

Proposed Method to Evaluate the Impact on Health Outcomes of Capacity Building for
Maintenance and Repair of Medical Equipment in Rwanda

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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ABSTRACT

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Abstract

It has been shown that training biomedical equipment technicians (BMETs) improves healthcare, but it is unclear if capacity building for repair and maintenance of medical equipment leads to improved patient health outcomes, and whether that relationship between equipment service and health can be measured.

Health indicators are identified that may be used to measure an impact on patient health outcomes of Engineering World Health's biomedical equipment repair and maintenance training program in Rwanda.

Fieldwork was conducted for 9 weeks in country to identify these indicators. Providers and administrators in twelve hospitals in Rwanda were interviewed about patient health outcomes, equipment use, and procedure preference based on equipment availability for selected clinical focus areas. Equipment availability and status were also surveyed. From the existing literature, expected health outcomes were compared between procedure preferences to estimate how patients would be affected by the availability of functional medical equipment.

Neonatal jaundice treatment with phototherapy lamps, neonatal thermoregulation with incubators, and oxygen provision for acute respiratory management were identified as areas where the relationship between equipment service

training and health could be measured. It is recommended that some of these areas be studied in the field to confirm and quantify the connection.

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1. Introduction

Engineering has taken a greater and greater role in the medical field over the last several decades. Medical equipment, specifically, is commonplace in developed settings and becoming so in developing settings. Developing countries are the fastest growing markets for medical equipment [1].

Medical equipment is an investment that includes initial capital, regular maintenance and repair. Many developing world countries rely on medical equipment donation, which often have high failure rates [1] [2]. Nonfunctional equipment in low-resource settings was found to be repairable in 66% of cases by a skilled technician using only locally available parts and minimal financial resources [3]. In light of this, Duke University's Developing World Healthcare Technology Lab (DHT Lab) and Engineering World Health (EWH) developed the Biomedical Equipment Technician training program (BMET). The BMET program trains local technicians in resource-poor settings to address common repair needs [4]. The program has been shown to reduce by half the number of out of service pieces of equipment. On the other hand, the health impact, that is change in patient outcomes as a result of the program, remains unclear.

Health technology assessment (HTA) is a broad term that considers the health benefits of a given technology-based intervention. In this context, technology is very broadly defined and can include things as disparate as vaccines and surgical procedures. HTA is applied to medical equipment in the developed world, but has generally been

limited to high costs interventions [5]. These assessments are rarely applicable in the developing world where available resources and technologies differ greatly. HTA in developing countries has primarily been limited to middle income countries [6] [7].

In this project, we propose to identify health outcomes that can be used as indicators of an impact on patient health outcomes of building capacity for medical equipment maintenance and repair through the BMET program in Rwanda.

2. Literature Review

Health technology is “the application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures, and systems developed to solve a health problems and improve quality of life” [8]. The focus in this project will be on the specific subset of health technology known as medical equipment. Medical equipment is defined as:

devices requiring calibration, maintenance, repair, user training, and decommissioning – activities usually managed by clinical engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following disease or injury; it can be used either alone or in combination with any accessory, consumable, or other piece of medical equipment [8].

Many public health expenditures and investments in the developing world come from developed countries. A significant majority of medical equipment, over 95%, in public hospitals in these regions, is imported in the form of donations and purchases [9]. Of donated equipment, the vast majority (96%) is not working within five years, while 39% was never functional in the developing setting [1]. A skilled technician with only locally available resources could repair a majority of nonfunctional equipment [3].

Engineering World Health, a nonprofit organization, focuses on improving healthcare in resource-poor settings through biomedical engineering initiatives. Based on the research on medical equipment, the Developing World Healthcare Technology Lab developed educational curriculum for medical equipment maintenance and repair

[3]. In late 2009, EWH began training biomedical engineering technicians in Rwanda.

The initial goal was to train 45 technicians to service every hospital in the country within three years. The program has since expanded to Ghana, Cambodia and Honduras [4].

The impact of this program on health care is clear from the number of technicians trained, repairs performed and equipment returned to service. For example, hospitals with a BMET trained technician had less out-of-service equipment in laboratories, operating rooms, and intensive care units than those without a BMET trained technician [3].

Yet, no direct link to health impact has been made. This link could be critical (1) to provide evidence to policy makers on the value of such programs, and (2) to provide direction for future equipment maintenance and repair capacity building programs.

In order to develop a method to establish this link, we first consider general health technology assessment. Due to the complex nature of health care and health technology, policy makers require frameworks and methodologies to evaluate technologies. This field, known as health technology assessment (HTA), can be defined as:

the systematic evaluation of properties, effects, and/or impact of health care technology. It may address the direct, intended consequences of technologies as well as their indirect, unintended consequences. Its main purpose is to inform technology-related policymaking in health care [10].

Several frameworks for the assessment of health technology exist, but evaluations are generally limited to new and expensive technologies [5] [11]. While this is valid in the developed context, in resource-poor settings a different range of technologies must be considered.

HTA organizations that have developed assessment frameworks include the WHO Collaborating Center for Knowledge Translation and Health Technology Assessment, Germany's Institute for Quality and Efficiency in Health Care (IQWiG), the Canadian Agency for Drugs and Technologies in Health (CADTH), and United Kingdom's National Institute for Health and Clinical Excellence (NICE) [12] [13] [14] [15]. In addition, the European Collaboration for Health Technology Assessment has published general guidance on the subject [16]. The main steps of these frameworks are same, but some variations exist.

First, the technology to be assessed is selected. As the primary goal of HTA is to guide policy decisions, the selection of a particular technology to assess is generally driven by policy needs [16]. It is often in response to questions regarding clinical value and coverage, or in response to the introduction of a new technology [13] [15]. In the case of IQWiG, assessments are not performed on a single technology, but an entire therapeutic area to identify the most efficient therapy or combination of therapies [13]. This initial impetus varies based on the needs and priorities of the requesting organization [14].

Once the initial decision to study a technology or therapeutic area has been made, a general assessment is done to clearly define the option being assessed [12]. Some frameworks pose the assessment as a comparison between the technology in question and an alternative or reference technology, generally selected as the standard of care [12] [14] [15]. IQWiG's method necessitates an assessment of all available alternatives [13]. In addition, a metric or metrics may be identified at this stage to quantify the clinical impact of the technology [14] [15] [16]. The target populations are also assessed in this phase [14] [15] [16]. Based on this assessment and the initial policy question, specific research questions are developed as the focus of the assessment [14] [16].

The next step is identifying the data and evidence behind each technology option being considered through the literature. This includes clinical impact (efficacy and effectiveness), costs, and other considerations.

When considering the clinical impact, it is critical to identify direct and final clinical outcomes wherever possible. These outcomes could be mortality, disability adjusted life years (DALYs), quality adjusted life years (QALYs), healthy year equivalents (HYEs), etc. and the selection is dependent on the therapy in question. When final or direct clinical outcomes are unavailable, surrogate outcomes can be used but must be selected carefully to maintain the integrity of the assessment [12] [13] [14] [15] [16]. NICE recommends QALYs be used as the health outcome whenever possible [15].

In the case of diagnostics, specificity and sensitivity can also be considered. Finally, the selected outcome should be cardinal. That is, if lifespan is chosen, then a twenty-year increase should be considered equivalent to two ten-year increases in lifespan [13].

When quantifying costs, both direct and indirect may be considered [12] [13] [14]. In addition, this assessment can be done from the point of view of the patient, payers, health system, or a combination of these [12] [13] [14] [16]. A clear time horizon should be selected to help delineate which costs should be included and which should not [14]. Finally, the full cost of the episode of care may be considered to better understand the impact of the technology in context [14].

In addition to clinical impact and costs, other considerations may be factored into the assessment including the impact on the organization [14] (for example, if the technology can be used in inpatient or outpatient settings), as well as social, psychological, and cultural aspects of a given treatment, and provider preference [16].

Once data have been collected, an economic evaluation involving the clinical impact and costs is performed. There are five types of evaluation. The simplest is a cost-minimization analysis. This method is only valid when comparing two (or more) technologies that are identical in all respects except cost. Then a simple comparison of costs is done and the lowest cost option is selected [12] [14] [16]. An example of this is comparing a generic version of a drug to a branded version [12].

In a cost-benefit analysis, clinical impact is converted to a monetary scale. Then a simple ratio between benefits and costs can be calculated. The technology with the most benefit for a given cost is selected. This method can be problematic as it may be difficult to determine monetary value of clinical benefits [12] [14] [16].

A cost-effectiveness analysis selects a natural unit for all clinical impact (such as mortality). As with a cost-benefit analysis, a ratio between effectiveness and costs is calculated [12] [14] [16]. The cost-effectiveness ratio of the technology or technologies under consideration is compared to the cost-effectiveness ratio of a reference method (typically the existing standard of care) to calculate an incremental cost-effectiveness ratio (ICER). The option with the lowest ICER is selected [14] [15]. IQWiG takes a broader approach. Each option is plotted on a graph with net cost on the x-axis and net effectiveness on the y-axis. An efficiency frontier is drawn capturing the options with the most optimal cost-effectiveness tradeoffs. A mix of the technologies that comprise this frontier is recommended [13].

A cost-utility analysis is similar to a cost-effectiveness analysis. Instead of using a natural unit to measure clinical impact, health-related preferences are used [12] [14] [15] [16]. The most commonly used measure is QALYs [14]. As above, an ICER can be calculated from a cost-utility analysis [14] [15]. NICE uses this evaluation method exclusively with QALYs as the preferred outcome measure [15].

The final economic evaluation method is a cost-consequence analysis. Each cost and outcome is listed separately in a disaggregated format. This method relies on the policy-maker to weigh the costs and outcomes and make a decision accordingly [14].

The final component of HTA is developing recommendations based on the economic evaluation, as well as the additional considerations such as organizational impact [12] [13] [14] [15] [16].

While all of these methods are relevant in their context, they cannot be directly applied to the research question at hand. Resource-poor settings vary from developed settings in three key ways. First, there is a much greater reliance on donations as opposed to purchasing medical equipment. As such, capital investment costs for medical equipment may play a smaller role in assessment. Next, resources, including medical equipment, in developing settings are generally used at capacity. Finally, all clinical options may not be available in all locations, resulting in patients being referred to hospitals with different available equipment and capabilities.

The next section lays out the method used to identify indicators of an impact on patient health outcomes of capacity building for medical equipment maintenance and repair through the BMET training program.

3. Methods

When medical equipment is unavailable in resource-poor settings, providers revert to less preferred clinical procedures, which in turn results in changes in health outcomes. Figure 1 below illustrates this cascade of changing outcomes when alternative clinical options are used.

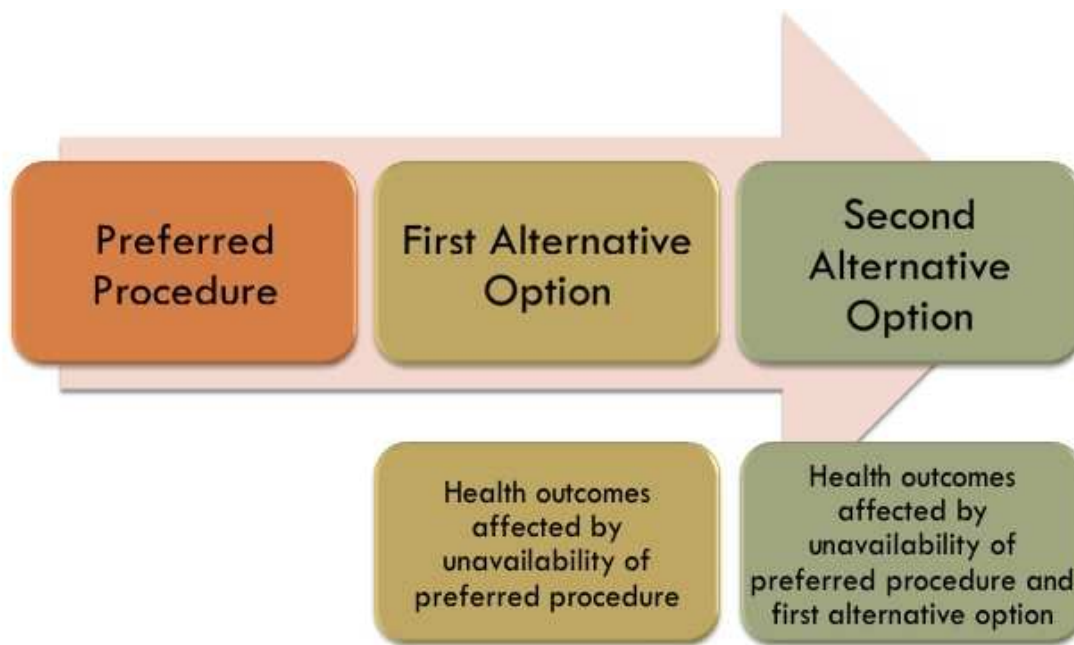


Figure 1: Clinical outcomes vary as providers use alternative procedures with changing availability of functional medical equipment

In this study, hospitals in Rwanda were surveyed to define the components of this cascade for selected health areas. These selected health areas and associated outcomes are intended to serve as indicators of the impact training for repair and maintenance of medical equipment in a hospital. The surveys included questions on clinical procedures, medical equipment use, costs, and health outcomes in selected

health areas. Both administrators and providers were interviewed, and an assessment of medical equipment availability and service status was done at each study location.

3.1 Focus Areas, Equipment, and Outcome Selection

Focus areas and associated medical equipment were selected based on the following key criteria.

First, the burden of death and disability in Rwanda was considered to ensure that the selected health areas were commonly addressed in hospitals of different sizes throughout the country. In addition, by selecting high burden diseases, it is more likely that alternative clinical procedures were in use. Finally, aggregated data on health indicators are more likely to be available for high burden conditions as these are of greater public health interest.

An initial list of the twenty most common causes of mortality and the twenty most common causes of morbidity were selected from the 2004 WHO Burden of Disease report. Common causes of morbidity and mortality partially overlap, resulting in a set of less than forty but more than twenty causes. Of this initial set, all types of injury were collapsed into a single group.

Second, several of these causes were eliminated from consideration as medical equipment was not used, or was used but was not critical for the procedures most commonly performed for prevention, diagnosis or treatment. If it is not critical to these procedures, then the equipment will not have an impact on health outcomes.

Diarrheal diseases, protein-energy malnutrition, unipolar depressive disorders, nephritis/nephrosis, lymphatic filariasis, and asthma were eliminated because no equipment is necessary for prevention, diagnosis or treatment. Meningitis, malaria, lower respiratory infections, and tuberculosis do generally require equipment for diagnosis, but because of the high incidence of these conditions or the speed of disease progression, treatment is often started based on symptoms alone without lab tests to confirm diagnosis. Therefore, these conditions were also eliminated from further consideration.

The third criterion considered was the selection of clearly measurable health outcomes. As these outcomes are intended to serve as indicators for the impact of training for equipment maintenance and repair, they should be easily measurable. In addition, these outcomes should have a direct relationship to the relevant health condition in order to reduce confounding by other factors.

Cerebrovascular disease, ischemic heart disease, and chronic obstructive pulmonary disease were rejected as the time between diagnosis, which requires medical equipment, and a measurable health outcome, such as mortality, can be many years. Several years of extensive medical records and equipment inventories, status, and repair records would be necessary to determine if a relationship existed between BMET training and the health outcome.

Several focus areas were removed from consideration because treatment is very rare. Birth asphyxia and birth trauma require equipment and have immediate, clear health outcomes, but were still eliminated; based on available inventories, hospitals in Rwanda generally do not have the equipment necessary for treatment of these conditions. Liver cancer was removed from consideration as it is rarely treated in Rwanda. Until 2012 there were no cancer specialists in Rwanda when a cancer center of excellence was opened in Butaro [17]. Finally, cataract treatment in Rwanda is highly centralized and rarely treated as well; there are only nine ophthalmologists in the country [18].

Finally, outside of burden of disease, high equipment areas such as imaging, surgery, and sterilization were considered.

Complex imaging equipment, such as CT scanners and MRI machines are generally not found in the country, and where found are not serviced by hospital staff. Instead, hospitals in Rwanda are equipped primarily with x-ray machines. X-rays contribute to trauma treatment for fractures by helping ensure that bones are set properly, which may in turn reduce disability. Disability, though, can be a long-term and not easily measureable health outcome.

Table 1 on page 14 summarizes focus areas, equipment, and health outcomes that were rejected for field study.

