provide specialty care (ex. Neurosurgery), there is no dedicated space to house the fragile neuro-patients. The neurosurgery theater is shared with other specialties and thus neurosurgery only occurs two days of the week. This limitation sometimes affects patient outcomes.

“A very good example is the case we had on Monday with a patient we identified in the emergency ward. He needed a craniotomy because he had too much pressure, intracranial pressure, we saw on CT scan and (he) was deteriorating so we said we want to operate (on the) patient, we could only take him to the theatre after 2pm and we lost him because there was no space.”

~ Doctor at Mbarara RRH

Mulago NRH

Interviews at Mulago NRH revealed deficiencies in the sewage system that significantly impacted daily activities. Patients and attendants (patient family members) must bring their own toilet tissue for the facilities and frequently use the incorrect tissue for a flush toilet; causing blockages. This issue has caused a sewage leak into the Operating Theater in the past. Water occasionally fails to be available and sinks in two of Mulago's seven theaters are not functional. Some departments of the hospital do not have hot water. Also non-functional at the time of this study was the CT scanner. The electricity at the hospital occasionally turns off, and this affects the operation of the elevators (lifts). Patients to be operated on for neurosurgery must be brought from the

third floor down to the first floor and the non-functional elevator may cause hours of delay.

Physical space at Mulago NRH is lacking in several departments. Although Neurosurgery has its own dedicated theater, the burden of trauma (emergency) neurosurgeries is so high that tumors, referred to as “elective” surgeries, are postponed indefinitely.

“Right now trauma is taking up about 80% of the space we have on our neurosurgical unit, which is supposed to be just 45 beds but [...] we are into the 60s or 80s at times when it is pretty bad with trauma. So the waiting time of patients we are taking two to three years for tumors to be operated. We have tried also to shorten that into probably one year but still one year is still unacceptable as regards the waiting times.”

~ Doctor at Mulago NRH

Physical infrastructure is also lacking to host the neurosurgery residents while they are on-call. Residents are not able to stay on the hospital campus and therefore are not as readily available in case of emergencies. The neurosurgeons do not have any private space to consult with patients about their conditions and patient privacy is non-existent. The neurosurgery ward is so overcrowded that doctors must advise patients in the corridors and verbally acknowledge infection status such as CD4 counts with no other option. Wound dressings are changed in extremely close proximity to other ill patients.

Night and weekend care services were lacking specifically for the oxygen plant, blood bank, laboratory, and back-up generator. Even within the theater, on nights and weekends, the neurosurgery theater is locked and the neurosurgeons must use the emergency theater with limited equipment available.

Across All Sites

The physical space limitation was apparent to staff across all sites. This was true in the surgical wards as well as the operating theaters and ICUs.

3.4.4 Infrastructure Assets

Gulu RRH

The hospital has a building under construction for imaging infrastructure. The staff felt that their theater space was mostly adequate since they had three theaters and few specialties to accommodate. Respondents also felt that their sterilization department is an asset based on their low infection rate.

Mbarara RRH

Mbarara RRH has the asset of unused physical space. They have an operating theater with eight rooms, but only four of which are used. In addition, they have an eight bed ICU which is frequently underutilized due to a lack of staff or equipment. The hospital does have a CT scanner built into the infrastructure, however, it was not functional during the study. Outside of the hospital, Mbarara benefits from community

medical infrastructure as they can refer patients to local private facilities when the CT scanner or laboratory is not functional.

Mulago NRH

Infrastructure assets at Mulago include a dedicated physical space for neurosurgery which allows both emergency *and* elective cases to be treated while keeping the surgical equipment in working order. The dedicated neurosurgery theater also has step-down transformers and power stabilizers in the wall socket to avoid equipment damage based on unstable electricity or an equipment voltage mismatch. Mulago also has an oxygen plant on-site.

Across All Sites

Respondents at all sites have methods for back-up power. Each hospital had at least one generator while Gulu RRH mentioned having back up inverters as well. Although generators have automatic switches to turn on when the electricity fails, these switches are disabled in order to save on fuel.

“The generator, it is there, which is something like three years ago. Some four years back they use it to run whenever power was not on, it would run for five hours, some time back it used to run the whole night, I think in the institution they could have realized that it was costly for them.”

~ Doctor at Gulu RRH

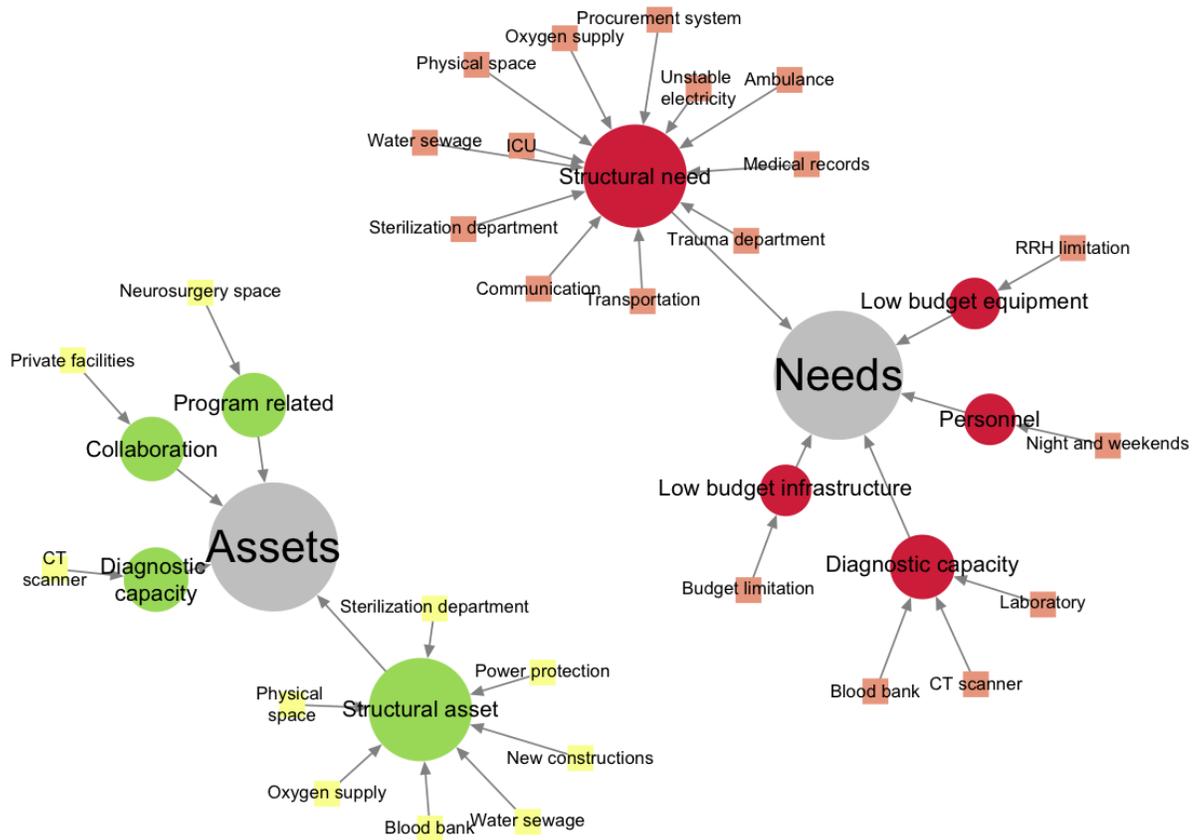


Figure 4: Concept Map Across Sites for Infrastructure

A concept map for the Infrastructure related themes across all sites is shown in figure 4. The concept bubbles are shown with larger diameters based on frequency of their mention.

3.4.5 Equipment Needs

Gulu RRH

Respondents at Gulu RRH spoke of several equipment items which they needed more of, such as suction machines, fully functional operating tables, oxygen concentrators and cylinders, electrosurgery units, and patient monitoring equipment

such as blood pressure machines and pulse oximeters. In the Medicine ward, there is only one patient monitor. The surgical staff mentioned lack of many instrument sets to perform specific procedures; including a neurosurgical set.

Although the hospital has a biomedical engineer on staff, she is paid by an NGO on contract and is not certain of her long term placement there. The biomedical engineer has difficulty keeping up with the workload of the entire hospital to include preventative maintenance, repair, and training staff on proper use. There were also strict limits on the spare parts budget which prohibited certain pieces from being repaired. Occasionally the spare parts were not available in Uganda, or no longer produced by the manufacturer. There are also times when the equipment may be fixable, but attempting to repair may nullify the warranty or service contract. These warranties and contracts are quite hard to actually enforce as the company's regional representatives are not often local to Uganda.

"We have a CD4 machine in the Lab. Fax caliber. That one, I cannot work on. Even if I have knowledge, I can't, because it is under a service contract. Most of those sophisticated equipment are under service contracts. Because I do not have the key, I have not been certified by the company to work on them."

~Maintenance staff at Gulu RRH

Mbarara RRH

During the study, Mbarara RRH had no functional ventilators, few patient monitors, and insufficient instrument sets. "Moon boots" for post-operative patients are

desired to prevent deep-vein thrombosis (DVT). Within the ICU, only half of their original eight suction machines are still functional and the central monitoring system is also in need of repair.

“At the moment our ICU is not ICU [...] I hope you saw the machines outside. They have all broken down, partly it’s because of the make, we first got Chinese that were breaking down often, then later when we got American model, servicing became a problem, as a result they worked a long time without service so they all broke down at ago. The spare parts have proved to be very expensive.”

~Doctor at Mbarara RRH

Staff mentioned that their equipment was previously in a better state as there was a biomedical engineer on staff. This engineer has been on leave for several years to pursue a doctoral degree in Biomedical Engineering outside of Uganda. In the meantime, the maintenance department performs repairs when possible, however their training is geared toward electrical and infrastructure solutions.