Table 1: Focus Areas, Equipment and Outcomes Rejected for Field Study

Focus Area	Criteria				Primary Reason(s) for Rejection	
	Burden of Disease (2004)		Ideal Medical Equipment	Method of Diagnosis		Health Outcome
	Deaths	DALYs				
Lower respiratory infections	26,171	843,199	X-ray for diagnosis	Symptoms		Treatment is drug therapy and does not include equipment
Diarrheal diseases	18,935	632,611	None	Symptoms		Treatment does not include equipment
Malaria	6650	277,106	Blood test	Symptoms		Treatment is drug therapy and does not include equipment
Tuberculosis	6503	186,934	Sputum test	Symptoms		Treatment is drug therapy and does not include equipment
Birth asphyxia and birth trauma	4971	236,856	Fetal monitoring devices and forceps	Equipment based		Relevant equipment is generally not available in Rwanda based on available inventories
Cardiovascular disease	4586	55,027	ECG for diagnosis	Equipment based	Mortality	Time lag between diagnosis and outcome can be years
Ischemic heart disease	3580	37,043	ECG and x-ray for diagnosis	Equipment based	Mortality	Time lag between diagnosis and outcome can be years
Protein-energy malnutrition	2316	127,520	Scale for diagnosis	Symptoms		Treatment does not include equipment
Meningitis	1947	67,584	Lumbar puncture	Symptoms		Treatment is drug therapy and does not include equipment

Focus Area	Criteria					Primary Reason(s) for Rejection
	Burden of Disease (2004)		Ideal Medical Equipment	Method of Diagnosis	Health Outcome	
	Deaths	DALYs				
Chronic obstructive pulmonary disease	1244	15,355	X-ray for diagnosis	Equipment based	Mortality	Time lag between diagnosis and outcome can be years
Liver cancer	1100	13,191		Equipment based		Rarely treated in Rwanda
Nephritis and nephrosis	936	17,348		Symptoms		Treatment is drug therapy and does not include equipment
Iron-deficiency anemia	846	48,387	Blood test	Equipment based		Treatment does not include equipment Time lag between diagnosis and outcome can be years
Unipolar depressive disorders	5	56,943	None	Symptoms		Treatment does not include equipment
Lymphatic filariasis	0	47,388	Blood test	Symptoms		Treatment is drug therapy and does not include equipment
Cataracts	0	45,257	Surgery	Equipment based	Vision loss	Treatment is rare and highly centralized
Asthma	614	39,720	None	Symptoms		Treatment does not include hospital equipment
Imaging			X-ray for fracture		Physical disability	No easily measureable outcome

Seven focus areas remained for field study based on the criteria discussed above.

Treatment for neonatal thermoregulation using an infant incubator or an infant warmer was considered, with the health outcomes of mortality, infection rate, growth velocity, and insensible water loss rate.

Neonatal jaundice treatment was also considered. Potential treatment options include phototherapy with lamps and exchange transfusions. Health outcomes include infection rate and time to recovery of bilirubin level.

For emergency care, both acute airway management and acute respiratory management were included. A suction machine, a laryngoscope, and a pulse oximeter were identified as necessary equipment to place an airway. A pulse oximeter, oxygen provision (cylinder or concentrator), and a ventilator were considered for breathing management. Health outcomes of mortality and hypoxemia were chosen for both acute airway and acute respiratory management.

During HIV/AIDS treatment with antiretroviral therapy (ART), regular monitoring of CD4 count and viral load has been found to improve mortality and slow disease progression. Therefore, a CD4 flow cytometer and a PCR machine were selected for ART treatment monitoring, with mortality and disease progression as the related health outcomes.

General anesthesia for surgery can be equipment intensive. A pulse oximeter, a capnograph, blood pressure monitoring (non-invasive, invasive, and cuff), oxygen

provision (cylinder or concentrator), a ventilator, and ECG monitoring were identified as necessary. Mortality and hypoxemia were selected as indicative health outcomes.

Surgical equipment sterilization was selected as the final focus area. Methods include autoclave, dry heat sterilization, and steaming. Surgical infection rate was selected as the related health outcome.

Table 2 on page 18 summarizes the areas that were studied in the field.

Table 2: Focus Areas, Equipment, and Health Outcomes Not Rejected for Field Study

Focus Area	Criteria			
	Burden of Disease (2004)		Medical Equipment	Health Outcome
	Deaths	DALYs		
Neonatal Thermoregulation	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Infant warmer and infant incubator	Mortality, growth velocity, insensible water loss rate, and infection rate
Neonatal Jaundice	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Phototherapy lamp and exchange transfusion equipment	Days to recovery of bilirubin level, and monthly febrility rate
Acute Airway Management	Injuries – 10,300	Injuries – 399,000	Suction machine, laryngoscope, and pulse oximeter	Mortality and hypoxemia
Acute Respiratory Management	Injuries – 10,300	Injuries – 399,000	Pulse oximeter, oxygen provision, and ventilator	Mortality and hypoxemia
HIV/AIDS Treatment Monitoring	20,200	557,000	CD4 count machine and PCR machine	Mortality and progression of disease stage

Focus Area	Criteria			
	Burden of Disease (2004)		Medical Equipment	Health Outcome
	Deaths	DALYs		
General Anesthesia for Surgery			Pulse oximeter, capnograph, blood pressure monitoring, oxygen provision, ventilator, and ECG	Mortality and hypoxemia
Surgical Equipment Sterilization			Autoclave, dry heat sterilizer, and steamer	Nosocomial infection rate

3.2 Hospitals and Surveys

Rwanda was selected as the study site as the Rwandan BMET training program is the most mature. In addition, existing evaluations of the BMET program had been conducted in country.

Hospitals were selected to include both urban and rural settings in four provinces. In addition, these hospitals represent a range of resources and capabilities from 70 – 429 hospital beds, 0 – 12 ICU/NICU beds, and 1 – 5 OR beds. The size of population served varied from 182,000 to 450,000, and the total number of patients seen from 5000 to over 70,000, with average occupancy rates ranging from 60% to 100%. The map in Figure 2 on page 21 shows the location of each surveyed hospital. Table 3 on page 22 summarizes key hospital characteristics.

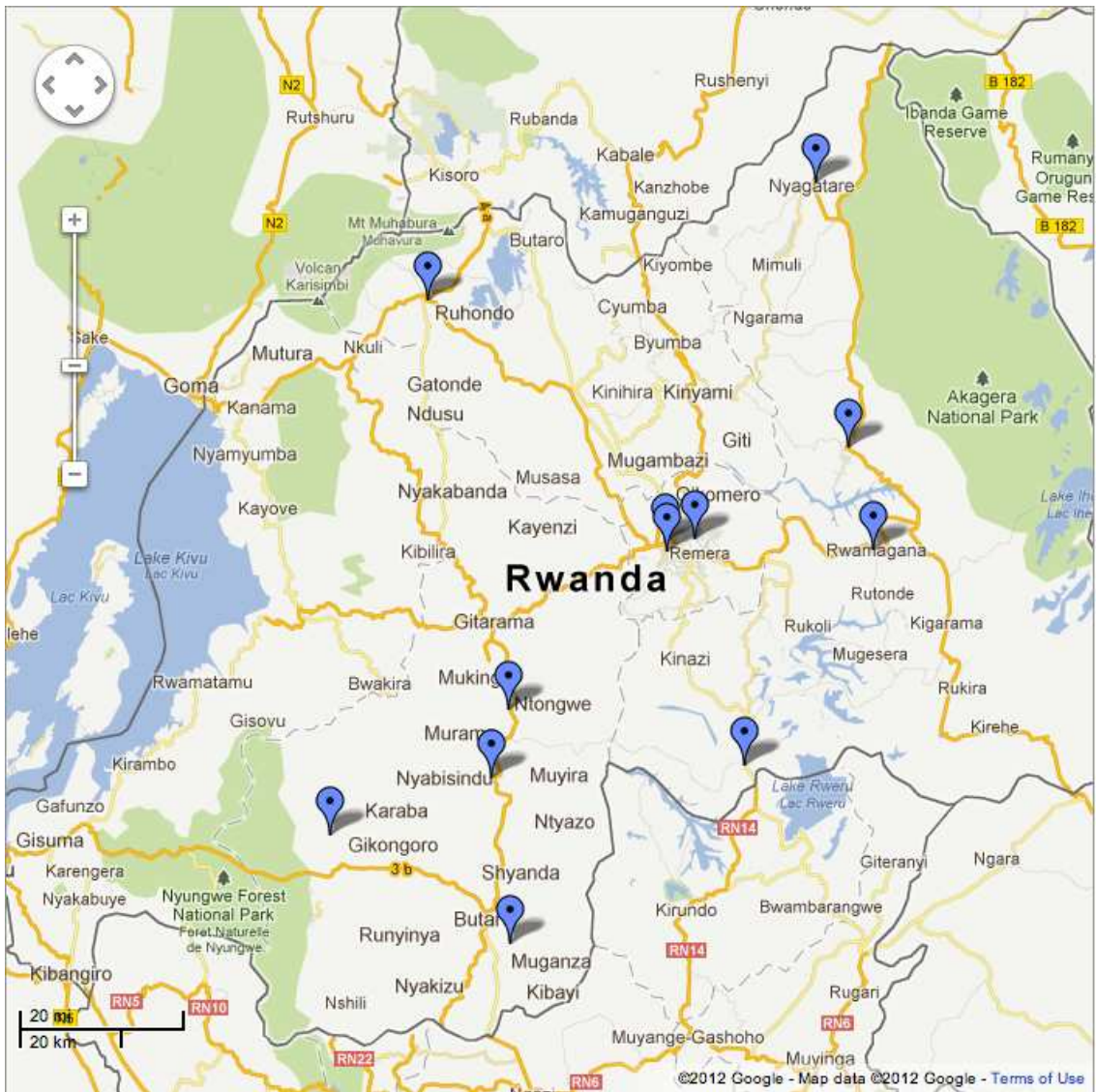


Figure 2: Study hospitals in Rwanda

Table 3: Characteristics of Surveyed Hospitals

Hospital	District	Province	Population Served	Beds	Average Occupancy Rate	Inpatients per Year	Outpatients per Year	OR Beds	NICU/ICU Beds
Rwamagana District Hospital	Rwamagana	Est	265,000	204	85%	6000	6000	2	3
Muhima Mother/Child Hospital	Muhima	Ville de Kigali	246,000	158	98%	Don't Know	15,000	2	0
Kibagabaga District Hospital	Kibagabaga	Ville de Kigali	450,000	200	75%	15,446	32,745	4	0
University Central Hospital of Kigali	Nyarugenge	Ville de Kigali		429					
Kibilizi District Hospital	Gisagara	Sud	182,600	110	60 - 70%	3490	9421	2	0
Kigeme District Hospital	Nyamagabe	Sud	183,048	161	Don't Know	4091	16,390	2	0
Ruhengeri District Hospital	Musanze	Nord	356,692	410	85%	70,570 total		5	12
Nemba District Hospital	Gukenze	Nord	254,000	167	70%	6000	24,000	2	10

Hospital	District	Province	Population Served	Beds	Average Occupancy Rate	Inpatients per Year	Outpatients per Year	OR Beds	NICU/ICU Beds
Nyanza District Hospital	Nyanza	Sud	210,000	Don't Know	100%	2400	18,250	2	0
Gitwe District Hospital	Ruhango	Sud	259,000	200	80%	5000 total		2	0
Nyagatare District Hospital	Nyagatare	Est	283,000	200	80%	16,800 total		1	0
Kiziguro District Hospital	Gatsibo	Est	195,000	70	Don't Know	Don't Know	Don't Know	2	5

Each hospital survey included three components: a director interview, provider interviews for each focus area, and an equipment survey.

Directors were interviewed regarding the key health outcomes at the facility level for each focus area.

For each focus area, a physician or nurse was interviewed about key health outcomes at the facility level. Providers were asked the cost of the procedure to the hospital, as well as the price to the patient. They were also surveyed on preferred procedures for the focus area, how this was indicated (e.g. lab tests, symptoms, etc.), and what medical equipment was necessary. The provider was asked what is done when the necessary equipment is unavailable, how this option affects health outcomes for an individual patient, as well as the causes and frequency of equipment unavailability. If more than one alternative option was used, providers were questioned about each to determine how the appropriate one was selected.

For the equipment survey, each piece of equipment identified as necessary for either the preferred options or the alternative options were surveyed. A photograph of each was taken. Manufacturer, model number, and serial number were recorded. The technician was asked who was responsible for repair and maintenance, if the piece was in service, if it was donated or purchased (and if so, for how much), maintenance costs (both consumables and spare parts), and finally how much time was spent on preventative maintenance. For equipment that was in use or otherwise inaccessible for

surveying, a copy of the hospital medical equipment inventory was requested from the technician. These inventories include manufacturer, model number, serial number, and equipment status.

Table 4 below summarizes key areas covered in each survey. All surveys are provided in Appendix A on page 85.

Table 4: Summary of Key Areas of Surveys

Survey	Key Questions
Director	<ul style="list-style-type: none"> • Key health indicators at the facility level for each focus area
Provider	<ul style="list-style-type: none"> • Key health indicators at the facility level • Clinical procedures • Order of preference of procedures • Costs and prices of procedures • Frequency and causes of equipment unavailability
Equipment	<ul style="list-style-type: none"> • Initial investment cost • Time and expense of maintenance • Time and expense of repair

4. Results

4.1 Study Sites and Interviewees

In June and July 2012, twelve hospitals were surveyed including ten district hospitals, one teaching hospital, and one maternal and child hospital. These hospitals were in four provinces across the country. Sixty-five interviews were conducted with twelve directors/administrators, thirteen doctors, 22 nurses, six anesthetists, and twelve biomedical equipment technicians.

4.2 Rejected Focus Areas, Equipment, and Health Outcomes

Based on the interview responses, an additional two criteria were developed. First, the medical equipment must be maintained and repaired by BMETs, as only this equipment will be relevant in determining the impact of the BMET training program. In addition, selected equipment must sometimes be unavailable. In cases when it is always available and functional, there would be no alternative procedure options to observe changes in health outcomes.

In the area of neonatal thermoregulation, radiant warmers were not used as a primary form of treatment. Instead, warmers were used when transporting infants, or for convenient access to the infant during clinical procedures, such as examinations and diagnostic tests. Radiant warmers are serviced by BMET technicians and are sometimes unavailable. In addition, they may even have an impact on health, but no clear and measureable health outcome was identified.

For neonatal jaundice, exchange transfusions were not used as a treatment in any surveyed hospitals, and so this treatment and related equipment were not pursued further.

Capnographs are not used when airways are placed. Several pieces of equipment are necessary for the placement of an airway, including suction machines, laryngoscopes, and pulse oximeter. Both the suction machine and laryngoscope are critical to airway placement, but both were always available in surveyed trauma wards. Pulse oximeters were not found to be critical to airway placement, and were also always available. As all equipment was always available, acute airway management was rejected from further consideration.

In addition to airway management, the use of pulse oximeters for acute respiratory management was also considered. As in the above case, they were not found to be critical to breathing management and were always available in surveyed trauma wards. Based on the failure to meet these two criteria, pulse oximeters were considered unsuitable. Ventilators were used for acute respiratory management in only two hospitals. Instead, a bag-valve-mask was commonly used. Ventilators were, therefore, rejected from further consideration.

All HIV/AIDS care is funded and administered at the federal level in Rwanda. Viral load tests for HIV/AIDS patients are conducted at a national reference laboratory, which is outside the purview of the BMET technicians. While CD4 counts are conducted

at hospitals throughout the country, the BMET technicians do not service the CD4 flow cytometers. As the technicians are not involved, both CD4 flow cytometers and PCR machines for HIV/AIDS treatment monitoring were rejected.

General anesthesia involves multiple types of equipment. All of these were rejected from further consideration. As was seen in the case of acute airway and respiratory management, pulse oximeters, oxygen provision and ventilators were always available. Capnographs were not used during general anesthesia procedures. ECG was found to be not critical. Finally, blood pressure monitoring (either by invasive blood pressure monitoring, non-invasive blood pressure monitoring or with a blood pressure cuff) was found both to not be critical when compared to other monitoring, as well as to always be available. As such, these pieces of equipment for general anesthesia were rejected.

Surgical equipment sterilization to prevent infection was typical done using autoclaves or dry heat sterilizers. In some cases, steamers were used as well. All surveyed hospitals had ample provision of surgical equipment sterilization. The available equipment was maintained and multiple backup options of equal effectiveness were generally available. In addition, if all sterilization provision failed, surgery was postponed until this was rectified. The entire area of surgical equipment sterilization was therefore rejected as the equipment was rarely unavailable and no measureable health outcome could be identified.

Table 5 on page 30 summarizes the focus areas, equipment and outcomes that were rejected based on these additional criteria. Tables 11 – 18 in Appendix B on page 140 detail findings for focus areas, equipment, and health outcomes rejected based on field study.

Table 5: Focus Areas, Equipment, and Health Outcomes Rejected Based on Field Study

Focus Area	Criteria				Primary Reason(s) for Rejection	
	Burden of Disease (2004)		Medical Equipment	Equipment Unavailability		Health Outcome
	Death	DALYs				
Neonatal Thermoregulation	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Infant warmer	Always insufficient number of functioning incubators	Mortality, infection rate, insensible water loss rate, and growth velocity	No clear and measureable health outcome
Neonatal Jaundice	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Exchange transfusion equipment (blood typing machine, etc.)	Frequently unavailable	Monthly febrility rate, and days to recovery of bilirubin level	Exchange transfusions not used as treatment
Acute Airway Management	Injuries – 10,300	Injuries – 399,000	Suction machine	Rarely unavailable	Mortality and hypoxemia	<ul style="list-style-type: none"> • Equipment is always available • Not critical to treatment
			Laryngoscope - critical			
			Capnograph			
			Pulse oximeter – not critical			

Focus Area	Criteria					Primary Reason(s) for Rejection
	Burden of Disease (2004)		Medical Equipment	Equipment Unavailability	Health Outcome	
	Death	DALYs				
Acute Respiratory Management	Injuries – 10,300	Injuries – 399,000	Pulse oximeter – not critical	Rarely unavailable	Mortality and hypoxemia	<ul style="list-style-type: none"> • Pulse oximeter is always available and not critical • Ventilator is not used
			Ventilator			
HIV/AIDS Treatment Monitoring	20,200	557,000	CD4 count machine – critical	Occasionally unavailable	Mortality and progression of disease stage	Not serviced by BMET technicians
			PCR machine – critical			
Surgical Equipment Sterilization			Autoclave – critical	Rarely unavailable	Nosocomial infection rate	<ul style="list-style-type: none"> • Equipment always available • No easily measurable health outcome
			Dry heat sterilizer – critical			
			Steamer – critical			

Focus Area	Criteria				Primary Reason(s) for Rejection	
	Burden of Disease (2004)		Medical Equipment	Equipment Unavailability		Health Outcome
	Death	DALYs				
General Anesthesia			Pulse oximeter – critical	Rarely unavailable		Equipment is not critical or always available
			Capnograph – not critical			
			Blood pressure monitoring – not critical			
			ECG – not critical			
			Ventilator			
			Oxygen provision			

4.3 Focus Areas, Equipment, and Health Outcomes Not Rejected Based on Field Study

Three focus areas were not rejected based on field study. In this section, background on each area is provided, followed by a summary of findings from field study. Finally, based on available evidence from the literature, health outcomes are projected for each procedure option used in Rwanda.

Following the IQWiG model, for each clinical procedure option inputs are plotted along the horizontal axis and outcomes along the vertical axis to compare relative efficiency. As discussed, the process of defining and quantifying inputs associated with a procedure can be complex. The Rwandan Ministry of Health sets procedure prices for public hospitals. These prices are determined based on the personnel needed, resources required, as well as overhead costs. Thus, these prices can be used as a proxy measure of cost of each procedure, and serve as a single-term summary of procedure inputs.

4.3.1 Neonatal Jaundice Treatment

4.3.1.1 Background

Newborns have naturally high levels of bilirubin, which generally reduce to normal levels within the first three days of birth. In cases of neonatal jaundice, bilirubin levels remain high or continue to rise [19].

Exposing infants to light with wavelengths from 400 to 520 nm has been found to assist the breakdown of bilirubin in the blood. Phototherapy is therefore used as a

treatment to reduce bilirubin levels in the blood [20]. Guidelines vary on what serum bilirubin levels warrant starting phototherapy treatment based on age and other risk factors. The American Pediatric Association recommends that phototherapy can be stopped when serum bilirubin levels fall below 14 mg/dL (239 $\mu\text{mol/L}$) [21].

The effectiveness of phototherapy varies based on the wavelength (range and peak) of the light source, the spectral irradiance of the light, the duration of exposure, and the amount of body surface exposed to the light source [20].

4.3.1.2 Findings

Six physicians and six nurses were interviewed at twelve hospitals regarding neonatal jaundice treatment. The providers at Rwamagana, Muhima, Kibagabaga, CHUK, Kibilizi, Kigeme, Ruhengeri, and Nemba were interviewed using the survey provided in Appendix A on page 90. The providers at Nyanza, Gitwe, Nyagatare, and Kiziguro were interviewed using the survey on page 125, also in Appendix A.

Of the twelve surveyed hospitals, diagnosis is based on symptoms in five hospitals and a serum bilirubin test in seven hospitals. At nine hospitals, providers prefer phototherapy lamps, two prefer sunlight with antibiotics (Kigeme and Kiziguro), and one prefers both phototherapy lamps and sunlight equally (Kibilizi). Surveyed hospitals have between zero and five lamps. Seven of the nine hospitals that prefer to use phototherapy lamps have faced shortages of equipment. Rwamagana, Kibagabaga, Muhima, and Gitwe have used alternative treatment options because machines were not

in service. Ruhengeri, Nemba, and Nyanza have used alternative treatment options because of an insufficient number of phototherapy lamps.

The alternative treatment option used at Rwamagana is sunlight. Muhima and Nemba both rotate infants under phototherapy lamps, which entails placing each infant under the phototherapy lamp for a shorter amount of time and alternating between patients. In Kibagabaga and Ruhengeri, multiple infants are placed under the same phototherapy lamp simultaneously when an insufficient number of functioning phototherapy lamps are available. Finally, Kibagabaga, Nyanza, and Gitwe all refer patients out to other hospitals as an alternative. While CHUK and Kibilizi have not faced phototherapy lamp shortages, providers at both hospitals would refer their patients to other hospitals if necessary.

Table 6 on page 36 summarizes the findings on neonatal jaundice. Figure 3 on page 38 summarizes treatment options used or considered in surveyed hospitals by decreasing order of preference.

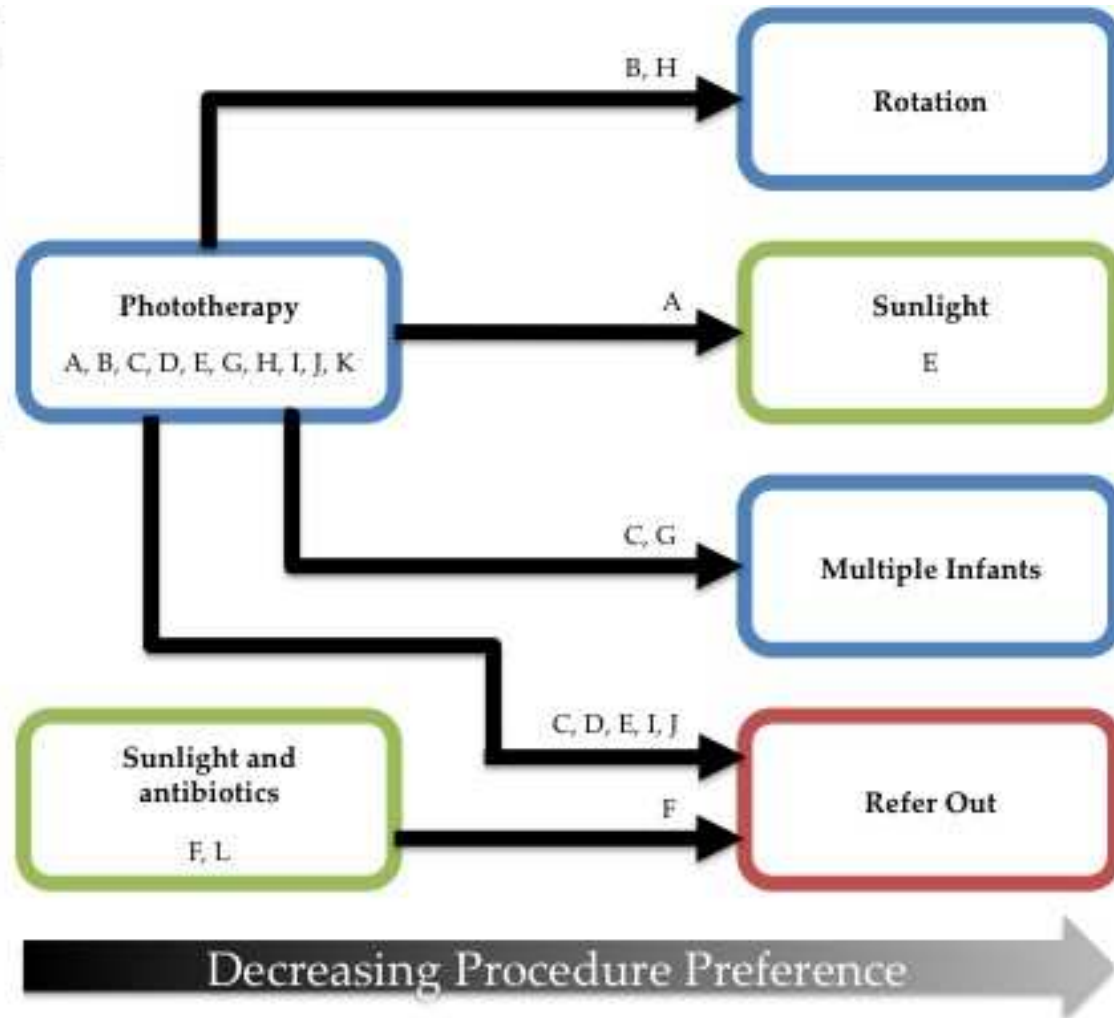
Table 6: Summary of Findings on Neonatal Jaundice

Hospital	Interviewee	Survey	Cases	Diagnosis Method	Primary Option	Alternative Option	Type of Lamp	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Rwamagana District Hospital	Physician	Survey A (page 90)	5 per month	Blood test	Phototherapy lamp	Sunlight	Conventional, blue fluorescent bulbs	1 per 3 months	Equipment not working	3	
Muhima Mother & Child Hospital	Physician	Survey A (page 90)	1 per week	Symptoms	Phototherapy lamp	Rotate infants	Conventional, blue fluorescent bulbs	Shortages more common during rainy season	Equipment not working	5	
Kibagabaga District Hospital	Nurse	Survey A (page 90)	3 per week	Blood test	Phototherapy lamps	Refer out	Conventional, blue and white fluorescent bulbs	1 per year	Equipment not working	2	
University Central Hospital of Kigali	Nurse	Survey A (page 90)	30 per month	Blood test	Phototherapy lamp	Refer out	Conventional, blue fluorescent bulbs	Never experienced equipment shortage		3	
Kibilizi District Hospital	Nurse	Survey A (page 90)	1 per month	Blood test	Phototherapy lamp (more severe), Sunlight (less severe)	Refer out	Conventional, blue fluorescent bulbs	Never experienced equipment shortage		1	
Kigeme District Hospital	Nurse	Survey A (page 90)	3 – 5 per month	Symptoms	Sunlight and antibiotics	Refer out severe cases				1	Lamp new in past week
Ruhengeri District Hospital	Physician	Survey A (page 90)	2 per week	Blood test	Phototherapy lamp	Multiple infants	Conventional, blue fluorescent bulbs	1 per week	Insufficient number of lamps	5	4 lamps new in last 3 months

Hospital	Interviewee	Survey	Cases	Diagnosis Method	Primary Option	Alternative Option	Type of Lamp	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Nemba District Hospital	Physician	Survey A (page 90)		Blood test	Phototherapy lamp	Rotate infants	Conventional, blue fluorescent bulbs		Insufficient number of lamps	1	Lamp replaced in last months
Nyanza District Hospital	Nurse	Survey B (page 125)	2 per month	Blood test	Phototherapy lamp	Refer out	Conventional, blue fluorescent bulbs		No equipment	1	Lamp new in last month
Gitwe District Hospital	Physician	Survey B (page 125)	2 per year	Symptoms	Phototherapy lamp	Refer out	Conventional, blue fluorescent bulbs	1 – 2 per year	Equipment not working	2	Both lamps repaired within 1 year
Nyagatare District Hospital	Physician	Survey B (page 125)	2 per month	Symptoms	Phototherapy lamp	None	Conventional, blue fluorescent bulbs	Never experienced equipment shortage		1	
Kiziguro District Hospital	Nurse	Survey B (page 125)		Symptoms	Sunlight and antibiotics	None				None	

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative

Surveyed Hospitals	
Experienced Equipment Unavailability	Considered Equipment Unavailability
A. Rwamagana	D. CHUK
B. Muhima	E. Kibilizi
C. Kibagabaga	K. Nyagatare
F. Kigeme	L. Kiziguro
G. Ruhengeri	
H. Nemba	
I. Nyanza	
J. Gitwe	



The first preference of each hospital is indicated by the letter in the procedure box.

Subsequent preferences are indicated by the letters on the arrows.

Figure 3: Preferences for treatment options for neonatal jaundice with changing equipment availability

4.3.1.3 Procedure Prices and Projected Health Outcomes

A number of health outcomes can be considered with neonatal jaundice. When untreated, or insufficiently treated, hyperbilirubinemia can lead to kernicterus and mortality [22]. Both mortality and kernicterus were rare, and in some cases never seen, in surveyed hospitals. As such, these health outcomes are not promising for further study. Variation in phototherapy treatment, including changes in intensity and wavelength of the light, duration of the treatment, and surface area of body exposed to the light, can lead to a longer time to recovery of bilirubin to normal levels. In addition, placing multiple infants under the same phototherapy lamp may lead to an increase in the incidence of febrility, as an indicator of an increase in the incidence of infection.

Phototherapy

Neonatal jaundice treatment includes a physician consultation, a total serum bilirubin lab test, and phototherapy treatment. Each day of phototherapy treatment is RWF 900. A consultation during hospitalization is priced at RWF 450. Finally, the lab test to measure total serum bilirubin level is priced at RWF 1097, but only seven of the twelve surveyed hospitals use this test [23]. The other five diagnose based only on symptoms. Thus, the average price of diagnosis is assumed to be RWF 640. In addition, serum bilirubin levels may be tested more than once to gauge progress and determine when to stop treatment.

Based on American Pediatric Association, term infants (greater than 38 weeks of gestation) who have risk factors (isoimmune hemolytic disease, G6PD deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis, or albumin level less than 3.0 g/dL), and premature infants with a gestation age of 35 – 36 weeks without any additional risk factors are considered at medium risk for hyperbilirubinemia. Phototherapy treatment is recommended for these infants if at least 4.5 days after birth they have a total serum bilirubin level between 18 mg/dL (308 $\mu\text{mol/L}$) and 22.5 mg/dL (385 $\mu\text{mol/L}$), and should be continued until this level drops and remains below 14 mg/dL (239 $\mu\text{mol/L}$) [21]. This is comparable to NICE guidelines recommending starting phototherapy for term infants at a total serum bilirubin level at least four days after birth of 20.5 mg/dL (350 $\mu\text{mol/L}$) or higher, and continuing until the level drops and remains below 17.5 mg/dL (300 $\mu\text{mol/L}$) [24].

Based on Tan's study of bilirubin response to phototherapy in neonates, phototherapy with light in the 425 – 475 nm wavelength range, and an average spectral irradiance of 30 $\mu\text{W/cm}^2/\text{nm}$ will lead to an average decrease in serum bilirubin level by approximately 50% in a 24-hour period [25]. Assuming an infant at medium risk is diagnosed with jaundice with a total serum bilirubin level of 22 mg/dL (376 $\mu\text{mol/L}$), following the American Pediatric Association guidelines, the infant would be treated with phototherapy for approximately one day.

In this scenario, treatment would include two serum bilirubin level tests – one for diagnosis and one to determine progress at 24 hours (RWF 640 each), one consultation (RWF 450), and one day of phototherapy treatment (RWF 900), for a total price of RWF 2630. The time to bilirubin level recovery is about one day.

Rotation

Based on existing evidence, it is likely that rotation of infants under phototherapy lamps increases the time to recovery of bilirubin level. A study conducted by Rubaltelli, et al. compared intermittent phototherapy to continuous phototherapy in full-term and otherwise healthy infants. Bilirubin levels in infants treated with continuous phototherapy decreased more than those treated with intermittent phototherapy. In term infants with initial bilirubin levels of approximately 14.5 mg/dL (248 $\mu\text{mol/L}$), 24 hours of continuous phototherapy brought serum bilirubin levels down to 11 mg/dL (188 $\mu\text{mol/L}$), 48 hours to 9 mg/dL (154 $\mu\text{mol/L}$), and 72 hours to 8 mg/dL (137 $\mu\text{mol/L}$). An equivalent amount of phototherapy delivered intermittently (six hours of phototherapy alternating with six hours of darkness) brought serum bilirubin levels down to 12.5 mg/dL (214 $\mu\text{mol/L}$), after 24 hours of therapy, 11 mg/dL (188 $\mu\text{mol/L}$), after 48 hours, and 10.5 mg/dL (180 $\mu\text{mol/L}$) after 72 hours [26].