Mulago NRH

With regard to neurosurgery, Mulago NRH needs more of the equipment that is intended to last for a finite period of time; such as surgical instruments, bone drills and drill bits. In addition, the neurosurgical staff expressed the need to do several neurosurgeries in the same day and complained that they must wait for the drills to be sterilized before moving to the next patient. Even though rapid sterilization would be ideal, their drills do not stand up well to sterilization in the long term. Sterilization is a

limiting factor in terms of capacity; there are not enough sterilizers, or enough space in their existing autoclave to meet the needs in the theater. Although equipment specific to the neurosurgery theater is well maintained due to the dedicated biomedical engineer, this is not the case for all theaters. Staff discussed a period of time during the last year when none of the suction machines were working in any of the operating rooms. The emergency theater has very little functional equipment on a routine basis.

“Our emergency setting is not so friendly that we can walk around with our diathermy machines and drills. So we can only use the drills when the main theatre is open and then when the main theatre is open and then when it comes to weekends public holidays like today, I cannot access the drill because it has to be kept and that becomes hard because if we had tumor operations then you have to use either a bone nibbler, you know you cannot access the drill and that becomes hard. And even the time you are going to spend on the patient becomes slow.”

~Resident at Mulago NRH

There are also substantial deficits outside of the theater. The referral and support departments for the theater (ICU, trauma, neuro-ward) complained of missing infusion pumps, feeding pumps, and monitoring equipment. The neuro-ward estimated that they need as many as 20 additional patient monitors for the high dependency unit. At the time of this study the neuro-ward had only six bedside monitors, all of which were dedicated to the high dependency unit with none for the remaining patients.

Staff felt that they greatly benefit from equipment donations from NGOs and international “friends,” but that the hospital does not take proper ownership of them.

This concept of ownership seemed to include routine maintenance and procuring consumables and spare parts to keep them functional.

“The hospital took a while, actually up to now it still struggles to own the (donated) equipment. [...] They don’t have a maintenance budget and when the machines break down to get the hospital to actually fund the repair that is difficult.”

~Doctor at Mulago NRH

Across All Sites

Each hospital independently described their need for additional suction machines, resuscitation equipment, patient monitors, ventilators, and autoclaves. Staff also explained that nearly everyone on staff would benefit from training on proper use and maintenance of the equipment. In addition to user error, equipment was frequently out of service due to over-use, missing consumables, inability to procure spare parts due to budget limitations or supply chain availability, commitment to an infeasible service contract, power damage, and lack of routine maintenance.

“We have had challenges in that some of the equipment donated does not come with operating manuals and so people do not know how to use them and they never take off. [...] They just gather dust nobody knows how to use them. Some of them are in languages we don’t understand. [...] The writing’s on the machine might be in another language totally which is not English therefore the staff cannot understand how to use it.”

~Administrator at Gulu RRH

3.4.6 Equipment Assets

Gulu RRH

Staff at Gulu RRH benefit from the use of non-standard or non-protocol equipment to meet patient needs. They discussed using the manual suction machine as a backup to the electric suction machine when it is out of service; although they noted that it is cumbersome to operate. Gulu RRH recently received a burr hole neurosurgical instrument set, but do not have a proper bone drill for the skull. This has inspired innovation among the staff at the hospital; when they perform orthopedic surgeries or the occasional neurosurgery, they use a hardware power drill and sterilize the bits after use.

“Like this is meant for the hardwares but we use it in surgery. What we do we wrap it in the autoclaved drip [...] If we had appropriate it would have been a power drill [...] but it’s quite expensive the hospital cannot afford it [...] at least we have about 90% of infection control using this.”

~Doctor at Gulu RRH

Mbarara RRH

Although the hospital does not have a biomedical technician or engineer, the maintenance department does occasionally perform preventative maintenance on medical equipment such as oxygen concentrators and autoclaves. Mbarara’s anesthesia equipment for surgery is well maintained; the staff noted this may be due to the fact that they keep their equipment locked in a private room when they are not using it. This concept of “personal ownership” of equipment was also practiced by the neurosurgery

team; the neurosurgeon keeps his own electrosurgery unit (diathermy) locked in his office when it is not in use.

“Anesthesia has the best equipment in the hospital because all the people in Anesthesia have been pushed towards that level of saying ‘this is ours.’ [...] If I am not using them, they are inside my room. [...] If we are not using them, in our room and they have to be under lock because we don’t want somebody to just come and pour water on it whatever. Now that is – which is not the right way of doing things but we have to accept it.”

~Doctor at Mbarara RRH

Mulago NRH

Mulago NRH’s equipment has benefitted from the biomedical technician staff; one of which is dedicated to neurosurgery. Much of the neurosurgery equipment is also “dedicated” and kept inside the neurosurgery theater under lock and key by theater in-charge staff when not in use by neurosurgery. Mulago also receives frequent medical equipment donations from the neurosurgery camps within the Duke-Mulago Collaboration.

“Almost they are all the same but for neuro- as I have told you due to proper maintenance that is why they are better and on top of that, they normally use those new equipment whenever they have a camp. At least something new comes in. But you find other theatres you have been using something of years and years. But for them at least they get new supplies whenever there is a camp.”

~Theater Nurse at Mulago NRH

Across All Sites

Each site mentioned the use of back-up machines at times when equipment breaks down. Although the back-ups are not always the preferred equipment, they will use them until the other equipment has been repaired.

“Like at the moment we have like two or three equipment. If one is not working we remove it away then bring the next which is working because they’re in these rooms, they are not far.”

~Nurse at Gulu RRH

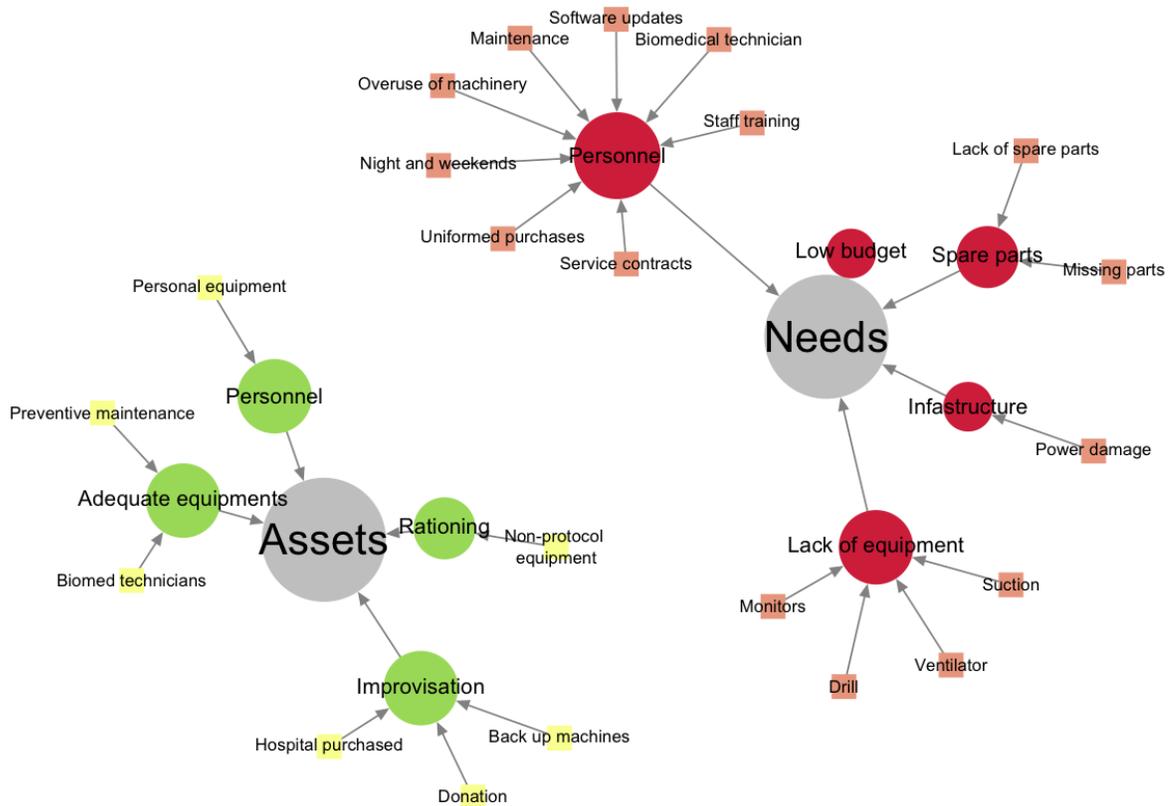


Figure 5: Concept Map Across Sites for Equipment

A concept map for the Equipment related themes across all sites is shown in figure 5. The concept bubbles are shown with larger diameters based on frequency of their mention.

3.4.7 Supply Needs

Gulu RRH

Staff at Gulu RRH discussed frequently running out of supplies such as gauze, gloves, and sutures. Staff also noted that the purchase of equipment consumables is limited by budget.

“That the equipment is fine but you need some consumables. Yeah I have seen that commonly with theatre lights. We need bulbs they have blown and we don’t have them in stock, the best would have been to purchase them in bulk and put them in the store and the engineer just keeps picking whenever they blow. But we are not able to do that because of the limited budget and so we just have to purchase for every machine as it breaks down.”

~Administrator at Gulu RRH

Mbarara RRH

Mbarara RRH occasionally runs out items like linen, x-ray films, gauze, gloves, sutures, and reagents for the laboratory. The hospital also must procure refills of compressed oxygen for the tanks from NMS located in Kampala and staff noted that the supply is never enough for their patient demand. Orders are placed to NMS for the adequate number of supplies for a variety of consumables and these items will not be delivered in the number requested. Staff speculated that this is based on their Regional Referral status as certain supplies might be saved for Mulago NRH only. Due to the short supply of certain items, staff sometimes take personal “ownership” of the supplies

that they need for their job roles, keeping supplies with them rather than leaving them in a community stock-room; this practice was noted specifically with the electrodes needed for the electrosurgery unit. After the procedure, the staff member leaves with the electrodes rather than leaving them with the machine.

“The National Medical Stores tells you, we are not going to give you that; we don’t have money for that. So that is the problem and that is why I was telling you that as soon as we make this place a national referral, the better for us.”

~Doctor at Mbarara RRH

Mulago NRH

Staff mentioned needing a consistent supply of food for the patients; including special diet food for patients in the ICU. At the moment it is the responsibility of the patient family to provide food for the patient. Staff discussed supply limitations due to stock-outs at NMS and local availability of equipment consumables and explained that this has led to the practice of reusing disposables until it is no longer possible.