Assuming an infant at medium risk is diagnosed with jaundice with a total serum bilirubin level of 22 mg/dL (376 $\mu\text{mol/L}$), following the American Pediatric Association guidelines, the infant would be treated with continuous phototherapy for

approximately one day (as before). If two infants are being treated with the same phototherapy lamp, assuming six-hour treatment periods and similar levels of bilirubin decrease as the infants in the Rubaltelli study, the infant would require two days of phototherapy treatment for bilirubin levels to fall below the recommended cutoff to stop therapy.

In addition, a study by Archibald, et al., found that risk of nosocomial infection increased with patient density (measured as patient-days) in a pediatric cardiac intensive care unit. The relationship was linear; each increase of 100 patient-days led to an increase in 6.5 infections per 1000 patient-days in one month. The same study found a median infection rate of 6.9 infections per 1000 patient-days [27]. Assuming a similar baseline and increase in infection rate, rotating infants would result in two additional infections per 1000 patient-days in one month (from 6.9 infections per 1000 patient-days to 8.85 infections per 1000 patient-days). Fever is an indicator of infection and it is expected that fever incidence would track with infection incidence.

Assuming as before that this treatment includes two serum bilirubin level tests, and one consultation, the total price of two days of phototherapy treatment is RWF 3530. The time to bilirubin level recovery is estimated to be two days. This is one day longer and the infection rate two infections per 1000 patient-days in one month more for rotating infants underneath lamps than with continuous phototherapy.

Multiple Infants

Another alternative option used by neonatologists in Rwanda is placing multiple infants under the same phototherapy lamp. Phototherapy using light in the blue-green spectrum (400 – 480 nm) with low spectral irradiance (approximately 5 $\mu\text{W}/\text{cm}^2/\text{nm}$) does cause a decline in serum bilirubin levels (about 17% of initial bilirubin levels in 24 hours). As spectral irradiance increases, the decline of serum bilirubin level increases as well, and this decline can be as much as 50% of initial bilirubin level in a 24-hour period. The minimum spectral irradiance necessary for phototherapy to achieve a decline of this magnitude is 31.85 $\mu\text{W}/\text{cm}^2/\text{nm}$ in the 440 – 480 nm wavelength range, and 54.71 $\mu\text{W}/\text{cm}^2/\text{nm}$ in the 400 – 480 nm wavelength range [25]. Irradiance can vary from the center of a phototherapy lamp to the periphery, in some cases by a factor of two. A study comparing several models of phototherapy lamps found that the drop-off in irradiance differs between models and is not necessarily linear [28].

Assuming an infant at medium risk is diagnosed with jaundice with a total serum bilirubin level of 22 mg/dL (376 $\mu\text{mol}/\text{L}$), following the American Pediatric Association guidelines, the infant would be treated with phototherapy for approximately one day (as before). If two infants are being treated simultaneously with the same phototherapy lamp, we can assume they are receiving one-half of the spectral irradiance as a single infant under a single lamp. Per Tan's study, a spectral irradiance of 15 $\mu\text{W}/\text{cm}^2/\text{nm}$ with light in the 425 – 475 nm wavelength range leads to approximately

a 30% decrease in total serum bilirubin level in a 24-hour period [25]. Therefore, the infant would require two days of phototherapy treatment for total serum bilirubin level to fall below the recommended cutoff to stop therapy.

Beyond time to recovery of bilirubin, infection rates are also likely affected by placing multiple infants underneath one lamp. Multiple studies have found that nosocomial infection rates are higher in multi-bed rooms than single-bed rooms in hospitals, and are higher in neonatal intensive care units (NICUs) than in other wards. This is true because of both increased airborne transmission of infection as well as increased contact with hospital staff and contaminated surfaces [29]. Based on this, placing infants underneath the same phototherapy lamp would lead to a higher rate of transmission of infectious agents from proximity to other infected infants and from increased contact with health care workers. Increased contact is likely as all infants are shifted and touched each time one infant is accessed for treatment.

A study conducted by Goh, et al., considering hepatitis B infection in households with acute cases identified bed/bedding sharing as a factor associated with increased transmission. Family members that shared beds/bedding with an infected person were 1.5 times as likely to also be infected as compared to family members who did not [30]. Based on this, as well as the additional risk of infection due to increased patient-days, placing two infants under a phototherapy lamp instead of one would result in an additional five infections per 1000 patient-days in one month (from 6.9 infections per

1000 patient-days to 12.11 infections per 1000 patient-days). Assuming fever tracks with infection, a similar increase in incidence of fever is expected.

As before, if this treatment includes two serum bilirubin level tests and one consultation in addition to phototherapy, the total price of two days of phototherapy treatment is RWF 3530. The time to bilirubin level recovery is about two days.

The estimated time to bilirubin level recovery is one day more than phototherapy with one infant underneath each lamp, and the infection rate five infections per 1000-patient days in one month greater than with the preferred option.

Discharge and Sunlight

The only available evidence regarding sunlight as a treatment for neonatal jaundice is from a single case series published by Cremer, et al. in 1958, which led to the advent of phototherapy treatment [31] [32]. The American Pediatrics Association does not recommend sunlight as a treatment because there are practical challenges associated with exposing naked infants to sunlight [21]. Average spectral irradiance of sunlight between 400 nm and 520 nm wavelength ranges from 64 $\mu\text{W}/\text{cm}^2/\text{nm}$ to 142 $\mu\text{W}/\text{cm}^2/\text{nm}$ with an average of 1.18 $\mu\text{W}/\text{cm}^2/\text{nm}$ (from Reference AM 1.5 Spectra), which is within the range of effective phototherapy [33]. But there is variation based on latitude, elevation, season, time of day, pollution, and atmospheric conditions that can lead to a reduction in solar spectral irradiance of almost 90% [34]. Indeed, the physician at Muhima noted that neonatal jaundice incidence was higher during the rainy season.

Therefore, it is likely that phototherapy by sunlight would on average lead to longer time to recovery of bilirubin level than phototherapy lamps.

Assuming an infant at medium risk is diagnosed with jaundice with a total serum bilirubin level of 22 mg/dL (376 $\mu\text{mol/L}$), following the American Pediatric Association guidelines, the infant would be treated with phototherapy for approximately one day (assuming phototherapy with light in the 425 – 475 nm wavelength range, and an average spectral irradiance of 30 $\mu\text{W/cm}^2/\text{nm}$, as before). If the same infant were instead treated using sunlight, continuous therapy would not be possible. In addition, solar spectral irradiance could fall below the minimum necessary to achieve a 50% decline in bilirubin level within a 24-hour period (as determined by Tan). The combination of these factors would lead to two to three days of treatment necessary for recovery of serum bilirubin level.

Infection rate is estimated to be lower for patients treated with sunlight as compared to those treated with phototherapy because these patients are not exposed to the hospital NICU environment.

This treatment would include one serum bilirubin level test and one consultation for a total treatment price of RWF 1090. The increase in bilirubin recovery time is 1.5 days and the decrease in infection rate is estimated to be three infections per 1000 patient-days in one month compared to treatment with a phototherapy lamp.

Discharge and Sunlight with Antibiotics

There is no existing evidence for antibiotics as a treatment for jaundice and therefore time to bilirubin recovery is likely to be the same for infants who are treated with only sunlight and those treated with both sunlight and antibiotics. Febrility rate would be lower for infants treated with sunlight and antibiotics as compared to those treated with sunlight alone.

Price of treatment would be higher than for sunlight alone due to expense of antibiotics. Based on a 2009 survey of the price of a two-week course of generic ciprofloxacin conducted by Health Action International, the price is estimated to be 1800 RWF [35].

The total price of treatment with sunlight including antibiotics including one serum bilirubin level test, one consultation, and a two-week course of antibiotics is RWF 2890. The increase in time to bilirubin recovery is 1.5 days more than treatment with a phototherapy lamp. The decrease in infection rate is six infections per 1000 patient-days in one month compared to conventional treatment.

Refer Out

When infants are referred to another hospital, the burden of seeking care at an alternative location is placed on the family, and may be too high for some families resulting in no treatment in some cases. This in turn can lead to a longer time to bilirubin recovery.

As no data is available on how many patients actually seek treatment at another location, a longer time to recovery of bilirubin level compared to providing phototherapy treatment is estimated. Infection rate, as indicated by fever, is estimated to be lower than providing phototherapy as infants may not be exposed to a NICU environment. The price of treatment is estimated to be lower than phototherapy treatment as well.

Referring out is estimated to result in an increase of three days for recovery of bilirubin level and a decrease of three infections per 1000 patient-days in one month. The

The prices and outcomes associated with each treatment option are summarized in the charts in Figures 4 and 5 on pages 48 and 49.

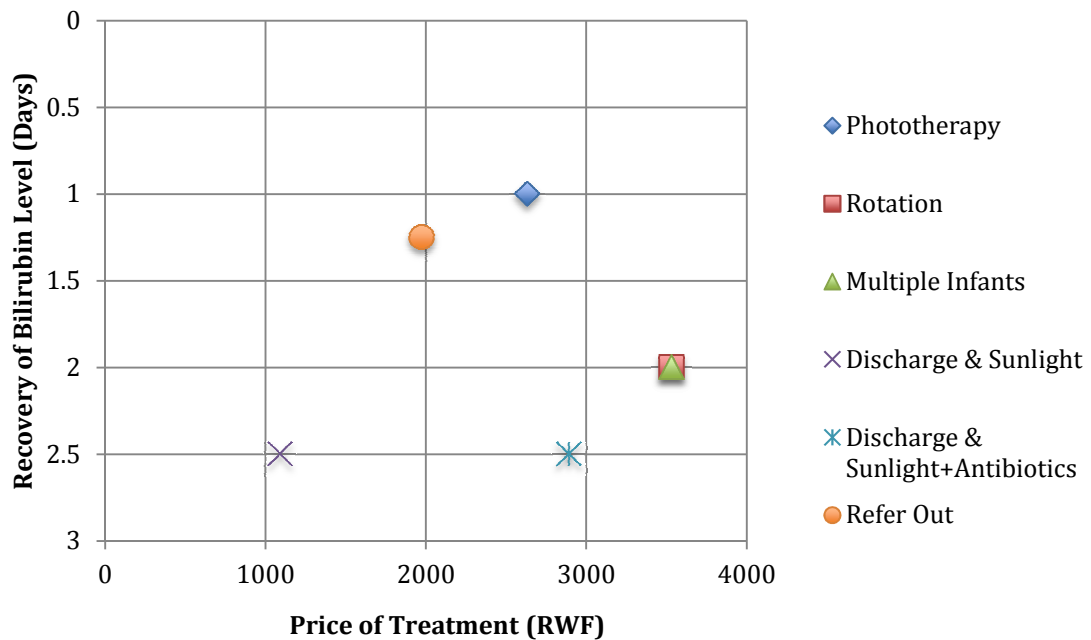


Figure 4: Prices and projected days to bilirubin recovery for neonatal jaundice treatment options

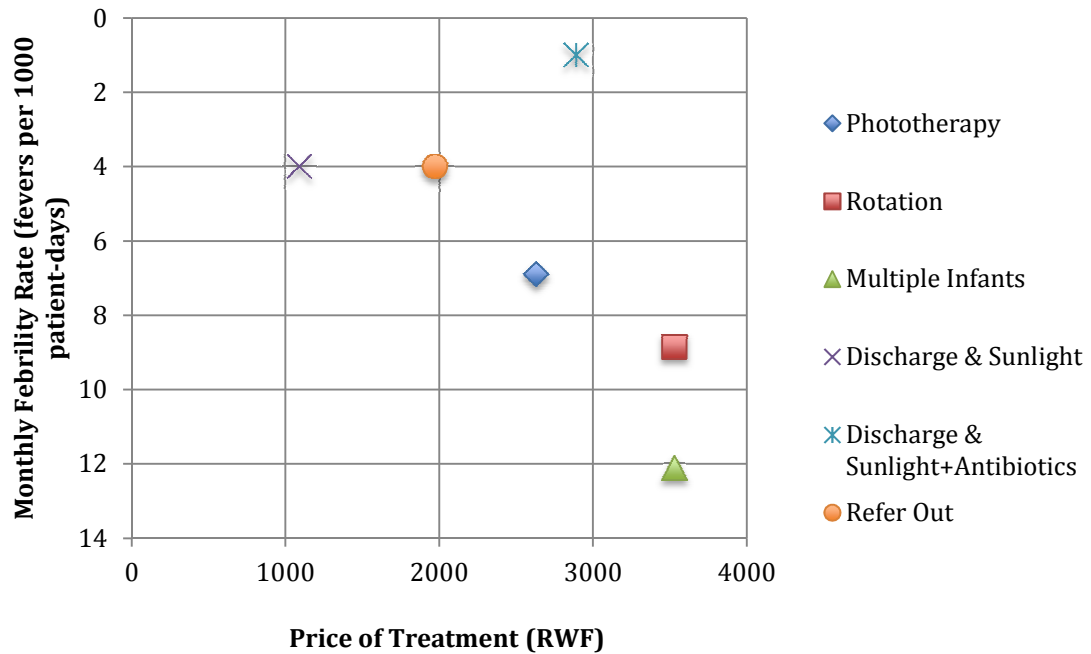


Figure 5: Prices and projected fever rate for neonatal jaundice treatment options

In summary, BMET training is hypothesized to measurably reduce the number of days to treat neonatal jaundice and to reduce the rate of infection in the NICU.

4.3.2 Neonatal Thermoregulation

4.3.2.1 Background

Normal body temperature for a neonate is between 36.5 °C and 37.5 °C, but their ability for thermoregulation is very limited. Without thermal protection, a neonate’s temperature can easily fall outside of this ideal range, resulting in increased morbidity and mortality [36].

Thermoregulation is done to maintain thermoneutrality of the infant’s environment [36]. This was defined by Hey to be the temperature range at which the

infant's heat production and evaporative water loss is minimal. That is, the infant is spending the least amount of energy necessary to maintain his body temperature [37]. Premature and low birth weight infants are less capable of thermoregulation, and thus the range of appropriate temperatures for this group is narrower. Additional factors that affect this range include the infant's skin temperature and age, as well as air humidity [36].

There are a number of options for thermoregulation including kangaroo care, infant warmers, and infant incubators. The World Health Organization recommends kangaroo care for stable infants who weigh at least 1500 g, and have no other complicating factors, such as sepsis or respiratory distress. Infant warmers are recommended for management of sick infants who weigh at least 2500 g. Finally, incubators are recommended for infants who weigh less than 1500 g, and infants who are sick or at-risk. This can include low temperature, respiratory distress (a respiratory rate of more than 60 breaths per minute, or chest retractions on expiration), or cardiac distress (a heart rate of less than 100 beats per minute) [38].

4.3.2.2 Findings

Six physicians and six nurses were interviewed at twelve hospitals regarding neonatal thermoregulation. The providers at Rwamagana, Muhima, Kibagabaga, CHUK, Kibilizi, Kigeme, Ruhengeri, and Nemba were interviewed using the survey provided in

Appendix A on page 95. The providers at Nyanza, Gitwe, Nyagatare, and Kiziguro were interviewed using the survey on page 129, also in Appendix A.

Ten of twelve surveyed hospitals use a combination of factors to determine use of an incubator for thermoregulation. Eight hospitals consider a skin temperature threshold (ranging from 35 °C to 37 °C), ten hospitals consider a gestation age threshold (ranging from 32 weeks to 37 weeks), nine hospitals consider a birth-weight threshold (ranging from 1200 g to 2500 g), and six hospitals consider vital signs (such as respiratory rate, oxygen saturation, and/or cardiac rate).

Surveyed hospitals have between three and thirteen incubators. Six of the twelve surveyed hospitals constantly suffer from a lack of functioning incubators. Only CHUK has never had to use an alternative to incubators for thermoregulation. Rwamagana, Kibagabaga, Kibilizi, Nemba, Nyanza, and Nyagatare all have experienced shortages of incubators due to high demand. Gitwe and Kiziguro have experienced shortages due to equipment failure. Muhima, Kigeme, and Ruhengeri have experienced shortages due to a combination of these two factors.

When faced with a shortage of incubators, all hospitals prioritize patients and select the healthiest infants for alternative treatment options. Two hospitals, Rwamagana and CHUK, consider only kangaroo care an alternative to an incubator. For other ten hospitals the first alternative is to place multiple infants in the same incubator. If there are still an insufficient number of functioning incubators, Muhima, Kibagabaga, Nemba,

Nyanza, Nyagatare, and Kiziguro use kangaroo care as an alternative as well.