“You find we have some of these consumables where you can say, this is a single use but of course we know if we throw away we are likely not to get any replacement we end up re-using them, disinfecting them, the airways, gadeoles, the re-breather masks and the nasal airways. Yah, we keep on re-using. We disinfect, we either soak in Jik or use other disinfectants so that we can keep on using on other patients.”

~Nurse at Mulago NRH

Across All Sites

Each site discussed limitations from receiving consumables exclusively from NMS. The regular stock-outs at NMS result in deliveries to the hospital of only part of their order, or wrong sizes of items like sutures, or none of the item they ordered at all. The lack of needed surgical supplies results in the cancellation of all elective surgeries until the next shipment such that the existing supply can be rationed on the emergency cases. This was not only true for disposables and equipment consumables, but also drugs. Staff discussed the regular practice of asking the patient families to go into town to purchase drugs or supplies on their own. Although there are local pharmacies where supplies can be purchased, the hospitals do not have additional budget resources to procure back-up supplies on their own. In emergency situations, patients are given substitute drugs that may not be as effective for the particular diagnosis. Staff also reported that some of the locally available drugs (generics) have questionable efficacy and are lacking in the active ingredients.

“And the brand. We have a problem with the brands in the country. He may be getting the brand of drugs where the amount of active ingredient in the drug is not right. So we have problems as far as branding is concerned. It puts patients at risk. So we have started prescribing brand names which is of course unethical as far as this hospital is concerned because we have no choice.”

~Doctor at Mulago NRH

3.4.8 Supply Assets

Across All Sites

References to consumables assets were extremely limited across all sites, thus there is little to report individually. The most commonly reported asset was from donations of drugs and consumables from surgical camps at the hospitals. Each hospital also explained a borrowing system from other neighboring facilities that is an asset in times of supply shortage.

“So those (supplies) keep running out often. [...] How I normally get around it, sometimes I buy them on my own, sometimes I get from the Heart Institute; sometimes you find something lying somewhere and no one knows what else to do with it and luckily it would be useful to you. You sort of stock pile the things somewhere [...] then there is also the camps then you get some things.”

~Doctor at Mulago NRH

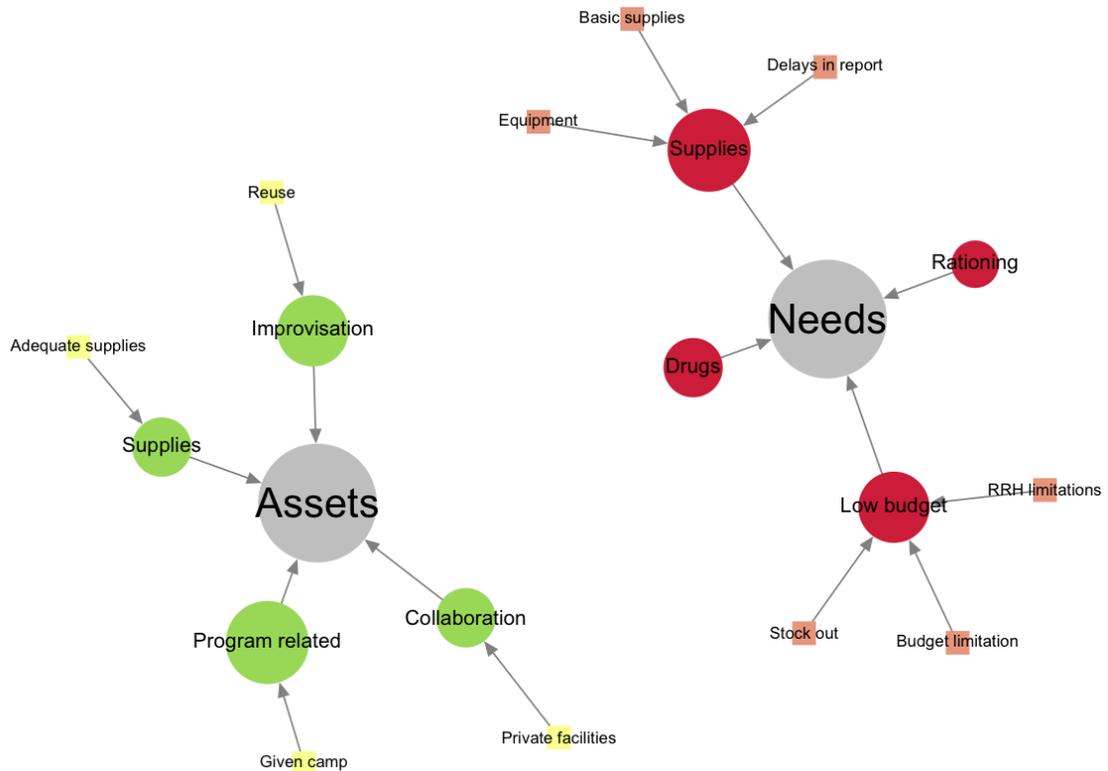


Figure 6: Concept Map Across Sites for Supplies

A concept map for the Supplies related themes across all sites is shown in figure 6. The concept bubbles are shown with larger diameters based on frequency of their mention.

3.4.9 Emerging Theme: Improvisation

During the in-depth interviews, the theme of improvisation emerged in 15 out of 39 interviews (38%). This concept was not introduced by the interview guide, but was separately brought up by staff at each site: 3/8 Gulu RRH interviews, 3/13 Mbarara RRH interviews, and 9/18 Mulago NRH interviews included improvisation. When the interviewer asked probing questions about supply shortages or equipment

malfunctions, respondents frequently answered that they would improvise to save a patient. The topics for which improvisation was mentioned included instruments, supplies, equipment, and personnel. The Mulago NRH respondents tended to have more improvisation responses to questions about supplies. This is different from Gulu and Mbarara RRH, whose anecdotes more commonly focused on equipment and instruments.

Table 15: Cross-site Improvisation Quotes

Gulu RRH	Mbarara RRH	Mulago NRH
<p>On Instruments: “Well there was a lot of <i>improvising</i> okay you use an instrument for the purpose it is not meant to be used. There were so many things there was a lot of <i>improvising</i>.” ~Administrator</p>	<p>On Instruments: “Many of these sets we use are incomplete, for example a craniotomy set for working on tumors in the brain, [...] operating of the spine we don’t have a set at all we are still <i>improvising</i>.” ~Doctor</p>	<p>On Supplies: “And for the sundries sometimes we always <i>improvise</i> as I said and we are going to continue with that for the safety of the patients and for the benefit of the patients. But everything we shall do for the safety of the patient.” ~Nurse</p>

Gulu RRH	Mbarara RRH	Mulago NRH
<p>On Equipment: “We use the common equipment for doing minor, minor surgeries but for [...] opening up the skull, yes we have a burr hole set. In the major theatre they <i>improvise</i> and they try to do burr holes and then possibly evacuate, but basically you can’t say that there is a sophisticated equipment that is used in neurosurgery [...] here. Most of the equipment that we have they are orthopedic surgery equipment.” ~Doctor</p>	<p>On Equipment: “You know the nature of our work also is, if you opened up the abdomen there is no option of you know I’m stuck or there is nothing I can do. You must <i>improvise</i> and make sure the patient is alive and everything is ok, so it’s; of course it increases the pressure on you yeah, you know, we need a better working environment.” ~Doctor</p>	<p>On Supplies: “The consumables, for that’s I can’t say that, how often we fail to get the consumables because sometimes we <i>improvise</i>, everything we <i>improvise</i>. So that this patient can be worked on – We just <i>improvise</i> in case we get a shortage, you can go to another theatre and ask, can you please give us something so that we can do on this patient that.” ~Nurse</p>
<p>On Equipment: “Sometimes you may not even have a [suction machine] here in emergency (theater) ,you get somebody having hyper secretion, he is having air blocked you can’t move around you know the situation of <i>improvising</i> most of the time you try your level best to see how can I suck out this, [...] but maybe I can’t say that there are all the things that we need to use in an emergency situation...” ~Doctor</p>	<p>On Equipment: “Yeah, it’s not really gross, they break down and I think we are also; if you’ve really been very keen we are good at <i>improvising</i> so I might be giving you a wrong perception because we are used to that <i>improvisation</i> and missing a suction for us might not be like gross.” ~Doctor</p>	<p>On Protocols: “Because I feel when people go there and see the right things being done, they know it is possible, because here we keep on saying you know the shortage, you see, the absence of such and such an item, such things. But what I have learnt in Uganda we are good at <i>improvising</i>. [...] Where people say they can't do something, for us we always look for something to fit in.” ~Nurse</p>

3.5 Comparison of Quantitative and Qualitative Needs

The needs identified by the PIPES methodology and the interview methodology were quite different and occasionally even contradicted each other. For example, Gulu’s PIPES assessment showed always available/sufficient supplies of 24/25 items; however during the interviews, supply shortages of gauze, sutures, and gloves were reported. Some of these differing results have been shown in Figure 7 for a subset of neurosurgery specific items. The qualitative results were classified as “No Need” if they were never mentioned as a need. “Some Need” indicated that the item was mentioned as a need, but by less than 50% of the respondents at that site. “Strong Need” indicated that the item was mentioned as a need by over 50% of respondents at that site.