Kibagababa and Nemba also use an infant warmer. Nyanza uses a heat lamp in addition to kangaroo care as an alternative option. Gitwe does not use kangaroo care as an alternative option. Instead they use heat lamps or refer patients out.

Table 7 on page 53 summarizes the findings on neonatal thermoregulation.

Figure 6 on page 55 summarizes treatment options used or considered in surveyed hospitals by decreasing order of preference.

Table 7: Summary of Findings on Neonatal Thermoregulation

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Rwamagana District Hospital	Physician	Survey A (page 95)	<ul style="list-style-type: none"> • Below 36 °C • Premature • Less than 1500 g 	Incubator	Kangaroo care	1 per week	Insufficient number of incubators	4	1 partially in service
Muhima Mother & Child Hospital	Physician	Survey A (page 95)	<ul style="list-style-type: none"> • Less than 37 weeks • Less than 2000 g 	Incubator	Multiple infants, kangaroo care	Always use alternative options	Insufficient number of incubators, and equipment not working	12	8 are poor quality
Kibagabaga District Hospital	Nurse	Survey A (page 95)	<ul style="list-style-type: none"> • Below 37 °C • Less than 36 weeks • Less than 2500 g • Poor vital signs 	Incubator	Multiple infants, infant warmer, kangaroo care	1 per year	Insufficient number of incubators	4	
University Central Hospital of Kigali	Nurse	Survey A (page 95)	<ul style="list-style-type: none"> • Below 36 °C • Less than 35 weeks • Less than 1500 g • Poor vital signs 	Incubator	Kangaroo care	Never experienced equipment shortage		13	2 out of service
Kibilizi District Hospital	Nurse	Survey A (page 95)	<ul style="list-style-type: none"> • Below 36 °C • Less than 37 weeks • Less than 2000 g • Poor vital signs 	Incubator	Multiple infants	2 per month	Insufficient number of incubators	4	1 out of service
Kigeme District Hospital	Nurse	Survey A (page 95)	<ul style="list-style-type: none"> • Below 35 °C • Less than 2000 g • Poor vital signs 	Incubator	Multiple infants	Usually multiple infants per incubator	Insufficient number of incubators, and equipment not working	5	3 new in last week

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Ruhengeri District Hospital	Physician	Survey A (page 95)	<ul style="list-style-type: none"> • Below 36.5 °C • Less than 37 weeks • Less than 2500 g • Poor vital signs 	Incubator	Multiple infants	Always multiple infants per incubator	Insufficient number of incubators, and equipment not working	10	2 out of service
Nemba District Hospital	Physician	Survey A (page 95)	<ul style="list-style-type: none"> • Below 36 °C • Less than 37 weeks • Less than 2500 g • Poor vital signs 	Incubator	Multiple infants, kangaroo care, infant warmer	Always use alternative options	Insufficient number of incubators	6	
Nyanza District Hospital	Nurse	Survey B (page 129)	<ul style="list-style-type: none"> • Less than 34 weeks 	Incubator	Multiple infants, kangaroo care, heat bulbs	Always use alternative options	Insufficient number of incubators	4	3 new in last month
Gitwe District Hospital	Physician	Survey B (page 129)	<ul style="list-style-type: none"> • Below 36 °C • Difficulty feeding 	Incubator	Multiple infants, heat lamp, refer out	Always use alternative options	Equipment was not working	5	1 out of service, 3 new in last month
Nyagatare District Hospital	Physician	Survey B (page 129)	<ul style="list-style-type: none"> • Premature 	Incubator	Multiple infants, kangaroo care	Always use alternative options	Insufficient number of incubators	4	2 out of service
Kiziguro District Hospital	Nurse	Survey B (page 129)	<ul style="list-style-type: none"> • Less than 32 weeks • 1200 – 1500 g 	Incubator	Multiple infants, kangaroo care	1 per month	Equipment was not working	3	

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative

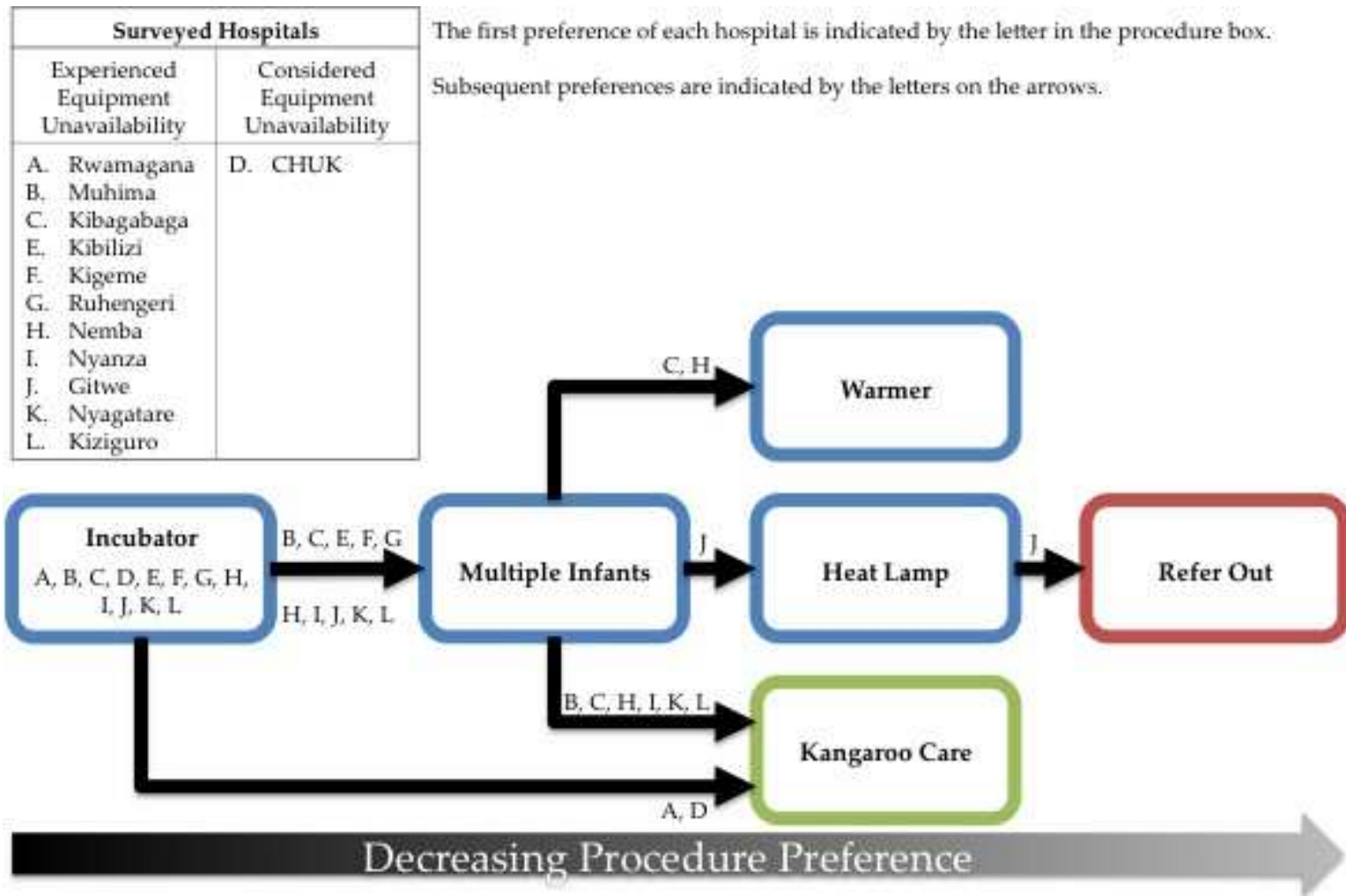


Figure 6: Preferences for neonatal thermoregulation options with changing equipment availability

4.3.2.3 Projected Health Outcomes

There is no definitive guidance on the appropriate duration of treatment in an incubator for infants who are premature, low weight, and have additional risk factors such as hypothermia or respiratory distress. The primary metric used is weight as this generally corresponds with ability to maintain temperature. Infants who weigh as little as 1600 g and are otherwise medically stable can be safely transferred from an incubator to an open cot without affecting weight gain or temperature stability [39]. In addition to weight gain, insensible water loss can vary based on the heat source used and has been seen at higher rates in infants who are in low humidity environments [40]. Insensible water loss rate may be difficult to track because this requires accurate measures of total fluid intake and output. Placing more than one infant in the same incubator likely leads to higher infection rates. To determine infection rate, a number of lab tests would be necessary because fever cannot be used as an indicator of infection for neonates that have limited capacity for self-thermoregulation. Finally, in the most severe cases, lack of neonatal thermoregulation can lead to mortality [36].

Infant Incubator

The price of neonatal thermoregulation treatment, regardless of the method used, is included in the price of hospitalization, which is RWF 480 per day. In addition, there is the initial consultation, which is priced at RWF 450 during hospitalization [23].

As stated previously duration of treatment in an incubator is variable, but the minimum studied weight at which a medically stable infant can be moved to an open cot without adversely affecting temperature stability and weight gain is 1600 g.

Based on a study by Kim, et al., determined a growth velocity of 15.2 g/kg/day in extremely low birth weight neonates (less than 1000 g) treated in incubators with humidity control [40]. Meyer, et al. determined a growth velocity of 16 g/kg/d in low birth weight neonates (less than 1750 g), and Marks, et al. found a growth velocity of 18.2 g/kg/d in very low birth weight neonates (less than 1500 g) [41] [42].

As with weight gain, a number of estimates exist for the rate of insensible water loss in neonates in incubators. Kim, et al., found a rate of 72.3 mL/kg/d for extremely low birth weight infants, while a meta-analysis by Flenady and Woodgate found a determined a rate of 33.8 mL/kg/d from three studies [40] [43].

Estimates of mortality risk of very low birth weight infants treated in incubators vary widely from 10% to 35% in one month from birth. The 35% mortality risk estimate comes from a meta-analysis of two studies conducted in developed settings in the 1960s, and is probably more comparable to present day low-resource settings [43] [44] [45] [46].

Finally, a study by Archibald, et al. determined a median infection rate of 6.9 per 1000 patient-days in one month in a pediatric intensive care unit [27].

An infant with birth weight of 1000 g, skin temperature of 32 °C, and a gestation age of 28 weeks, would remain in an incubator until reaching a weight of 1600 g. We

assume a growth velocity of 15.5 g/kg/day. Using the exponential model (determined by Patel, et al. to be the most accurate of commonly used models for very low birth weight premature infants):

$$\text{Days to Weight Gain} = \frac{1000 \times \ln \frac{\text{Final Weight}}{\text{Initial Weight}}}{\text{Growth Velocity}}$$

the number of days to achieve a weight gain of 600 grams at this growth velocity is 30 days [47]. An insensible water loss rate of 55 mL/kg/d, an infection rate of 6.9 per 1000 patient-days in one month, and a mortality risk of 25% in one month are assumed based on existing literature.

The total price of this treatment is RWF 14,850, which includes 30 days of hospitalization (RWF 480 per day) and a consultation (RWF 450).

Multiple Infants

In the case of a single infant in an incubator, the incubator environment can be optimized to that infant's needs. As discussed above, the thermoneutral environment is more narrowly defined for premature, low birth weight infants compared to healthier infants. Incubator temperature can be controlled either automatically based on the infant's skin temperature, or manually based on the incubator temperature. Two studies have examined the impact of these temperature control options on low birth weight infants. Both found a decrease in mortality when abdominal skin temperature is used to regulate the incubator temperature. This difference was even more pronounced in very low birth weight infants (800 g - 1600 g). A meta-analysis of these studies found that

mortality risk decreased from about 52% to about 35% within two weeks of birth in this group, a risk ratio of 0.66 (95% CI 0.48, 0.90) [44]. When multiple infants are placed in the same incubator, by necessity the incubator control must be based on air temperature, so an increase in mortality is expected.

Growth velocity would likely be lower as well because each infant would expend more energy on maintaining body temperature.

Infection rates are likely to increase due to increased contact both with other infants and with health care providers, as well as the longer duration of stay. Archibald, et al. found that each increase of 100 patient-days led to an increase of 6.5 infections per 100 patient-days in one month [27]. Goh, et al. found that family members that shared beds/bedding with an infected person were 1.5 times as likely to also have hepatitis B as compared to family members who did not [30].

As additional infants would not impact the humidity control of the incubator, no change in insensible water loss rate is projected.

Assuming two infants with birth weight of 1000 g, skin temperature of 32 °C, and gestation age of 28 weeks placed in the same incubator, mortality risk would increase from 25% to 38% in one month (based on a risk ratio of 0.66 from the meta-analysis comparing temperature control methods in incubators by Sinclair) [44]. We assume a slightly lower growth velocity of 14.5 g/kg/d, which would result in 32 days of treatment to achieve a weight of 1600 g. The infection rate is expected to increase from 6.9

infections per 1000-patient days to 12.11 infections per 1000 patient-days. Insensible water loss rate would remain 55 mL/kg/d.

The total price of this treatment would include 32 days of hospitalization (RWF 480 per day) and a consultation (RWF 450), which is RWF 15,810.

Infant Warmer

Studies comparing radiant heat warmers to incubators have generally found them to be comparable. The primary difference is a higher rate of insensible water loss in infants placed underneath a radiant warmer. A meta-analysis of three studies determined an increase in insensible water loss rate of 0.94 mL/kg/h (95% CI 0.47, 1.41) [43]. In addition, a study by Kim, et al. found that extremely low birth weight infants treated in a humidified incubator had a higher growth velocity of 15.2 g/kg/d compared to 13.5 g/kg/d in infants treated in a non-humidified incubator [40]. The temperature of the infant warmer is not set based on the skin temperature of the neonate, and thus would lead to an increase in mortality, as determined by both Day, et al. and by Buetow and Klein [45] [46]. Based on the higher insensible water loss rate, the lower growth velocity and the lack of temperature control, mortality is expected to be higher when infant warmers are used than when multiple infants are placed in a single incubator. Infection rates are likely to be similar to that of placing a single infant in an incubator.

Assuming an infant with birth weight of 1000 g, skin temperature of 32 °C, and a gestation age of 28 weeks, insensible water loss would increase by 22.6 mL/kg/d

compared to treatment in an incubator. Growth velocity would decrease to 13.8 g/kg/d. To reach the desired weight of 1600 grams, the infant would need to be treated for 34 days. Infection rate would be comparable to single infants in incubators at 6.9 infections per 1000 patient-days per month. Finally, mortality risk is estimated to be 42% in one month.

The total price of treatment for 34 days of hospitalization (RWF 480 per day) and one consultation (RWF 450) is RWF 16,770.

Heat Lamp

While there is no literature comparing heat lamps to other treatment options, they are similar to radiant warmers. Unlike warmers, minimal temperature control is feasible with heat lamps; insensible water loss rate is likely to be greater for infants treated with heat lamps than with radiant warmers. Growth velocity is estimated to be slightly lower than with radiant warmers. The lack of heat control, along with the increased insensible water loss and the decreased growth velocity would lead to a higher risk of mortality in one month. Infection rates would not be affected by use of a heat lamp.

Again, assuming a neonate with birth weight of 1000 g, skin temperature of 32 °C, and gestation age of 28 weeks, growth velocity is estimated to be 13.1 g/kg/d, requiring 36 days of treatment to achieve the target weight of 1600 g. Insensible water

loss is estimated to be 85.4 mL/kg/d, and one-month mortality risk to be 45%. Finally, infection rate would remain 6.9 infections per 1000 patient-days per month.

The total price of treatment for 36 days of hospitalization (RWF 480 per day) and one consultation (RWF 450) is RWF 17,730.

Kangaroo Care

While there is literature on kangaroo care for premature and low birth weight neonates, it has not been studied for medically unstable infants. Existing literature has found that mortality rates are comparable to conventional care for stable infants [48]. As with the infant warmer, temperature control and humidity control are not possible with kangaroo care, but there are added advantages as the infant has near constant monitoring and immediate access to the mother for feeding and attention. Insensible water loss rate and infection rate are likely similar to an infant warmer, while growth rate is assumed to be slightly higher and mortality risk slightly lower.

Assuming an infant with birth weight of 1000 g, skin temperature of 32 °C, and a gestation age of 28 weeks, growth velocity is estimated to be 14.2 g/kg/d and one month risk of mortality to be 40%. Insensible water loss rate is estimated to be 77.6 mL/kg/d and infection rate to be 6.9 infections per 1000 patient-days per month, as with the infant warmer.

Given this, treatment duration is expected to be 33 days. The total price for 33 days of hospitalization (RWF 480 per day) and one consultation (RWF 450) is RWF 16,290.