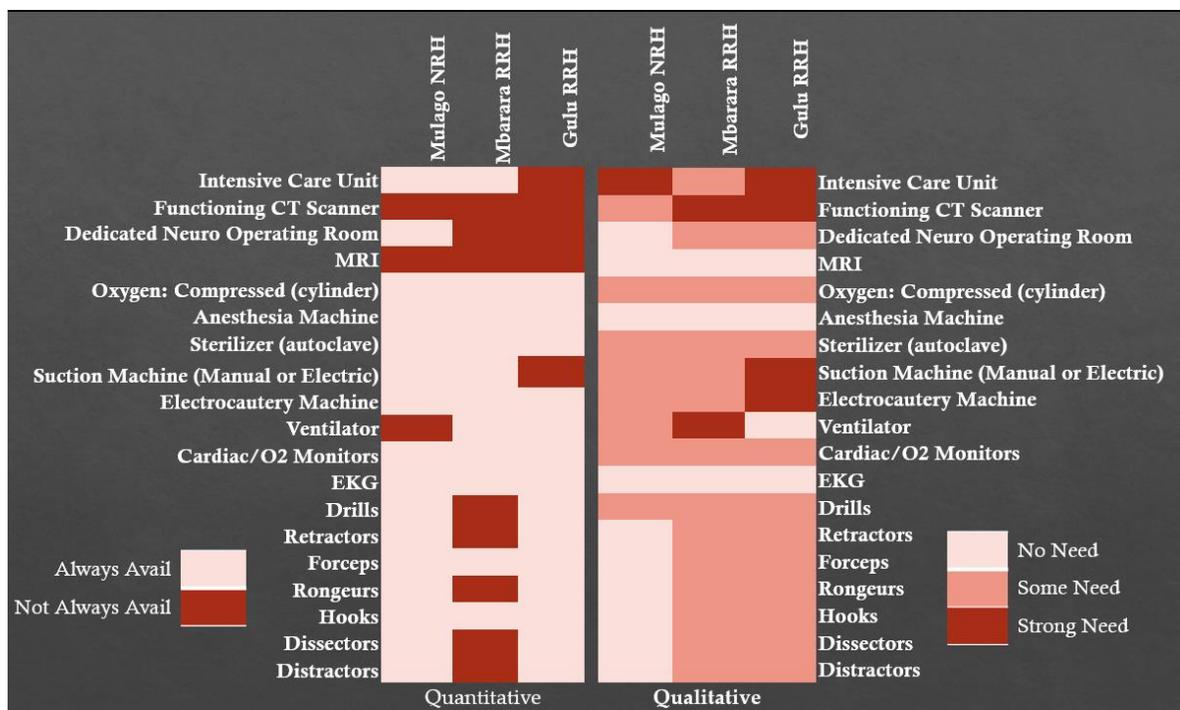


Figure 7: Comparison of Needs by Differing Methodologies

3.6 Formative Evaluation of the Duke-Mulago Collaboration: In-Depth Interviews

This study included interviews of 18 staff workers at Mulago NRH, some of which had exposure to the Duke-Mulago Collaboration. This collaboration includes the neurosurgical camps, neurosurgery residency program, equipment donations, and the establishment of a dedicated theater and biomedical technician for neurosurgery. Staff were overall quite pleased with the progress in Neurosurgery at Mulago NRH.

“Even administration, whenever they have visiting teams like politicians, [...] they always look at Neuro-ward, and that is where they bring the visitors because they are always sure. Because despite the challenges that we face in the hospital there is always somebody on the ward to take care of the patients and we try our best. It is not the best to the standard of international standard but to our standard it is the best so far. So we really feel happy about that, we are really grateful.” ~Neuro-ward Nurse

3.6.1 Neurosurgery Camps

With regard to the neurosurgical camps, staff appreciated the complexity of cases that were performed when the Duke staff visited Mulago NRH and found it to be an excellent learning opportunity for the neurosurgeons and nurses and wished the camps would last longer for more knowledge transfer. Nurses in the ICU noted that program camps used to station nurses from Duke inside the ICU in order to ensure training was also available in this area, but the most recent camps did not bring ICU nurses. The trauma unit also asked that nurses be stationed there to train them during future camps.

Anesthesia staff had critiques of the camp training as well; their trainees seem to feel useless and stop attending to the surgeries.

“It is just because they feel left out. No one wants to stand there looking or when they know they could do something. So they won't be there more than one or two days.” ~Anesthesiologist

During the week-long camps, additional salary is paid to the theater staff that supports the longer hours and extra work required for the camps and this is greatly appreciated. This additional stipend is not distributed to nurses in the ICU despite the increase in their workload during camps; they found this to be somewhat frustrating. This opinion was also expressed by nurses in the trauma unit.

The camps bring supplies of disposables and one-time use equipment with them which are also valued by the staff. These supplies are used during the camps, but also last for several months after the camp is complete; hopefully, as staff expressed, until the next camp. One staff member discussed how they ration suction tubes between camps.

“What we do here when we are in the camp and the Duke people come, they come with a lot of those sucker tubes. So for them they use only once and they discard. For us when they discard we collect them, wash them and we keep when they go we re-use, we pick one by one until it is used up. [...] They bring those long tubes, we cut them into pieces use, throw and get another one; that is how we are.”

~Neurosurgery Nurse

Despite their happiness with receiving supply donations from the camps, some staff expressed the need for the camps to continue with regularity so that their stock of supplies could be maintained based on the camps rather than NMS.

“There is still a lot of challenges ahead of us and as I said with these supplies they bring, if they could keep on coming at least we wouldn’t run out of some of those things which are very essential.”

~Anesthesia Nurse

3.6.2 Neurosurgery Residency

The current and past residents of the residency program expressed satisfaction with being the pioneers of neurosurgery training inside Uganda. The training program is provided at very low cost of tuition and the residents are paid a stipend; several respondents expressed appreciation for this. Residents also spoke highly of the rotational part of the program which would send them outside of Uganda to train for some time at a high volume center such as Duke; but noted that this part of the training program is being somewhat neglected. This is due to the high value the residents bring to Mulago NRH once they are trained; they become a major part of the neurosurgical workforce and are quite busy performing surgeries.

“When you start training here, after two years, you’re good at doing most of the – you know, the quick-quick cases and so nobody wants to let you go.” ~ Neurosurgery Resident

Residents had a few other concerns such as lack of provided housing close to the hospital and the corresponding transportation costs, and the lack of on-call rooms

where the residents could rest or study on-site. All residents that were interviewed expressed a need for designated study time; their heavy workload minimizes time for this. Some residents even noted nervousness over the exams that would come at the end of their residency without this time to learn.

“But you know if I have gone through sessions of having exams, you know like now I wouldn’t be afraid of doing a general surgery like fellowship exam because I know I was taught, there was a background, but now if you tell me that ok let’s take you through an exam in neurosurgery. Yah I will be here two years but I’ll have doubts because I don’t have that time to read that time to go through what is expected.”

~Neurosurgery Resident

Although the residency program has had success with its graduates thus far, there are still struggles with providing adequate training. During a medical residency, the residents are supposed to shadow and assist the attending doctors to learn procedures and patient care. In Mulago’s case, the attending neurosurgeons are not always available to train the residents as they have private practices outside of Mulago NRH.

“Some of these things are not sustainable at the end of the day. Why am I saying they are not sustainable? [...] Because I can train as a specialist and I earn 800 dollars a month. [...] No matter what the president says or the system says; none of us as specialists can actually do that. [...] A patient will not be happy to see me if I haven’t shaved in the morning because I didn’t have a razor blade to do that or I didn’t shower because I didn’t have money to pay for my water bills. [...] No one here is going to

work up to midnight because I need to supplement my income somewhere else.”

~Attending Neurosurgeon

This lack of availability of the attending neurosurgeons was also noted by the residents as an area for improvement.

“I think you need to spend like at least, at least eight hours a day [...] with the attender which is not the case here. [...] What happens here is that, you do the rounds, like you do half of the rounds alone then after the round you have to go to the emergency room, theater just because the case is simple he (the attending neurosurgeon) won't come to the theatre. So you will end up spending most of the day alone and you have to communicate on phone. [...] So it affects the way you relate with your attenders, I don't know whether you learn much from them.”

~Neurosurgery Resident

3.6.3 Dedicated Neuro-Equipment and Biomedical Technician

Staff discussed benefits from many of the equipment donated to Mulago NRH from the program. Equipment is brought for the neuro-operating theater, but also sometimes for the Neuro-ward and ICU. Despite engaging biomedical engineers from Duke to guide suitable donations, sometimes equipment does not last as long as hoped.

“That time they brought us 500 many monitors, small monitors but they are very good. Actually up to now, some are still functional. The only problem is that they bring these machines but they don't bring consumables for them or some few spares, because like when we lose the propacks and the whatever the government cannot buy those spares

because they say they have not planned for them, but they are very good, those propacks.”

~ICU Nurse

Many respondents noted the benefits of having a private room for neurosurgery to keep their equipment safe. Having the dedicated neuro-theater has also enabled staff to perform more neurosurgery cases. Staff also noted the improvements they have seen since the hiring of a dedicated biomedical technician to maintain neuro-equipment. The biomedical technician at Mulago NRH is paid directly by funds related to the Duke-Mulago Collaboration rather than the hospital or MOH.

4. Discussion

4.1 PIPES Surgical Capacity

Scores for the PIPES Assessments at Ugandan public hospitals (between 9.24 and 10.95) are similar to results from other LMICs (Groen et al., 2012; Markin et al., 2013) with the exception of Mulago NRH (20.67). Mulago's score was somewhat elevated compared to other sites due to the large number of staff there (133 surgical staff members). Creators of PIPES intended for the numbers of staff and operating rooms to be without limit in order to give these items additional statistical weight, arguing that even when all of the other items on the assessment have been supplied, it will be the number of operating rooms and full time staff that will make the most impact on provision of surgical care (Groen et al., 2012).

Although PIPES was adapted from the WHO Tool for the Situational Analysis of Emergency and Essential Surgical Care with dichotomous responses in order to reduce ambiguity (Markin et al., 2013), we found that having only two options such as "always available" or "not always available," resulted in some subjectivity in responses. A higher PIPES index should correspond with increased surgical capacity (Markin et al., 2013), however, one of our respondents at Mbarara RRH scored the hospital with a lower capacity (9.24) than Gulu RRH (9.62). We would argue that Mbarara RRH has substantially greater surgical capacity based on our field observations, however, this is not reflected in the score. Respondents would sometimes disagree on fundamental items

such as whether or not their incinerator was always available. These differences in scoring could be affected by the respondent interpretation of “always available/sufficient” or “not always available/sufficient,” or perhaps by the interviewer’s instructions for the respondent on interpreting these questions. The PIPES Assessment is not accompanied by an interview guide or instructions for administration.

This result questions the reliability of the PIPES Assessment between respondents. Inter-rater reliability was assessed in a prior study which compared PIPES scores when the tool was answered by physicians or nurses at facilities in Bolivia. “Inter-rater reliability was found to be moderate for the Infrastructure and Procedures sections, fair for the equipment section, and poor for the supplies section” (Markin et al., 2014). Authors of this study suggested that the low reliability in the equipment in supplies sections may be due to the dichotomous answer format; while it may be appropriate for Infrastructure and Procedures, it may need revision for the others (Markin et al., 2014). Our results support the poor reliability in the supplies section; the three respondents in Mbarara disagreed on answers to 9/25 items. We also found great variation in responses to the Personnel section; this may have been due to the respondent’s decision to include training staff such as residents and interns, or OBGYN staff which may be located a separate unit from the other surgeries.

4.2 Gulu RRH: Pre-Operative Limitations

As a Regional Referral Hospital, Gulu has a basic surgical staff and is able to perform the many surgical procedures. In terms of Neurosurgery, however, Gulu RRH is limited by the lack of a CT scanner and neurosurgeon. These limitations are not specific only to Gulu RRH, but also are true for the entire Northern region of Uganda in both public and private facilities. A CT Scanner somewhere in the region would enable a neurosurgeon to establish a practice; either within Gulu RRH or at a private facility. However, until there is a regional CT scanner available, a neurosurgeon would have limited incentive to move to Gulu; they would not be able to practice as a neurosurgeon.

Based on this pre-operative limitation, Gulu RRH will refer out many of their patients to neighboring Lacor Hospital to benefit from an ICU, or to Mulago NRH more than seven hours away by car. Gulu RRH respondents discussed a few examples of performing neurosurgeries such as emergency craniotomies for trauma cases, but this is seldom done (twice in the last year) and outcomes thus far have not been positive. Gulu RRH is far more comfortable with referring the patient to a location with proper infrastructure, equipment, and personnel, however, when the patient cannot pay the expense to be transferred to Mulago NRH, the staff will make an attempt to save the patient's life.

4.3 Mbarara RRH: Intra/Post-Operative Limitations

Mbarara RRH has benefitted from a recent renovation during which an eight bed ICU and eight room operating theater was built. Their significant staff shortage, however, has limited them from fully utilizing these assets. The theater has four operating rooms on each of two floors, and only the bottom floor is used. Staff mentioned not having an extra nurse to watch patients during recovery from anesthesia and thus these patients are left in the theater corridors to recover where staff is continually passing by. Many staff members at Mbarara RRH agreed that additional staff had not been hired to fill the additional theaters or recovery area due to its Regional Referral Status. Although our respondents reported that there has been a plan to transition Mbarara RRH to a National Referral Hospital, the policy changes such as increased budget or staffing have been slow in coming. Regional Referral Hospitals are not required to provide comprehensive specialty surgeries (Anonymous, 2010a) and thus the MOH has limited incentive to open positions for them at Mbarara RRH. Currently there are two National Referral Hospitals in Uganda, but aside from Mulago, the second one is a mental health facility and has limited surgical services.

The recent renovation also benefitted the ICU and catered directly to the staff shortage by utilizing staff-efficient equipment. All eight rooms have monitors which communicate with the central monitoring system such that nurses may have an eye on all eight patients at once. The ICU is reserved for patients with the largest of care needs;

many of which are on life support. Thus having a low nurse-to-patient ratio is a necessity in the ICU even more than on the medical or surgical wards. Nurses in the ICU expressed stress over handling more than two patients at a time. During data collection for this study, the central monitoring system was non-functional, as were all ventilators in the ICU. This rendered the ICU to only step-down unit status as it could not provide life support. Without a functional ICU, neurosurgeries are frequently postponed or referred to neighboring facilities. This ICU limitation was caused in part due to a personnel need for a biomedical engineer or technician. Ventilators, along with nearly all medical equipment, require routine preventative maintenance, calibration, and cleaning. These tasks are typically the responsibility of a biomedical technician employed by a hospital, but Mbarara RRH does not have one on staff. None of the hospitals studied actually had a biomedical engineer or technician on staff that was paid by the MOH, but Mulago NRH and Gulu RRH both had staff that were paid by separate NGO funds. Mbarara RRH had only a self-trained part-time volunteer that worked on equipment when time would allow.

4.4 Mulago NRH: Post-Operative Limitations

Since the construction of a neurosurgery dedicated operating room at Mulago NRH, the hospital has been able to perform a larger amount of neurosurgeries (Haglund et al., 2011). Prior to the Duke-Mulago Collaboration that sponsored the up-fit of a tea room into an operating room, the neurosurgery specialty shared its operating space with

other specialty surgeries. Surgical staff reported reliable equipment within the operating theater due to infrastructure additions such as the built-in power step-downs, as well as personnel additions such as the dedicated neuro-biomedical technician. Training programs at Mulago NRH for neurosurgery and anesthesiology have improved the human resource limitation within surgery and neurosurgery. Supplies for surgery have also improved in the past few years based on regular neurosurgery camps that are a part of the Duke-Mulago Collaboration. Each camp brings an abundance of supply donations to use during the camps, however, there are frequently abundant extra supplies that the hospital uses to sustain their surgeries until the next camp. Although this is a short-term asset to Mulago NRH, staff expressed difficulty in procuring many of these supplies from the NMS and therefore their main supply seems to be from the camps or other donors. This is a concern for the long-term supply of certain consumables; if there is a year that a camp cannot take place due to political instability, funding, or other reasons, the supply of consumables at Mulago NRH may suffer significantly and the existing progress within neurosurgery may be halted or even regress somewhat.

Even with this increased capacity for neurosurgery, Mulago struggles to keep up with the patient demand for neurosurgery in both elective and emergency cases. As the only non-mental health National Referral facility, in 2009, staff were already serving a catchment population of 30 million instead of ten million as the facility was designed to meet (Anonymous, 2010a).

Elective neurosurgeries are frequently postponed due to a lack of space in the ICU to care for them post-operatively. Mulago's ICU has only three to four functional beds (functional meaning with nursing staff and working equipment such as a monitor and ventilator). This bottleneck within the ICU has resulted in heavy utilization of beds on the neurosurgical ward where there is a high-dependency unit for patients to be closely monitored. Unfortunately, the staff shortage and overcrowding issues has resulted in poor monitoring in the ward and even in the high-dependency unit. Several respondents discussed examples of poor patient outcomes in the neuro-ward due to a lack of monitoring by staff or equipment. In contrast with elective cases where there may be time to postpone for a few days, emergency cases are given higher priority. However, even if the theater space is created to treat them, there may still be no place for them to recover post-operatively and thus they wait for longer than ideal times in the casualty and trauma departments. Sometimes these emergency trauma cases are brought to the overcrowded and understaffed neuro-ward to await their procedure.

4.5 Ugandan Public Hospitals: Spectrum of Limitations

Across all sites, there were limitations that were continuously present; one of which was equipment resources. This result has been shown in prior literature with estimations of nearly 40% of equipment out-of-service in developing countries (Perry & Malkin, 2011). The most common equipment requests were for monitors, suction machines, electrosurgery units (diathermy), ventilators, and neurosurgical drills. Aside

from the drills, these equipment types are commonly out of service in resource poor settings (R. Malkin & Keane, 2010).

These three hospitals were frequent recipients of equipment donations, but staff noted that they do not always have a lasting impact. Reasons for failure included missing parts at the time of donation, lack of maintenance, lack of user training, and damage from electrical power fluctuations or incompatible voltage ratings. The need for spare parts was also cited as an issue, but this had a variety of causes, including: inability to procure spare parts locally, inability to afford the manufactured part from the international vendor, the spare parts were no longer made due to the age of the equipment, and lack of accounting for the new equipment in the budget. The last item in this list exemplifies the idea of “ownership” that was discussed by respondents; because the equipment was donated, the administrative bodies would not add in accounting to procure parts or maintenance for it. This would sometimes include purchasing a service contract directly from the vendor, which can be extremely costly and difficult to access. These equipment challenges are not unique to Uganda; power damage, lack of maintenance, and user training in particular have been documented in a variety of LMICs (R. A. Malkin, 2007).

Some of these issues with equipment could be addressed if a biomedical technician or engineer was on-staff at each hospital. Although Gulu RRH and Mulago NRH both had a biomedical staff member, neither was directly employed by the

hospital. Gulu's biomedical engineer was on a short term contract with a local NGO, while Mulago's biomedical technician is employed with Duke-Mulago Collaboration funding. This demonstrates the lack of value placed on this position within the government hospital. At the time of interviews in Mbarara, the ICU had been shut down for months due to non-functional ventilators; a problem that could have been prevented by biomedical staff (Robert A. Malkin & Whittle, 2014). It is possible that hospital administrators assume the existing maintenance department staff would be sufficient to meet all of the hospital's needs; however since 89% of engineering requests in resource poor hospitals are for medical equipment, specialization for this task seems worthwhile (R. Malkin & Keane, 2010).

In addition to equipment limitations, all three hospitals struggled with procurement of supplies from the NMS and discussed the common practice of having their patients (or families) purchase drugs in town from a private pharmacy. Similar results with regard to pharmaceutical supply were also found during a 2012 study; all 14 surveyed hospitals reported routine shortages of essential medicines (Linden et al., 2012). This issue was present at all three hospitals, but seemed to be less of a concern at Gulu RRH based on interviews and answers to the PIPES assessment; Gulu answered that they had sufficient quantities of nearly all items. Although we are not certain of the validity of these answers by the Gulu PIPES respondent, it is possible that they do in fact

have more supply assets due to less surgical specialization, and therefore less supply need in the hospital.

The supply problem exists despite substantial effort from Uganda within the Health Sector Strategic and Investment Plan from 2010 through 2015; these efforts included absolute funding increases for medicines and an increase in storage capacity at NMS. Additionally, there is a National Drug Policy in place which aims to ensure access to essential medicines and health supplies; and within the public sector, these supplies will come from NMS only (Anonymous, 2010a). There is also an enforcement agency for the drug policies: the National Drug Authority. This organization, however, has limited capacity (Anonymous, 2010a).