Refer Out

When infants are referred to another hospital, the burden of seeking care at an alternative location is placed on the family, and may be too high for some families resulting in no treatment in some cases. As no data is available, we assume a higher one-month mortality risk, higher insensible water loss rate, and lower growth velocity, but a lower infection rate. The price of treatment is estimated to be lower than hospitalization as well.

Referring out is estimated to increase mortality risk to 75% and insensible water loss rate to 66.3 mL/kg/d. Growth velocity is estimated to decrease to 11.6 g/kg/d. Finally, infection rate is estimated to decrease to 4 infections per 1000 patient-days per month. The total price of treatment is estimated to be RWF 3500.

The prices and outcomes associated with each treatment option for thermoregulation are summarized in the charts in Figures 7 – 10 on pages 64 – 65.

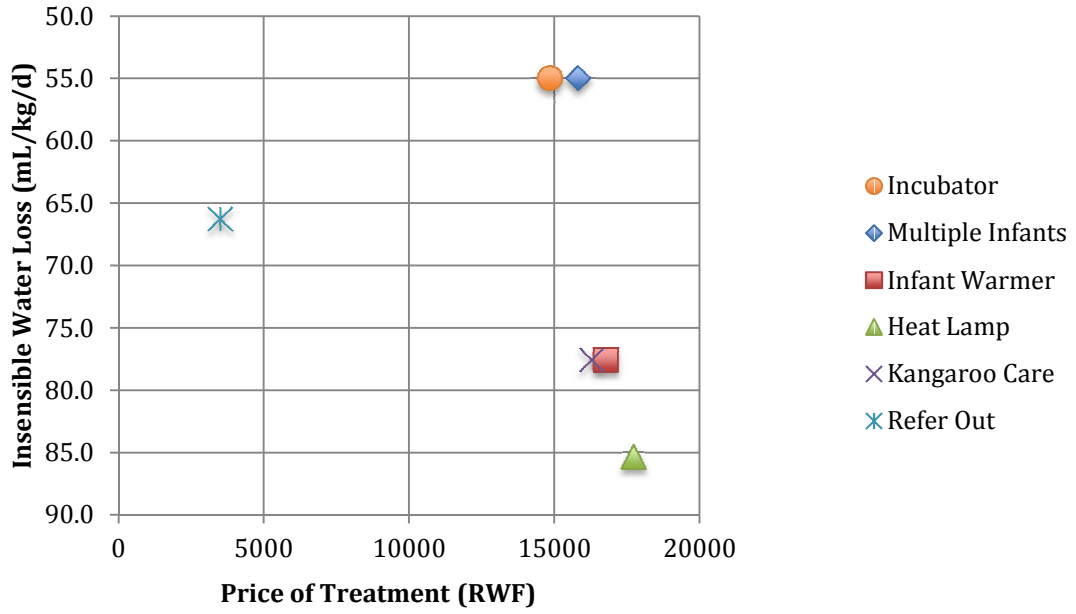


Figure 7: Prices and projected insensible water loss rate for neonatal thermoregulation options

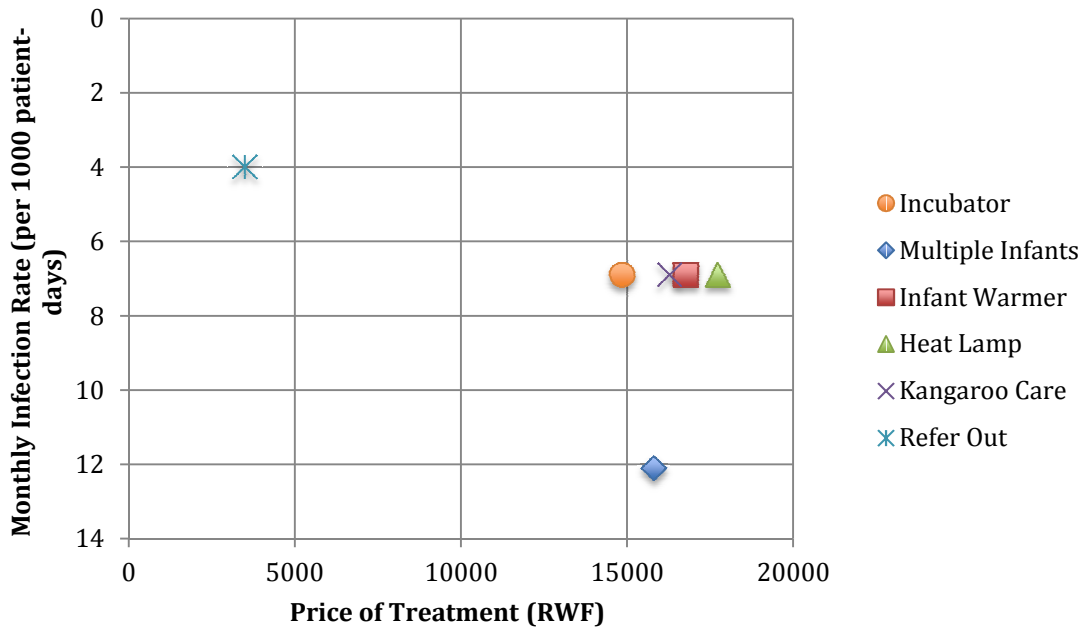


Figure 8: Prices and projected monthly infection rate for neonatal thermoregulation options

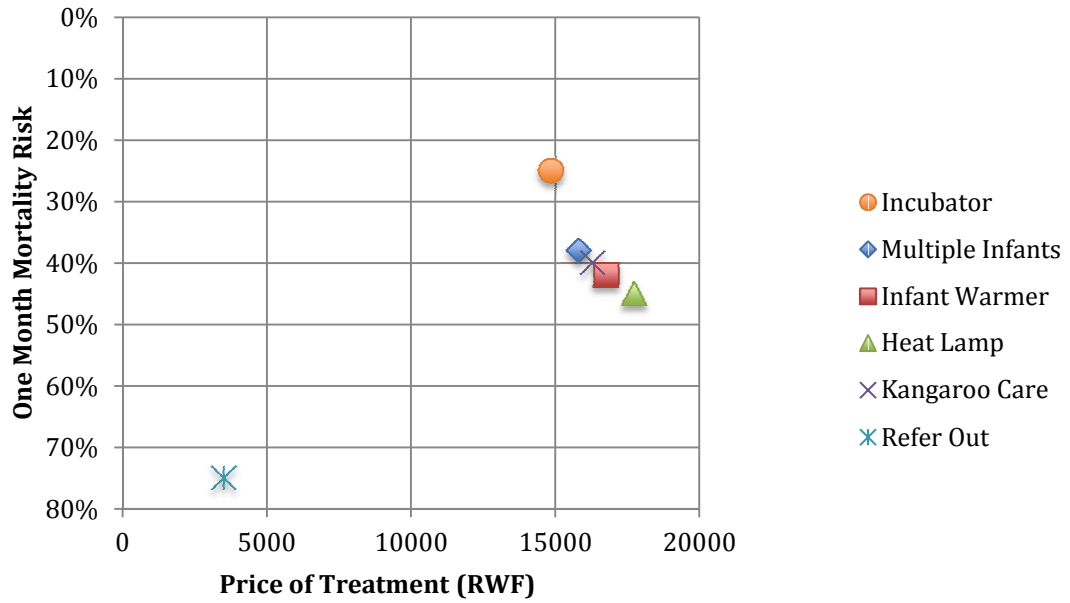


Figure 9: Prices and projected one-month mortality risk for neonatal thermoregulation options

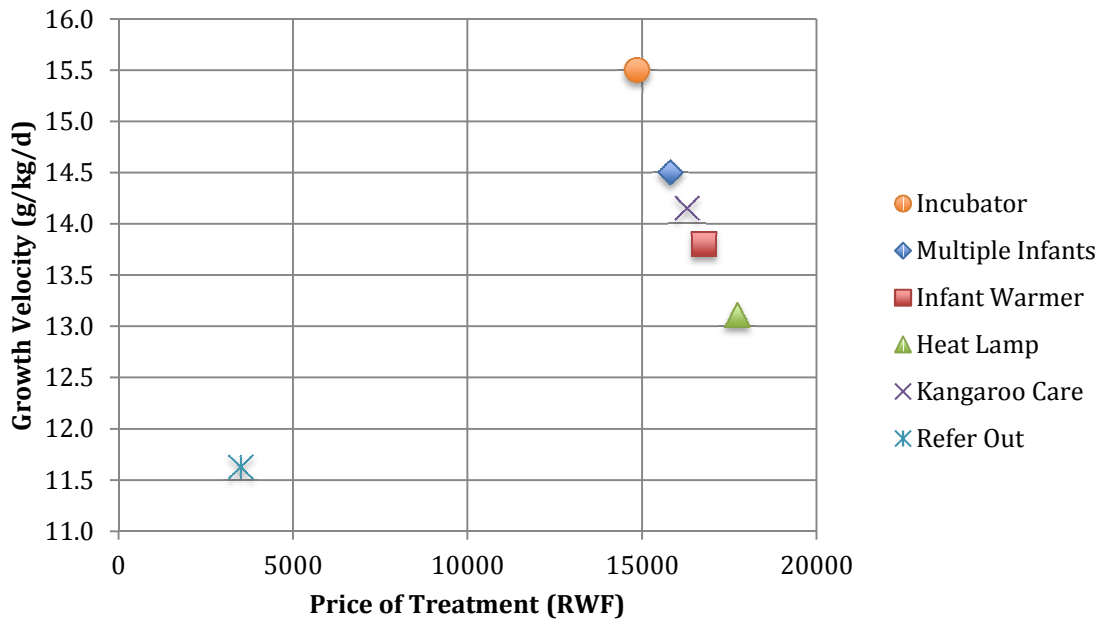


Figure 10: Prices and projected growth velocity for neonatal thermoregulation options

In summary, BMET training is hypothesized to lower infant mortality, infection rate, and insensible water loss rate, and to increase growth velocity in very low-birth weight neonates (less than 1000 g) who are born premature (gestation age of 28 weeks) and are hypothermic (temperature of 32 °C).

4.3.3 Acute Respiratory Management

4.3.3.1 Background

Hypoxemia is a deficiency of oxygen in blood and can be treated with supplemental oxygen therapy and mechanical ventilation. While the exact relationship between hypoxemia and outcomes is not well defined and varies by condition, a drop in partial pressure of oxygen in arterial blood (PaO_2) below about 60 mmHg has been associated with higher in-hospital mortality in several studies of critically ill patients [49].

PaO_2 is related to arterial oxygen saturation by the oxyhemoglobin dissociation curve. A PaO_2 of 60 mmHg is approximately equivalent to an oxygen saturation of 91%. Oxygen therapy is continued until the patient is able to maintain an oxygen saturation of at least 95% in room air [50]. Peripheral oxygen saturation, which can be measured non-invasively with a pulse oximeter, can be used to approximate arterial oxygen saturation when a laboratory blood gas test is untenable due to time or resource constraints.

4.3.3.2 Findings

Of the twelve surveyed hospitals, nine had trauma units. At two hospitals, Nyanza and Kibagabaga, major trauma cases are not seen. Three physicians and six nurses were interviewed on acute respiratory management. The providers at Rwamagana, Kibagabaga, CHUK, Kibilizi, Ruhengeri, and Nemba were interviewed using the survey provided in Appendix A on page 105. The providers at Nyanza, Nyagatare, and Kiziguro were interviewed using the survey on page 132, also in Appendix A.

Five of the nine hospitals used a combination of oxygen saturation and respiratory rate to determine if supplemental oxygen should be provided, while two (Kibagabaga and Nemba) based the decision only on oxygen saturation, and Kiziguro used only respiratory rate. Nyanza determined use of oxygen therapy based on a combination of respiratory rate, cardiac rate, and blood pressure.

All nine hospitals use either a cylinder or concentrator as their primary method of providing oxygen. If unavailable, CHUK, Kibilizi, and Nyagatare all use a bag-valve-mask instead. At Rwamagana and Kiziguro, patients are prioritized. The patient with the greatest likelihood of survival is provided oxygen first. When it is no longer needed by that patient, oxygen is then provided to other patients. Finally, in Nemba, when an insufficient number of oxygen cylinders are available, patients are referred to another service within the hospital.

Four hospitals, Rwamanaga, Nemba, Nyagatare, and Kiziguro have all faced equipment shortages. In Kiziguro, this was because equipment was out of service. In the three other hospitals, it was due to an insufficient amount of equipment, which is outside of the control of the BMET.

Table 8 on page 69 summarizes the findings on oxygen provision for acute respiratory management. Figure 11 on page 71 summarizes oxygen provision options for acute respiratory management used or considered in surveyed hospitals by decreasing order of preference.

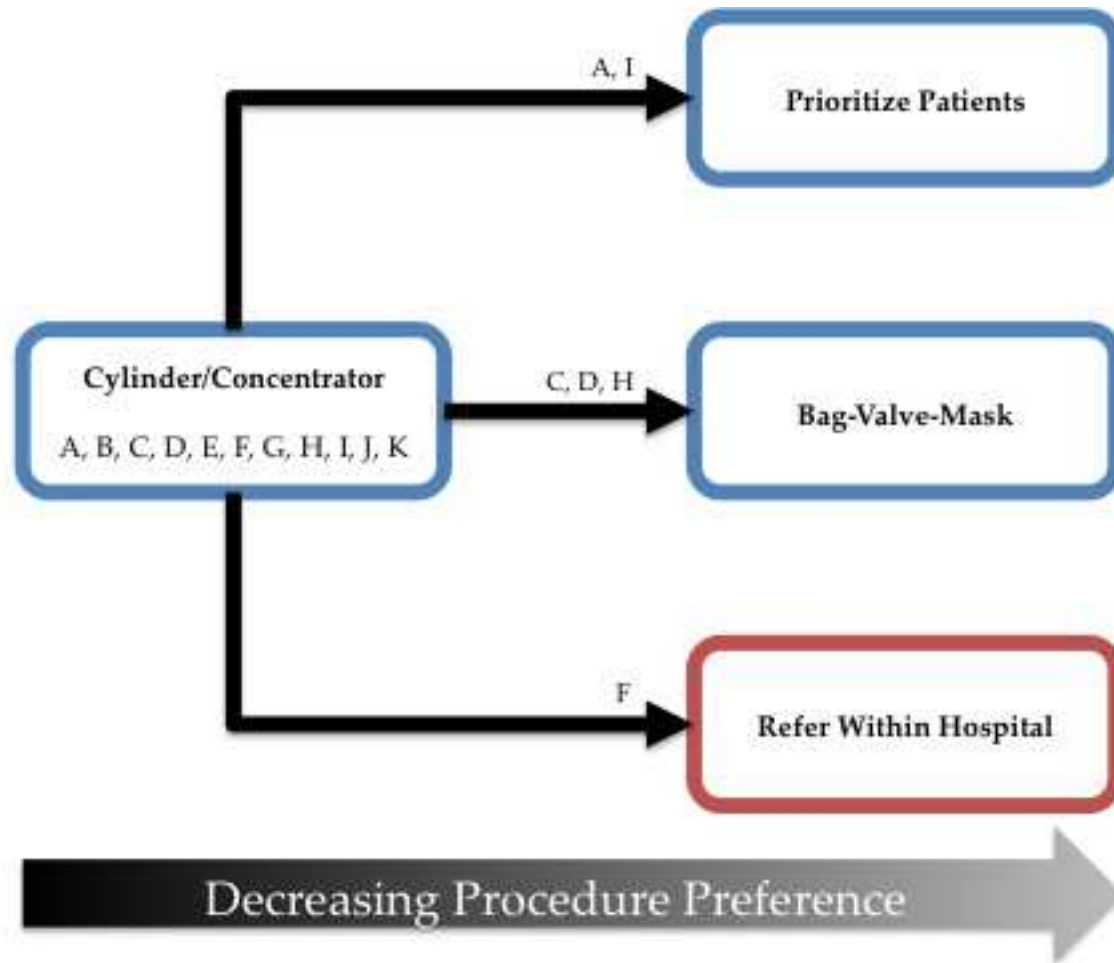
Table 8: Summary of Findings on Oxygen Provision for Acute Respiratory Management

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Rwamagana District Hospital	Physician	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Cylinder, Concentrator	Prioritize patients	2 – 3 times per month	Insufficient amount of equipment	<ul style="list-style-type: none"> • 15 cylinders • 9 concentrators 	
Kibagabaga District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Concentrator, Cylinder		Never experienced equipment shortage		18 concentrators	4 out of service, No major trauma
University Central Hospital of Kigali	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Wall concentrator	Bag-valve-mask	Never experienced equipment shortage			
Kibilizi District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Concentrator	Bag-valve-mask	Never experienced equipment shortage		1 concentrator	
Ruhengeri District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Concentrator, Cylinder		Never experienced equipment shortage		6 concentrators	
Nemba District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Cylinder	Refer within hospital	1 per month	Insufficient number of cylinders	1 cylinder	

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Nyanza District Hospital	Nurse	Survey B (page 132)	<ul style="list-style-type: none"> • Respiratory rate • Cardiac rate • Blood pressure 	Concentrator		Never experienced equipment shortage		4 concentrators	No major trauma
Nyagatare District Hospital	Nurse	Survey B (page 132)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Concentrator	Bag-valve-mask	1 per day	Insufficient number of concentrators		
Kiziguro District Hospital	Nurse	Survey B (page 132)	Respiratory rate	Concentrator	Prioritize patients	1 per year	Equipment was not working		

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative

Surveyed Hospitals	
Experienced Equipment Unavailability	Considered Equipment Unavailability
A. Rwamagana	B. Kibagabaga
F. Nemba	C. CHUK
H. Nyagatare	D. Kibilizi
I. Kiziguro	E. Ruhengeri
	G. Nyanza



The first preference of each hospital is indicated by the letter in the procedure box.