Finally, the remaining need which requires significant attention is the shortage of medical staff in the public sector; including nurses, doctors, and biomedical technicians. All sites noted the lack of nurses to care for patients in the medical, surgical, and neuro-wards, along with the intensive care and trauma units. Instead of nurses providing care and monitoring to patients in the overcrowded wards, it is the patient's family members, known as attendants, which care for them without proper medical training. This shortage results in less attention to individual patients, especially on nights and weekends when the staff numbers are fewer. The shortage may also contribute to poor infection control practices on the wards; especially in times of emergency. Nurse respondents spoke of having to use the same suction machine and tubing between

patients at times when they might be alone with no one to assist them in cleaning or replacing tubing when multiple patients are aspirating at the same time.

With regard to physicians such as surgeons, the resource shortage is also substantial, but varies geographically. Ninety percent of the physicians in Uganda practice in the capital city of Kampala, where Mulago NRH is located (Anonymous, 2010b). Physicians in this study supported the desire to stay in an urban center like Kampala while outlining the need for private practice to support themselves.

Administration at Gulu RRH acknowledged the difficulty in recruitment due to this limitation. Staff discussed very low pay in the public sector and the lack of motivation to stay at one of the referral hospitals when they could profit more from a private practice. The low pay coupled with limitations that keep them from practicing their specialty contributes to brain drain when physicians learn of better opportunities abroad.

4.6 Implications for policy and practice

This research will most directly enable change to the Duke-Mulago Collaboration with regard to running the neurosurgery camps and the residency program. Based on the in-depth interviews, assets were discussed far more frequently at Mulago NRH than at Mbarara or Gulu RRHs and this may be due in part to this Collaboration. The program has brought lots of benefit to neurosurgery at Mulago NRH and Uganda now has two more neurosurgeons in public practice than they had a year prior. Previously there were only five in public practice for the entire country. We would advise, however,

at the recommendation of the residents and attendings involved with the program, that the curriculum be strengthened by increased time allotted to study and training quality be improved by more interaction time between residents and attending neurosurgeons.

These changes will be difficult as the attendings pursue their private practice outside the hospital, thus there must be some system of accountability or motivation for the attendings to participate. The residents are paid a stipend for their living expenses and time; perhaps a partial stipend could be allocated to just one of the attendings to incentivize them to be present for training of the residents. Another challenge is making time for study; as soon as the residents have learned some skills, they become very valuable within the theater and take on more responsibility. This either adds to the number of patients able to be treated (for trauma especially) or creates additional time for the attending neurosurgeons to attend to their private practice patients. The residents discussed having less face to face interactions with the attendings as their training was underway.

Another necessary change to the Collaboration has to do with the supply chain. Despite the benefit from increased supplies of consumables from regular neurosurgery camps at Mulago NRH, this practice should be altered. Speaking with staff at Mulago revealed that Duke is the *only* supply for certain items and that they try to just ration until the next camp. This indicates that Duke is now a significant contributor to the Mulago supply chain while their supply from NMS is less reliable. This is not a unique

problem to the Duke-Mulago Collaboration; global initiatives (non-government) are responsible for nearly 70% of health commodities in Uganda (Anonymous, 2010a). The government reports reasons for shortages as procurement delays, incorrect orders, late orders, and poor record keeping. National data indicates yearly stock out times of 72.9 days at public health facilities compared to 7.6 days at mission facilities (Anonymous, 2010a).

Although donations are effective as a “band-aid” for a short period of time, a long term solution needs to be available. This could be a change to policy for procurement from NMS, an increase in the budget ceiling for supplies, or a change in the supply source entirely. The Duke-Mulago group has a project underway to repair this issue; they are hoping to build a Uganda Neuroscience Institute (UNI) that will be a standalone health center which receives funds separately from Mulago NRH. The organization would be modeled after the Uganda Heart Institute and the Uganda Cancer Institute. The UNI, however, will still be located in Kampala and thus this is only a solution for neurosurgery at Mulago NRH. Once the neurosurgery camps have expanded to the future sites at Mbarara and Gulu RRH, the supply problem will likely follow.

After assessing the potential sites for neurosurgery outside of Kampala, it seems that the Duke-Mulago Collaboration model could be expanded to Mbarara RRH in the near future, but a biomedical technician will be needed promptly to keep any donated

equipment in working order. Expansion to Gulu RRH may take a few additional years for surgical capacity to increase, including the procurement of a CT scanner somewhere in the Norther Region and a neurosurgeon willing to practice there.

Another very important finding of this study applies to medical and surgical curriculum. Considering the substantial discussion and use of improvisation in patient care, it seems that this theme should be addressed in medical training. Prior to the Duke-Mulago residency program, all of the neurosurgeons in Uganda had to do their residency outside of Uganda in a higher income country. They learned the standard protocols for patient care, which are frequently infeasible in a resource-restricted setting. A strength of the Duke-Mulago residency is that the trainees learn to operate in the same setting where they will eventually practice; thus they learn to cope with the need for improvisation.

To improvise on a patient during surgery or neurosurgery is ethically questionable. It is also questionable to train someone to perform sub-standard procedures for a subset of the population. One might wonder why the clinical practice guideline or protocol is not worth enforcing on a patient at a public hospital in Uganda. However, we would argue that it is not a question of worth, but rather necessity. In a resource-poor setting, improvisation might be the last chance to save the life of a patient that would otherwise have no chance to survive. For example, without having tried it before, a neurosurgeon may not feel ready to perform an emergency craniotomy on a

TBI patient without an electrosurgery machine to minimize blood loss and cauterize the vessels. However without the surgery, the patient will surely die or be severely disabled for life; thus having the prior training with sub-standard equipment might be a life-saving intervention.

4.7 Implications for further research

This study has highlighted the need for adjustment to the surgical capacity tools available. We found the PIPES tool to be somewhat subjective based on the respondent's knowledge or bias. Additionally, there was no provided guideline for administration of the tool; this would ensure that at least the interviewers had the same interpretation of words like "sufficient." There are currently three tools used in the literature; PIPES, the WHO Tool for Situational Analysis to Assess Emergency and Essential Surgical Care, and a tool from the Harvard Humanitarian Initiative (HHI). Although these three tools have finite differences to measure the same things, PIPES is the only tool that has a corresponding PediPIPES assessment to measure capacity for pediatric surgery. Thus for groups that may want to draw parallels between general surgery and pediatric surgery capacity, PIPES is the only viable option. As prior literature has suggested (Markin et al., 2014), we recommend minor revisions to the tool such that its inter-rater reliability may be improved. Further research will be needed on the validity and reliability of its revision.

Even with the identified limitations to surgical capacity tools, these tools are the most efficient means available to gather information about surgical capacity across many sites or countries. The binary answering system for PIPES of “always” or “not always” available makes the tool easy to administer. The in-depth interviews identified several needs that were missed in the PIPES assessments, however the qualitative tools utilized in this study would not be feasible to administer on a large scale. We believe that surgical capacity tools are valuable as a comparative tool; to examine differences in needs between countries or regions and to make generalizable claims about the regions based on its ability to be widely administered. However, before policy decisions or funding allocations are made based on the results, we would recommend a more in-depth examination of the sites to be affected; perhaps with qualitative methodology. This would clarify any discrepancies or gaps from the surgical capacity tool prior to investment of funds.

4.8 Study strengths and limitations

This study had several strengths; we believe this is the only surgical capacity assessment that has involved qualitative aspects by interviewing healthcare providers in Uganda. Due to the limitations of some of the existing surgical capacity tools, we feel the qualitative aspect of this study tells a more accurate and in-depth story of the current needs and assets at the visited sites. We also note that studies of surgical capacity tend to include both public and private facilities; and although this is the most accurate for what

is *available*, it is not always what is *accessible*. The poorest members of the community are relegated to using the public facilities as services are provided at low cost to the patients; thus we feel that this study accurately depicts surgical capacity which is accessible to all members of the population.

Despite these strengths, we feel that not performing a more thorough PIPES reliability study was a missed opportunity. At Mbarara RRH, we only had the opportunity to speak to three staff members about the PIPES tool, however we could have spoken attempted to fill out the PIPES assessment with each person that we met with for an in-depth interview; which would have allowed us to assess reliability among 39 respondents. Although this is probably better as the subject of a separate project as the main study aim, it would have been a valuable addition to this study.

5. Conclusion

The needs for surgery in Uganda are substantial; and the needs for neurosurgery are even larger. We argue that an improvement in the surgical specialty that requires the most robust infrastructure and equipment would also improve all other surgical specialties and thus attention needs to be given to the improvement of neurosurgery in Uganda. Therefore the Duke-Mulago Collaboration should plan for expansion to future sites with concern for sustainability; especially for supplies. The plan for a Uganda Neuroscience Institute may have impact on some of the existing challenges of the Collaboration, and could be further explored.

In the public sector of healthcare provision, great strides are needed on human resources; efficiently advertising and filling the hospital positions, but also financial incentive or other benefits to keep existing employees engaged. Government administrative bodies need to allocate resources for biomedical technicians or engineers in the public sector. This small allocation of resources may prevent millions of dollars in equipment loss. Country wide infrastructure improvements to roads, electricity, and water would be valuable for progress in supply chain management and equipment maintenance; however these structural changes will take substantial time and investment.

The concept of improvisation requires further investigation with regard to surgery in resource-restricted settings. There is a small body of literature that documents

the practice of improvisation in healthcare, however it would be beneficial to review this literature in full in order to make recommendations for this practice.

Appendix A: Adapted PIPES Data Collection Tool

Basics			(Mulago Only) Available prior to 2008?	Notes
Type of Healthcare Facility				
Hospital Beds				
Personnel	Total Number			
General Surgeon				
Anesthesiologists (MD)				
Medical doctors (doing surgery)				
Nurse anesthetists				
Infrastructure	Always Available (1)	Not Always Available (0)	Available prior to 2008?	Notes
Running Water				
External Electricity				
Backup Generator				
Incinerator				
Medical Records				
Emergency Department (Casualty)				
Postoperative care area (Recovery)				
Intensive Care Unit				
Pretested blood (blood bank)				
Lab to test blood and urine				
X-ray Machine				
Ultrasound machine				
CT Scanner				
MRI				
Operating Rooms	How Many:			
Neurosurgical Op Rooms	How Many:			
Procedures	Done (1)	Not Done (0)	Performed prior to 2008?	Notes

Resuscitation				
Suturing				
Wound debridement				
Incision & drainage of abscess				
Laparotomy				
Cricothyroidotomy				
Tracheostomy				
Chest tube insertion				
Burn management				
Cesarean Section				
Dilation & Curettage				
Tubal ligation				
Hysterectomy				
Obstetric fistula repair				
Appendectomy				
Hernia repair – elective				
Hernia repair – strangulated				
Hydrocele				
Bowel resection and anastomosis				
Male circumcision				
Biopsy (lymph node, mass, other)				
Cholecystectomy				
Skin grafting				
Pediatric hernia repair				
Pediatric abdominal wall defects				
Repair imperforate anus				
Splinting				
Casting				
Traction (closed fracture)				
Open treatment of fracture				
Management of osteomyelitis				
Amputation				

Clubfoot repair				
Cleft lip repair				
Contracture release				
Laparoscopic surgery				
Regional anesthesia blocks				
Spinal anesthesia				
Ketamine anesthesia				
General anesthesia				
Neuro: VP Shunt, ETV and EVD				
Neuro: Spina bifida repair				
Neuro: Myelomeningocele/encephalocele repair				
Neuro: Craniotomy/Craniectomy for tumor				
Neuro: Craniotomy/Craniectomy for fracture				
Neuro: Cyst drainage and abscess removal				
Neuro: Evacuation of bleeds				
Neuro: Spinal surgery (Laminectomy, microdisectomy, tumor removal)				
Neuro: Others (flap, skin grafting)				
Equipment	Always Available (1)	Not Always Available (0)	Dedicated to Neurosurgery?	Notes/Available prior to 2008?
Cardiac/O2 Monitors				
EKG				
Drills				
Retractors				
Forceps				

Rongeurs				
Hooks				
Dissectors				
Distractors				
Oxygen: Compressed (cylinder)				
Oxygen: Concentrator				
Resuscitator bag valve & mask (adult)				
Resuscitator bag valve & mask (pediatric)				
Oropharyngeal airway (adult)				
Oropharyngeal airway (pediatric)				
Ventilator				
Endotracheal tubes (adult)				
Endotracheal tubes (pediatric)				
Anesthesia machine				
Pulse oximeter				
Oxygen mask & tubing				
Stethoscope				
Blood Pressure measuring equipment				
Thermometer				
Instrument Sets (abdominal, C-section)				
Kidney dish stainless steel				
Sterilizer (autoclave)				
Suction pump (manual or electric)				
Electro cautery machine				
Vaginal speculum				
Endoscopes (gastro, colon, broch)				
Operating room lights				

Supplies	Always available/ sufficient (1)	Not always available/ sufficient (0)	Available prior to 2008?	Notes
Gloves (sterile)				
Gloves (examination)				
Nasogastric tubes				
Intravenous fluid infusion sets				
IV cannulas				
Syringes				
Disposable needles				
Tourniquet				
Sterile gauze				
Bandages (sterile)				
Adhesive tape				
Suture (absorbable)				
Suture (non-absorbable)				
Urinary catheters				
Sharps disposable container				
Scalpel blades				
Face masks				
Eye protection (goggles, safety glasses)				
Apron				
Boots (theatre shoes)				
Gowns (for surgeon/scrub nurse)				
Drapes (for operations)				
Chest tubes				
Trach tubes				
Laparoscopic supplies				

Appendix B: Interview Guide for Mulago NRH (by Role)

For use with Neuro Nurses/Neurosurgeons/Anesthesia

Opening Questions: Current status of program

- Your hospital has been performing neurosurgeries for a long time, but this new initiative with the Twinning program was established in 2008 and has been up and running for a few years now. What are your impressions so far?
- How has it changed your daily activities?
- Running and sustaining a neurosurgical program in a public hospital is quite a feat; what are you the most proud of?
 - Most successful aspects?
 - When you look to the future, what changes would you want to see?
 - What are the barriers?
 - Pressures you feel?
 - Main struggles?
- Since its establishment, have you seen an overall change in institutional culture here? What word would you use to describe the institutional culture within neurosurgery?

Subtopic: Equipment

- Transition: You mentioned several issues with not having certain important pieces of equipment; let's talk about this a bit more.
- Can you tell me a bit about the equipment you use on a daily basis?
- How do you feel about the equipment used during Neurosurgical operations?
 - Can you tell me about a time that you didn't have what you needed?
 - What have you learned from working with this equipment?
- How does the equipment used for neurosurgery compare with the equipment used for other tasks?
- In your role, what is the most important piece of equipment for your job?
 - If it is broken, what do you do?
 - Is this a common occurrence?
 - Is there a system in place to fix that equipment? How do you feel about that system? Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?

- Can you tell me about a time when this stopped you from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the neurosurgery unit is donated from Duke and other organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist neurosurgery?

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to neurosurgery?
 - Operation, recovery, ICU?
- Do you think this devoted space is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in neurosurgery?
- Are there other systems you can think of that would help this program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- Transition: So even if all of these things were ideal, are you concerned that there may still be patients you would not be able to help? Why?
- When you cannot treat a particular neurosurgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program?
 - Human resources? Financial resources? Equipment technicians? Pre/post op? Staff Training?
- Are you getting the administrative and financial support you need to run a unit that would best meet the needs of your patients?
 - If not, what would you change?

- If the support is there but you cannot get to the resources, what is getting in the way?
 - Is program leadership able to influence program outcomes? In what way?
- Are there any current solutions being implemented to remediate any of the items we have discussed so far? (ex. Equipment, infrastructure, patient population, human resources)
 - Have they been effective?
 - Are they sustainable?
- What other needs to meet the “ideal” have we not covered?
 - Do you have any ideas on how to meet them?
- Anything else I (or the administration) should know?

For use with Biomed and Equipment Technicians

Opening Questions: Current status of program

- Your hospital has been performing neurosurgeries for a long time, but this new initiative with the Twinning program was established in 2008 and has been up and running for a few years now. What are your impressions so far?
- How has it changed your daily activities?
- Running and sustaining a neurosurgical program in a public hospital is quite a feat; what are you the most proud of?
 - Most successful aspects?
 - When you look to the future, what changes would you want to see?
 - What are the barriers?
 - Pressures you feel?
 - Main struggles?
- Since its establishment, have you seen an overall change in institutional culture here? What word would you use to describe the institutional culture within neurosurgery?

Subtopic: Equipment

- Transition: You mentioned several issues with not having certain important pieces of equipment; let’s talk about this a bit more.
- Can you tell me a bit about the equipment you use (or repair) on a daily basis?
- How does the equipment used for neurosurgery compare with the equipment used for other tasks?

- Since you are the repair system for broken equipment, from your perspective, how do you feel about the equipment referral system?
 - Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped your team from doing their job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the neurosurgery unit is donated from Duke and other organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist neurosurgery?
- How have you and your colleagues been trained? Is there a formalized training program available?
- What is the spare parts budget and equipment budget of the hospital?
- What percentage of equipment is donated (estimate)?
- What is your most difficult technical obstacle you need to overcome in order to do your job more effectively?
 - What healthcare technology on the current (or used) market would meet this need?
 - What are you currently using to solve this problem of unmet equipment needs?
- What equipment do you most need at your hospital?
 - Can you describe specifically what you would need that equipment/instrument to do?
 - Where and how will the equipment/instrument be used?
 - If you had that piece of equipment, would there be anything preventing you from using it?
- Are there any additional needs specific to the neuro department? Do you foresee future issues with equipment in that department?

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to neurosurgery?
 - Operation, recovery, ICU?

- Do you think this devoted space is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in neurosurgery?
- Are there other systems you can think of that would help this program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- Transition: So even if all of these things were ideal, are you concerned that there may still be patients you would not be able to help? Why?
- When you cannot treat a particular neurosurgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program?
 - Human resources? Financial resources? Equipment technicians? Pre/post op?
 - Staff Training?
- Are you getting the administrative and financial support you need to run a unit that would best meet the needs of your patients?
 - If not, what would you change?
 - If the support is there but you cannot get to the resources, what is getting in the way?
 - Is program leadership able to influence program outcomes? In what way?
- Are there any current solutions being implemented to remediate any of the items we have discussed so far? (ex. Equipment, infrastructure, patient population, human resources)
 - Have they been effective?
 - Are they sustainable?
- What other needs to meet the “ideal” have we not covered?
 - Do you have any ideas on how to meet them?
- Anything else I (or the administration) should know?

For use with Administrators

Opening Questions: Current status of program

- Your hospital has been performing neurosurgeries for a long time, but this new initiative with the Twinning program was established in 2008 and has been up and running for a few years now. What are your impressions so far?
- How has it changed your daily activities?
- Running and sustaining a neurosurgical program in a public hospital is quite a feat; what are you the most proud of?
 - Most successful aspects?
 - When you look to the future, what changes would you want to see?
 - What are the barriers?
 - Pressures you feel?
 - Main struggles?
- Since its establishment, have you seen an overall change in institutional culture here? What word would you use to describe the institutional culture within neurosurgery?

Subtopic: Equipment

- Transition: You mentioned several issues with not having certain important pieces of equipment; let's talk about this a bit more.
- Can you tell me a bit about the equipment used by Neuro on a daily basis?
- How do you feel about the equipment used during Neurosurgical operations?
 - Can you tell me about a time that you didn't have what you needed?
 - What have you learned from working with this equipment?
- How does the equipment used for neurosurgery compare with the equipment used for other tasks?
- When equipment is broken, how do you feel about the repair system? Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped you (or the medical staff) from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?

- Much of the equipment in the neurosurgery unit is donated from Duke and other organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist neurosurgery?

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to neurosurgery?
 - Operation, recovery, ICU?
- Do you think this devoted space is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in neurosurgery?
- Are there other systems you can think of that would help this program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- Transition: So even if all of these things were ideal, are you concerned that there may still be patients you would not be able to help? Why?
- When you cannot treat a particular neurosurgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program?
 - Human resources? Financial resources? Equipment technicians? Pre/post op?
 - Staff Training?
- Are you getting the administrative and financial support you need to run a unit that would best meet the needs of your patients?
 - If not, what would you change?
 - If the support is there but you cannot get to the resources, what is getting in the way?
 - Is program leadership able to influence program outcomes? In what way?