Subsequent preferences are indicated by the letters on the arrows.

Figure 11: Preferences for oxygen provision options for acute respiratory management with changing equipment availability

4.3.3.3 Projected Health Outcomes

As mentioned, the relationship between hypoxemia and outcomes is disease-specific and not precisely defined. Studies by Kilgannon, et al.; de Jonge, et al.; Bellomo, et al.; and Eastwood, et al. have all identified a U-shaped relationship between PaO₂ and in-hospital mortality in mechanically ventilated ICU patients and resuscitated non-traumatic cardiac patients [51] [52] [53] [54]. That is, hypoxemic and hyperoxemic patients have higher mortality than normoxemic patients. Based on this, risk of mortality within 24 hours of admission is selected as a health outcome indicator for oxygen provision for acute respiratory management. In addition, as oxygen saturation can be used to determine if a patient is hypoxemic, oxygen saturation within one hour of admission can be considered as well.

Oxygen therapy is priced at RWF 900 per hour and hospitalization is RWF 480 per day [23].

Cylinder or Concentrator

Kilgannon, et al., found that hypoxemic cardiac arrest patients had a higher risk of in-hospital mortality compared to normoxemic cardiac arrest patients (57% compared to 45%) [51]. De Jonge, et al., found an odds ratio of 1.12 for in-hospital mortality within 24 hours of oxygen therapy of hypoxemic mechanically ventilated ICU patients as compared to normoxemic patients [52].

We assume a 24-hour mortality risk of 25% for a hypoxemic patient (oxygen saturation below 91%) seeking emergency care who is given supplemental oxygen. While available literature does not provide an exact relationship between oxygen therapy and oxygen saturation, we assume that oxygen saturation would increase to 98% after one hour of therapy. In addition to oxygen therapy, the patient is assumed to be mechanically ventilated with a bag-valve-mask, as is consistent with standard hypoxemia treatment.

24 hours of oxygen therapy (RWF 900 per hour) and one day of hospitalization (RWF 480 per day) are assumed. The total price of treatment is therefore RWF 22,080.

Prioritize Patients

When faced with equipment shortages, in some hospitals patients are prioritized. Some are selected to receive oxygen while others do not. We assume an increase in 24-hour risk of mortality due to lack of oxygen therapy of about 50% (from 25% to 75%). In assuming two hypoxemic patients seek treatment simultaneously, one patient would receive oxygen therapy while the second patient would not. For the first patient, the 24-hour risk of mortality would be 25% as before, while for the second patient the 24-hour risk of mortality would be 75%. Thus, the average 24-hour risk of mortality for the total patient population would be 50%. In addition, while one-hour oxygen saturation would increase for the first patient, while it would remain below 91% for the second patient,

thus the average one-hour oxygen saturation for the total patient population would be 94%.

As both patients would be hospitalized for one day (RWF 480), but only one would receive 24 hours of oxygen therapy, the average total treatment price is RWF 11,280.

Bag-Valve-Mask

If oxygen therapy is unavailable, in some hospitals, patients are only mechanically ventilated. As before, this would increase mortality within 24 hours from 25% to 75%. One-hour oxygen saturation will remain below 91% for the patient. The total price of treatment is limited to one day of hospitalization, which is RWF 480.

Refer Within Hospital

Finally, one hospital refers patients to another service within the hospital for oxygen therapy when faced with equipment shortages. We assume a slightly higher mortality rate due to the delay in receiving treatment and the uncertainty of availability of oxygen provision at the other service. Mortality risk within 24 hours is assumed to increase to 30%. The price of treatment remains RWF 22,080 with 24 hours of oxygen therapy (RWF 900 per day) and one day of hospitalization (RWF 480).

The prices and outcomes for each treatment option is summarized in Figures 12 and 13 on page 75.

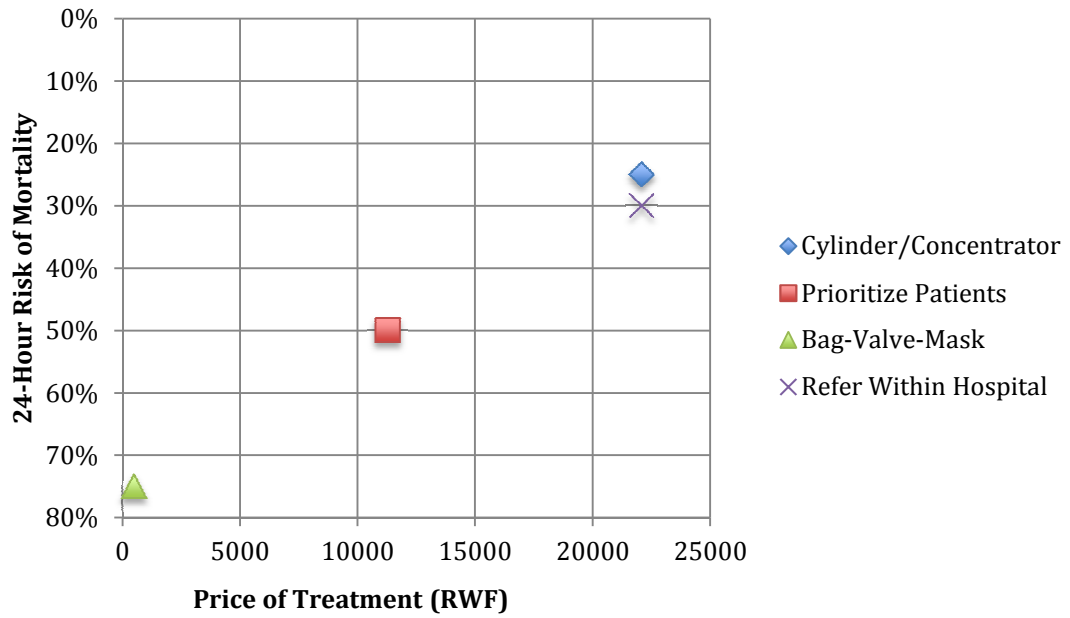


Figure 12: Prices and projected 24-hour mortality risk for acute respiratory management options

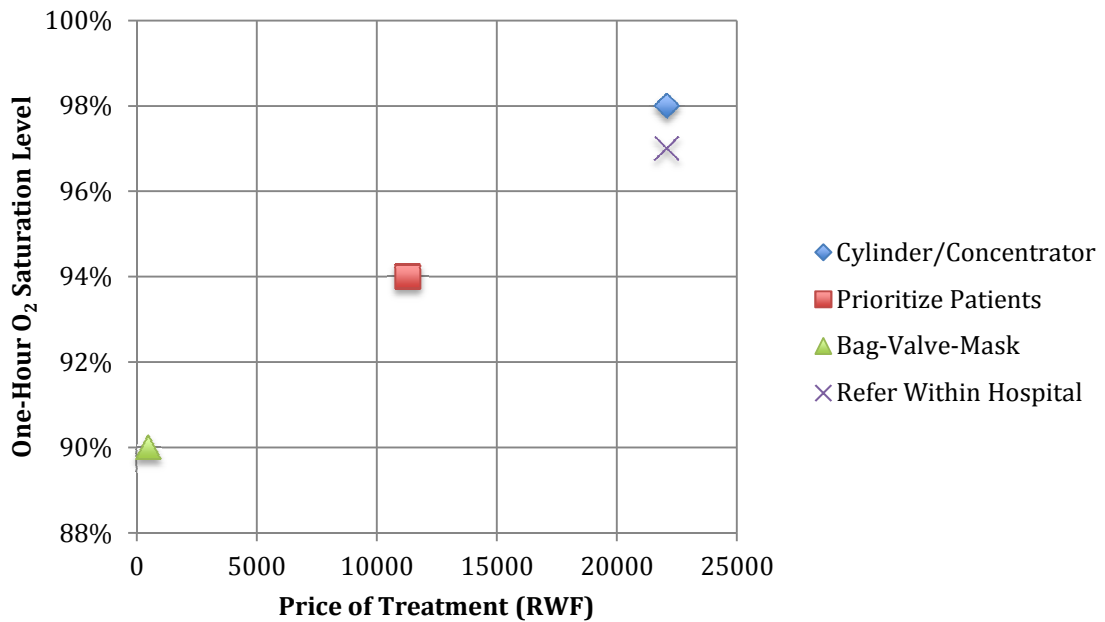


Figure 13: Prices and projected one-hour mortality risk for acute respiratory management options

In summary, BMET training is hypothesized to increase oxygen saturation and reduce mortality in trauma units with sufficient equipment for treating hypoxemic patients.

Table 9 on page 77 summarizes the focus areas, equipment, and health outcomes that were not rejected based on field study.

Table 9: Focus Areas, Equipment, and Health Outcomes Not Rejected Based on Field Study

Focus Area	Criteria				
	Burden of Disease (2004)		Medical Equipment	Equipment Unavailability	Health Outcome
	Death	DALYs			
Neonatal Thermoregulation	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Incubator	Insufficient functioning equipment	Mortality risk, infection rate, growth velocity, and insensible water loss rate
Neonatal Jaundice	Neonatal infections and other conditions – 7200	Neonatal infections and other conditions – 252,000	Phototherapy lamp	Insufficient functioning equipment	Febrility rate and time to recovery of bilirubin level
Emergency Breathing Management	Injuries – 10,300	Injuries – 399,000	Oxygen provision (cylinder or concentrator)	Insufficient functioning equipment	24-hour mortality risk and one-hour oxygen saturation level

5. Discussion and Recommendations

5.1 Proposed Method

Based on the results of this study, it is clear that the connection between biomedical equipment technician training and patient health outcomes both exists and is measurable. Certain pieces of equipment are critical to optimal care of patients. When this equipment is unavailable, alternative care options are relied upon. Based on both the provider interviews and the available literature, these alternative options result in poorer health outcomes for patients.

It is hypothesized that BMET training measurably reduces the number of days of treatment and the rate of infection in the NICU for neonatal jaundice patients. BMET training is also hypothesized to reduce infant mortality, infection rate, and insensible water loss rate in very low birth weight, premature neonates. Finally, it is hypothesized that BMET training increases oxygen saturation and reduces mortality in hypoxemia patients in trauma units.

The measurability of this relationship between BMET training and health is challenging. As an initial approach, the health conditions that are most burdensome for Rwanda were selected, but many of these were immediately removed from further consideration because medical equipment was not used for their prevention, diagnosis or treatment. Others were rejected because the medical equipment used was not critical to care. A third group of conditions was rejected because the associated health outcomes

are not easily measurable. Finally, several conditions were eliminated from consideration because their treatment is rare in Rwanda. In addition to the burden of disease, broad areas that are equipment intensive were considered, such as imaging. In particular, x-ray is widely used in Rwanda. Unfortunately, no clear health outcome that would be affected by the unavailability of x-ray could be identified.

From this initial review, several areas were selected for further in Rwanda. This fieldwork resulted in many of these areas being removed from consideration for a number of reasons. Some equipment (CD4 flow cytometers and PCR machines for HIV) was not under the purview of the BMETs. Some equipment was not used in local practice and procedures. Several pieces of equipment while used were identified as not critical to care. Conversely, some pieces of equipment were considered critical but were always available.

5.2 Alternative Approaches and Limitations

While burden of disease was used to develop an initial list of possible focus areas, other approaches may be feasible. Starting from a healthcare perspective, the most commonly performed procedures could have been identified for initial consideration. Alternatively, national clinical guidelines seem promising, but based on the range of responses received regarding treatment procedures, it seems unlikely that guidelines are being adhered to strictly enough to use as a basis of study.

In addition, there may be other areas where equipment is critical to positive health outcomes that were not fully explored. Diagnostics, for example, can be imperative to developing an appropriate treatment plan. When diagnosis is inexact or delayed, treatment and therefore health outcomes are likely affected. The measurement of this impact is more complicated, but may be no less valuable in evaluating the health impact of BMET training.

The proposed indicators are suitable for clear, short-term impact on health outcomes, but due to the complex relationship between medical equipment, healthcare, and health, a number of approaches are likely necessary to develop an understanding of the full health impact of biomedical equipment repair and maintenance training.

5.3 Recommendations for Future Studies

While there is strong reason to believe that a connection between health outcomes and equipment maintenance and repair exists in the three areas that were not rejected based on fieldwork, there is no direct evidence. If captured, this would make evident the need for and clinical value of BMETs in hospitals and Rwanda. The following three studies may help develop this evidence base.

For neonatal jaundice treatment, time to recovery of bilirubin level and rate of fever were identified as health indicators of equipment status. A prospective cohort study should be conducted in hospitals with a trained BMET and otherwise comparable hospitals without a trained BMET. Patients eligible for the study would be neonates with

jaundice severe enough to require treatment with phototherapy treatment (bilirubin level above 18 mg/dL). Bilirubin level can be tracked daily using a transcutaneous bilirubin measurement. Fever can be determined daily with a skin thermometer. Antibiotic use would need to be tracked because this would affect rate of fever. Hospitals with trained BMETs should show more rapid drops in bilirubin and less incidence of fever.

For neonatal thermoregulation, health outcomes identified include growth velocity, insensible water loss rate, infection rate, and mortality. Patients eligible for the study would be very low birth infants who were born prematurely and are hypothermic. Infection rate and insensible water loss are difficult to measure. Growth velocity can easily be determined by weighing the infant daily. Mortality is also easy to assess. A study of both of these outcomes in neonates in comparable hospitals with and without a BMET would likely show a difference.

Finally, for oxygen provision in breathing management, 24-hour mortality and one-hour oxygen saturation level are promising health indicators of equipment status. Patients eligible for this study would be patients presenting at the emergency room for hypoxemia. Oxygen saturation can easily be measured hourly with a pulse oximeter. Mortality can also be monitored. A comparison of these outcomes for hypoxemic patients (admitted to the emergency room with oxygen saturation levels at or below

91%) in comparable hospitals with adequate equipment with and without a trained BMET should show a difference.

From the options laid out above, further work is needed to select one or two health outcomes to be studied as indicators of an impact on patient health outcomes of the BMET training program in Rwanda.

Table 10: Summary of Recommended Studies

Focus Area	Recommended Study		
	Patient Population	Medical Equipment	Health Outcome
Neonatal Jaundice	<ul style="list-style-type: none"> • Neonate • Bilirubin level above 33 mg/dL 	Phototherapy lamp	<ul style="list-style-type: none"> • Febrility rate (skin temperature) • Days to recovery of bilirubin level (transcutaneous bilirubin level)
Neonatal Thermoregulation	<ul style="list-style-type: none"> • Neonate • Birth weight below 1000 g • Gestation age below 28 weeks • Temperature below 32 °C 	Incubator	<ul style="list-style-type: none"> • One-month mortality risk • Growth velocity (scale)
Emergency Breathing Management	<ul style="list-style-type: none"> • Oxygen saturation below 91% • Presenting to ER 	Oxygen provision (cylinder or concentrator)	<ul style="list-style-type: none"> • 24-hour mortality risk • One-hour oxygen saturation level (pulse oximeter)

6. Conclusion

It is clear that a link between patient health outcomes and biomedical equipment repair and maintenance exists. In addition, this relationship is likely measurable, but requires careful selection of health outcomes and equipment. Studies of neonatal jaundice, neonatal thermoregulation, or oxygen provision for acute respiratory management are recommended to directly evaluate the hypothesis that BMET training improves patient health outcomes.