- Are there any current solutions being implemented to remediate any of the items we have discussed so far? (ex. Equipment, infrastructure, patient population, human resources)
 - Have they been effective?
 - Are they sustainable?
- What other needs to meet the “ideal” have we not covered?
 - Do you have any ideas on how to meet them?
- Anything else I (or the administration) should know?

For use with staff in the referral departments

Opening Questions: Current status of program

- Your hospital has been performing neurosurgeries for a long time, but this new initiative with the Twinning program was established in 2008 and has been up and running for a few years now. What are your impressions so far?
- How has it changed your daily activities?
- Running and sustaining a neurosurgical program in a public hospital is quite a feat; what are you the most proud of?
 - Most successful aspects?
 - When you look to the future, what changes would you want to see?
 - What are the barriers?
 - Pressures you feel?
 - Main struggles?
- Since its establishment, have you seen an overall change in institutional culture here? What word would you use to describe the institutional culture within neurosurgery?

Subtopic: Equipment

- Transition: You mentioned several issues with not having certain important pieces of equipment; let’s talk about this a bit more.
- Can you tell me a bit about the equipment you use on a daily basis?
- How do you feel about the equipment used during Neurosurgical operations?
 - Can you tell me about a time that you didn’t have what you needed?
 - What have you learned from working with this equipment?
- How does the equipment used for neurosurgery compare with the equipment used for other tasks?
- In your role, what is the most important piece of equipment for your job?

- If it is broken, what do you do?
- Is this a common occurrence?
- Is there a system in place to fix that equipment? How do you feel about that system? Would you change or improve it?
- Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped you from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the neurosurgery unit is donated from Duke and other organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist neurosurgery?

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to neurosurgery?
 - Operation, recovery, ICU?
- Do you think this devoted space is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in neurosurgery?
- Are there other systems you can think of that would help this program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- Transition: So even if all of these things were ideal, are you concerned that there may still be patients you would not be able to help? Why?
- When you cannot treat a particular neurosurgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program?
 - Human resources? Financial resources? Equipment technicians? Pre/post op?
 - Staff Training?
- Are you getting the administrative and financial support you need to run a unit that would best meet the needs of your patients?
 - If not, what would you change?
 - If the support is there but you cannot get to the resources, what is getting in the way?
 - Is program leadership able to influence program outcomes? In what way?
- Are there any current solutions being implemented to remediate any of the items we have discussed so far? (ex. Equipment, infrastructure, patient population, human resources)
 - Have they been effective?
 - Are they sustainable?
- What other needs to meet the “ideal” have we not covered?
 - Do you have any ideas on how to meet them?
- Anything else I (or the administration) should know?

Appendix C: Interview Guide for Mbarara/Gulu RRH (by Role)

For use with staff in Neuro/Referral Departments

Opening Questions: Current status of program

- Your hospitals are linked to medical universities that will produce future surgeons and possibly neurosurgeons and this makes your site a great candidate for a future neurosurgery program. How do you feel about this possibility?

Subtopic: Equipment

- Transition: There may be several issues with not having certain important pieces of equipment; let's talk about this a bit more.
- Can you tell me a bit about the equipment you use on a daily basis?
- Since your hospital does not routinely perform complex neurosurgeries, let's talk about general surgery. How do you feel about the equipment used during surgical operations?
 - Can you tell me about a time that you didn't have what you needed?
 - What have you learned from working with this equipment?
- In your role, what is the most important piece of equipment for your job?
 - If it is broken, what do you do?
 - Is this a common occurrence?
 - Is there a system in place to fix that equipment? How do you feel about that system? Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped you from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the hospital is donated from various organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist general surgery or neurosurgery? Also consider pre and post-operative care.

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to surgery?
 - Operation, recovery, ICU?
 - Does it seem like there would be enough space for a dedicated neurosurgery unit?
 - How would you feel about dedicating resources to a new unit like this?
- Do you think this devoted space (to surgery) is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in surgery?
- Are there other systems you can think of that would help your existing surgical program or enable a future neurosurgery program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- When you cannot treat a particular surgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?
- Do you think there are sufficient patient needs to demand a neurosurgical program at your hospital? What do you expect to be their largest needs (procedure) based on your surrounding community?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program if one was established here?
 - Human resources?
 - Financial resources?
 - Equipment technicians?
 - Pre/post op?
 - Staff Training?
- Do you foresee getting the administrative and financial support you would need to run a unit that would meet the needs of your patients?
 - If not, why not?
- Any other barriers to establishing a neurosurgical unit that we not covered?

- Do you have any ideas on how to overcome them?
- Anything else I (or the administration) should know?

For use with staff in Biomed/Equipment Repair

Opening Questions: Current status of program

- Your hospitals are linked to medical universities that will produce future surgeons and possibly neurosurgeons and this makes your site a great candidate for a future neurosurgery program. How do you feel about this possibility?

Subtopic: Equipment

- Transition: There may be several issues with not having certain important pieces of equipment; let's talk about this a bit more.
- Can you tell me a bit about the equipment you use on a daily basis?
- Since your hospital does not routinely perform complex neurosurgeries, let's talk about general surgery. How do you feel about the equipment used during surgical operations?
 - Can you tell me about a time that you didn't have what you needed?
 - What have you learned from working with this equipment?
- In your role, what is the most important piece of equipment for your job?
 - If it is broken, what do you do?
 - Is this a common occurrence?
 - Is there a system in place to fix that equipment? How do you feel about that system? Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped you from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the hospital is donated from various organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist general surgery or neurosurgery? Also consider pre and post-operative care.

- How have you and your colleagues been trained? Is there a formalized training program available?
- What is the spare parts budget and equipment budget of the hospital?
- What percentage of equipment is donated (estimate)?
- What is your most difficult technical obstacle you need to overcome in order to do your job more effectively?
 - What healthcare technology on the current (or used) market would meet this need?
 - What are you currently using to solve this problem of unmet equipment needs?
- What equipment do you most need at your hospital? (Does not need to be surgical)
 - Can you describe specifically what you would need that equipment/instrument to do?
 - Where and how will the equipment/instrument be used?
 - If you had that piece of equipment, would there be anything preventing you from using it?
- Are there any additional needs specific to the surgical department? Do you foresee future issues with equipment if a neurosurgical unit was established?

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to surgery?
 - Operation, recovery, ICU?
 - Does it seem like there would be enough space for a dedicated neurosurgery unit?
 - How would you feel about dedicating resources to a new unit like this?
- Do you think this devoted space (to surgery) is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in surgery?
- Are there other systems you can think of that would help your existing surgical program or enable a future neurosurgery program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- When you cannot treat a particular surgery patient – why is that?

- Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?
- Do you think there are sufficient patient needs to demand a neurosurgical program at your hospital? What do you expect to be their largest needs (procedure) based on your surrounding community?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program if one was established here?
 - Human resources?
 - Financial resources?
 - Equipment technicians?
 - Pre/post op?
 - Staff Training?
- Do you foresee getting the administrative and financial support you would need to run a unit that would meet the needs of your patients?
 - If not, why not?
- Any other barriers to establishing a neurosurgical unit that we not covered?
 - Do you have any ideas on how to overcome them?
- Anything else I (or the administration) should know?

For use with Administrators

Opening Questions: Current status of program

- Your hospitals are linked to medical universities that will produce future surgeons and possibly neurosurgeons and this makes your site a great candidate for a future neurosurgery program. How do you feel about this possibility?

Subtopic: Equipment

- Transition: There may be several issues with not having certain important pieces of equipment; let's talk about this a bit more.
- Can you tell me a bit about the equipment you use on a daily basis?

- Since your hospital does not routinely perform complex neurosurgeries, let's talk about general surgery. How do you feel about the equipment used during surgical operations?
 - Can you tell me about a time that you didn't have what you needed?
 - What have you learned from working with this equipment?
- In your role, what is the most important piece of equipment for your job?
- If it is broken, what do you do?
 - Is this a common occurrence?
 - Is there a system in place to fix that equipment? How do you feel about that system? Would you change or improve it?
 - Is the repair timeline reasonable? Do the repairs last? If not – why not?
- When something is not working or not available, what is the most common reason?
 - Can you tell me about a time when this stopped you from doing your job?
- (If not already discussed) Do you ever run out of consumables for equipment and/or supplies that keep you from doing your job? How do you handle this?
 - If this happens often, what do you think is the problem?
- Much of the equipment in the hospital is donated from various organizations. How do you feel about equipment donations?
- Are there any additional unmet equipment needs that would assist general surgery or neurosurgery? Also consider pre and post-operative care.

Subtopic: Infrastructure

- Transition: so even if we had all of the ideal equipment, are there problems with infrastructure (electricity/water/physical space)?
- How do you feel about the amount of space dedicated to surgery?
 - Operation, recovery, ICU?
 - Does it seem like there would be enough space for a dedicated neurosurgery unit?
 - How would you feel about dedicating resources to a new unit like this?
- Do you think this devoted space (to surgery) is underutilized?
 - Ex. Hours of the day in operation? Multitasking the suite?
- Are the electricity problems a severely limiting factor in surgery?
- Are there other systems you can think of that would help your existing surgical program or enable a future neurosurgery program?
 - Referral, medical records, staff scheduling, procurement/supplies, running water, etc.

Subtopic: Patient Needs

- When you cannot treat a particular surgery patient – why is that?
 - Can you think of a time when you had to cancel or reschedule a surgery for a particular patient?
- How do you feel about the pre/post-op care at your hospital?
- Do you think there are sufficient patient needs to demand a neurosurgical program at your hospital? What do you expect to be their largest needs (procedure) based on your surrounding community?

Concluding Questions

- Transition: We have covered several limitations in this environment; what else do you see as the biggest barriers to a successful neurosurgery program if one was established here?
 - Human resources?
 - Financial resources?
 - Equipment technicians?
 - Pre/post op?
 - Staff Training?
- Do you foresee getting the administrative and financial support you would need to run a unit that would meet the needs of your patients?
 - If not, why not?
- Any other barriers to establishing a neurosurgical unit that we not covered?
 - Do you have any ideas on how to overcome them?
- Anything else I (or the administration) should know?

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