Appendix A: Surveys

Field study surveys are provided in this section, including:

1. Director Survey
2. Provider Surveys:
 - a. Neonatal Jaundice Treatment
 - b. Neonatal Thermoregulation
 - c. HIV Treatment
 - d. Acute Airway and Breathing Management
 - e. Sterilization of Surgical Equipment
 - f. General Anesthesia for Surgery
3. Technician and Equipment Survey

These surveys were used at 8 hospitals:

1. Rwamagana District Hospital
2. Muhima Mother and Child Hospital
3. Kibagabaga District Hospital
4. University Central Hospital of Kigali (CHUK)
5. Kibilizi District Hospital
6. Kigeme District Hospital
7. Ruhengeri District Hospital
8. Nemba District Hospital

Director Survey

Date:

Time:

Name:

Title:

Cell Phone:

Email:

Facility Name:

District:

Province:

Type of facility:

Managing Authority:

Referral hospital

Government public

District hospital

Government non-public

Health center

Private

Clinic

NGO/Community

Other _____

Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I know that my colleague Lillian Gu spoke with you earlier this year. I will be as brief as possible. I do not anticipate spending more than 20 minutes with you. At your hospital, we are hoping to:

1. Speak with you
2. Speak with hospital technicians about equipment availability and survey equipment status
3. Speak with clinicians and hospital staff about select conditions including:

HIV Treatment

1. Referred to:
2. Cell Phone:
3. Title:

Airway & Breathing Management

1. Referred to:
2. Cell Phone:
3. Title:

General Anesthesia (Surgery)

1. Referred to:
2. Cell Phone:
3. Title:

Neonatal Hypothermia

1. Referred to:
2. Cell Phone:
3. Title:

Neonatal Jaundice

1. Referred to:
2. Cell Phone:
3. Title:

Equipment Sterilization for Surgery

1. Referred to:
2. Cell Phone:
3. Title:

Does that sound okay? With you, I would specifically like to discuss if health outcomes are available at the facility level for certain key indicators. Do you have any questions before we begin?

Director Survey

Referred to:

Cell Phone:

Title:

From Lillian Gu's survey:

Date:

1. The hospital serves a population of _____ people
 2. The hospital has _____ beds
 3. The usual occupancy rate is _____ % of beds filled
 4. _____ inpatients are seen in a year
 5. _____ outpatients are seen in a year
 6. _____ operating beds are in use
 7. _____ ICU/NICU beds are in use
1. Would it be possible for me to look at and photograph your logbook in which you track health outcomes?
- Yes, photo number:
- No

2. HIV/AIDS

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many HIV patients are treated with antiretrovirals therapy monthly?
- b. What is the mortality rate of HIV patients who are on ART?
- c. What is the average length of life after diagnosis?
- d. Are there any other health outcomes related to HIV tracked at the facility level?
 No
 If yes, what?

Director Survey

3. Infant Jaundice

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many cases of infant jaundice are seen monthly?
- b. How many of these cases progress to Kernicterus?
- c. What is the mortality rate of infant jaundice patients?
- d. Are there other health outcomes related to infant jaundice tracked at the facility level?
 No
 If yes, what?

4. Infant Hypothermia

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many cases of infant hypothermia are seen monthly?
- b. What is the mortality rate of these cases?
- c. Are there other health outcomes related to infant hypothermia tracked at the facility level?
 No
 If yes, what?

5. Trauma

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many head injury cases are seen monthly?
- b. What is the mortality rate of these cases?
- c. What is the rate of anoxic brain injury among these cases?
- d. Are there other health outcomes related to head injury tracked at a facility level?
 No
 If yes, what?

Director Survey

6. Surgical Equipment Sterilization

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many surgeries are performed each month?
- b. What is the surgical site infection rate?
- c. Are there other health outcomes related to surgical infection tracked at a facility level?
 - No
 - If yes, what?

7. General Anesthesia

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many general anesthesia procedures are performed each month?
- b. How many adverse events due to general anesthesia?
- c. Are there other health outcomes related to patients who receive general anesthesia tracked at a facility level?
 - No
 - If yes, what?

Provider Survey – Neonatal Jaundice Treatment

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for infant jaundice in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat infant jaundice or are you familiar with infant jaundice treatment protocols in this hospital?
 - Yes
 - No
 - a. Can you connect me with a provider in the hospital who treats infant jaundice or is familiar with the treatment for infant jaundice?
 - Name:
 - Cell Phone:
 - Title:
2. How many cases of infant jaundice are treated in a typical month?
3. How many of these cases progress to Kernicterus?
4. What is the mortality rate of infant jaundice patients?
5. Are there other health outcomes related to infant jaundice are tracked at the facility level?
 - No, skip to next question
 - If yes, what?

Provider Survey – Neonatal Jaundice Treatment

6. Which of the following treatments are used for infant jaundice?
- Phototherapy
 - Exchange transfusion
 - Other _____
 - Don't know
7. For phototherapy, if used:
- a. On what basis is the decision to start phototherapy made?
 - Bilirubin level
 - 1. What threshold? _____
 - 2. How is this measured?'
 - Clinical symptoms
 - 1. What symptoms?
 - 2. How are these measured?
 - Other _____
 - 1. How is this measured?
 - b. What percent of infant jaundice cases require phototherapy? _____
 - c. What percent of phototherapy patients require an exchange transfusion as well? _____
 - d. What type of phototherapy is used?
 - Conventional
 - Fiberoptic
 - Sunlight
 - Don't know
 - e. What type of light source is used?
 - Fluorescent
 - Blue Bulbs
 - White Bulbs
 - LED
 - Other _____
 - f. Other than the phototherapy light, do you consider any equipment essential to this treatment option? That is, treatment would not be possible without this equipment?
 - No, skip to next question
 - If yes, what?
 - g. What is the price to the patient for phototherapy treatment? _____
 - h. What is the cost to the hospital for phototherapy treatment? _____
 - i. If don't know to both of the above price/cost, who would know:
 - 1. Referred to:
 - 2. Title:

Provider Survey – Neonatal Jaundice Treatment

3. Cell Phone:

- j. Do you ever place more than one infant under the same set of phototherapy lights?
 - No, skip to next question
 - Yes
 - 1. How frequently does this occur? _____
- k. Have you ever been unable to use phototherapy when it was indicated?
 - No, skip to next question
 - Yes
 - 1. What is done in this situation?
 - Refer to another hospital
 - Exchange transfusion
 - Sunlight
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when phototherapy is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why phototherapy was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____

8. For exchange transfusion, if used:

- a. What is the basis of the decision to perform an exchange transfusion?
 - Bilirubin level
 - 1. What threshold? _____
 - 2. How is this measured?'
 - Clinical symptoms
 - 1. What symptoms?
 - 2. How are these measured?
 - Other _____
 - 1. How is this measured?
- b. What percent of infant jaundice cases require exchange transfusion? _____
- c. What percent of exchange transfusion patients require phototherapy as well? _____
- d. What is the price to the patient for an exchange transfusion? _____
- e. What is the cost to the hospital for an exchange transfusion? _____
- f. If don't know to both of the above price/cost, who would know:
 - 1. Referred to:
 - 2. Title:

Provider Survey – Neonatal Jaundice Treatment

3. Cell Phone:

- g. Which of the following equipment do you have available to perform exchange transfusions?
- Fluid pump
 - Blood type matching
 - Filtration
 - Warmer
 - Cardiac monitor
 - Respiratory monitor
 - Oxygen
 - Suction machine
 - Other _____
- h. Is there equipment that you do not have available which you would like for exchange transfusions?
- No
 - Yes
 - 1. Do you believe patient outcomes would be better if this was available?
 - No
 - If yes, what health outcomes/conditions and how?
- i. Have you ever been unable to perform an exchange transfusion when it was indicated?
- No
 - Yes
 - 1. What is done in this situation?
 - Refer to another hospital
 - Phototherapy
 - Sunlight
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when exchange transfusion is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why exchange transfusion was not an option the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____
9. For additional treatment options (if applicable, and includes the use of equipment):
- a. On what basis is the decision to use this therapy made?

Provider Survey – Neonatal Jaundice Treatment

- Bilirubin level
 - 1. What threshold? _____
 - 2. How is this measured?'
 - Clinical symptoms
 - 1. What symptoms?
 - 2. How are these measured?
 - Other _____
 - 1. How is this measured?
- b. What percent of infant jaundice cases require this treatment? _____
- c. What is the price to the patient for this treatment? _____
- d. What is the cost to the hospital for this treatment? _____
- e. If don't know to both of the above price/cost, who would know:
- 1. Referred to:
 - 2. Title:
 - 3. Cell Phone:
- f. Have you ever been unable to use this treatment when it was indicated?
- No, skip to next question
 - Yes
 - 1. What is done in this situation?
 - Refer to another hospital
 - Exchange transfusion
 - Sunlight
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when this treatment is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why this treatment was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____
10. Are there a treatment options you would like to use but are unable to do so?
- No, end
 - Yes
 - a. What type of treatment?
 - b. Why are you unable to do this?

Provider Survey – Neonatal Hypothermia Treatment

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for infant hypothermia in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat infant hypothermia or are you familiar with infant hypothermia treatment protocols in this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with a provider in the hospital who treats infant hypothermia or is familiar with the treatment for infant hypothermia?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many cases of infant hypothermia are treated in a typical month?
3. What is the mortality rate of infant hypothermia patients?
4. Are there other health outcomes related to infant hypothermia that you track at the facility level?
 - No, skip to next question
 - If yes, what?

Provider Survey – Neonatal Hypothermia Treatment

5. Which of the following treatments are used for infant hypothermia?
- Infant incubator
 - Infant warmer
 - a. What type? _____
 - Kangaroo care
 - Swaddling
 - b. What type? _____
 - Other
 - Don't know
6. For Incubator, if used:
- a. What determines the use of an infant incubator?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____
 - Low birth weight
 - i. What weight range or threshold? _____
 - Clinical symptoms
 - i. What clinical symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?
 - b. Other than the incubator, is there any equipment you consider necessary to treating infant hypothermia with an incubator? Such as monitoring?
 - No, skip to next question
 - If yes, what?
 - c. What is the price to the patient for treatment with an incubator? _____
 - d. What is the cost to the hospital for treatment with an incubator? _____
 - e. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - f. Have you ever been unable to use an incubator when it was indicated?
 - No, skip to next question
 - Yes
 - i. What is done in this situation?
 - Refer to another hospital
 - Multiple babies in a single incubator

Provider Survey – Neonatal Hypothermia Treatment

- Infant warmer
- Kangaroo care
- Swaddling
- No alternative available
- Other _____
- ii. Do you believe patient outcomes are different when an incubator is not available?
 - No
 - If yes, what health outcomes/conditions and how?
- iii. Do you know why an incubator was unavailable the most recent time you were unable to use it?
- iv. How frequently does this occur? _____

7. For Infant Warmer, if used:

- a. What determines the use of an infant warmer?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____
 - Low birth weight
 - i. What weight range or threshold? _____
 - Clinical symptoms
 - i. What clinical symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?
- b. If more than one type of warmer is available, what determines which type is used?
- c. What is the price to the patient for treatment with an infant warmer? _____
- d. What is the cost to the hospital for treatment with an infant warmer? _____
- e. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
- f. Other than the warmer, is there any equipment you consider necessary to treating infant hypothermia with an incubator? Such as monitoring?
 - No, skip to next question
 - If yes, what?
- g. Have you ever been unable to use an infant warmer when it was indicated?

Provider Survey – Neonatal Hypothermia Treatment

- No, skip to next question
- Yes
 - i. What is done in this situation?
 - Refer to another hospital
 - Multiple babies in a single warmer
 - Infant incubator
 - Kangaroo care
 - Swaddling
 - No alternative available
 - Other _____
 - ii. Do you believe patient outcomes are different when a warmer is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why a warmer was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____

8. For Kangaroo Care, if used:

- a. What determines the use of an infant warmer?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____
 - Low birth weight
 - i. What weight range or threshold? _____
 - Clinical symptoms
 - i. What clinical symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?

9. For swaddling, if used:

- a. What determines the use of an infant warmer?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____

Provider Survey – Neonatal Hypothermia Treatment

- Low birth weight
 - i. What weight range or threshold? _____
- Clinical symptoms
 - i. What clinical symptoms?
 - ii. How are they measured?
- Other _____
 - i. How is this measured?

10. For other treatment options (if applicable, and includes the use of equipment)

- a. What determines the use of this treatment?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____
 - Low birth weight
 - i. What weight range or threshold? _____
 - Clinical symptoms
 - i. What clinical symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?
- b. What is the price to the patient of this treatment? _____
- c. What is the cost to the hospital of this treatment? _____
- d. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
- e. Have you ever been unable to use this treatment when it was indicated?
 - No, skip to next question
 - Yes
 - i. What is done in this situation?
 - Refer to another hospital
 - Multiple babies in a single warmer
 - Infant incubator
 - Kangaroo care
 - Swaddling
 - No alternative available
 - Other _____

Provider Survey – Neonatal Hypothermia Treatment

- ii. Do you believe patient outcomes are different when this treatment is not available?
 - No, skip to next question
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why this treatment was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____
11. Are there a treatment options you would like to use but are unable to do so?
- No, end
 - Yes
 - c. What type of treatment?
 - d. Why are you unable to do this?

Provider Survey – HIV Treatment

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for HIV treatment in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat HIV patients or are you familiar with HIV treatment protocols in this hospital?
 - Yes
 - No
 - a. Can you connect me with a provider in the hospital who treats HIV patients? Or is familiar with HIV treatment protocols?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many HIV patients are treated with antiretroviral therapy in a typical month?
3. What is the mortality rate of HIV patients who are on ART?
4. What is the average length of life after diagnosis?
5. Are there any other health outcomes related to HIV that are tracked at the facility level?
 - No

Provider Survey – HIV Treatment

- If yes, what?
- 6. Are patients on ART monitored regularly?
 - No, skip to last question
 - Yes
- 7. As standard practice for monitoring patients on ART, is CD4 count measured?
 - No, skip to next question
 - Yes
 - a. How many times per year is CD4 count measured for a patient? [If this varies, note range and ask for what is most commonly done] _____
 - b. How is CD4 count measured?
 - Flow cytometry
 - Other: _____
 - Don't know
 - c. Is this test done in the hospital lab or an outside lab? Hospital Outside
 - d. What is the price to the patient to run one test? _____
 - e. What is the cost to the hospital to run one test? _____
 - f. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - g. Have you ever been unable to do the test for any reason?
 - No, skip to next question
 - Yes
 - 1. What is done in that situation?
 - a. Use another lab
 - i. What lab is used? _____
 - b. Do another test
 - i. What test is done? _____
 - c. No alternative available
 - d. Other _____
 - 2. Do you believe patient outcomes are different when this test is not available?
 - a. No
 - b. If yes, what health outcomes/conditions and how?
 - 3. Do you know why the test was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____

Provider Survey – HIV Treatment

8. As standard practice for monitoring patients on ART, is viral load measured?
- No, skip to next question
 - Yes
 - a. How many times per year is viral load measured for a patient? [If this varies, note range and ask for what is most commonly done] _____
 - b. What test is used to measure viral load?
 - PCR test
 - Other: _____
 - Don't know
 - c. Is this test done in the hospital lab or an outside lab? Hospital Outside
 - d. What is the price to the patient to run one test? _____
 - e. What is the cost to the hospital to run one test? _____
 - f. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - g. Have you ever been unable to do the test for any reason?
 - No
 - Yes
 - 1. What is done in that situation?
 - a. Use another lab
 - i. What lab is used? _____
 - b. Do another test
 - i. What test is done? _____
 - c. No alternative available
 - d. Other _____
 - 2. Do you believe patient outcomes are different when this test is not available?
 - a. No
 - b. If yes, what health outcomes/conditions and how?
 - 3. Do you know why the test was unavailable the most recent time you were unable to use it?
 - 4. How frequently is this test unavailable? _____

9. As standard practice for monitoring patients on ART, is any other clinical monitoring done?
- No, skip to next question
 - Yes
 - a. What clinical symptoms are monitored?

Provider Survey – HIV Treatment

- b. What test is used? (If does not use equipment, skip to next question)
 - _____
 - Don't know
 - c. How many times per year for a patient? [If this varies, note range and ask for what is most commonly done] _____
 - d. Is this test done in the hospital lab or an outside lab? Hospital Outside
 - e. What is the price to the patient to run one test? _____
 - f. What is the cost to the hospital to run one test? _____
 - g. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - h. Have you ever been unable to do the test for any reason?
 - No, skip to next question
 - Yes
 - 1. What is done in that situation?
 - a. Use another lab
 - i. What lab is used? _____
 - b. Do another test
 - i. What test is done? _____
 - c. No alternative available
 - d. Other _____
 - 2. Do you believe patient outcomes are different when this test is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why the test was unavailable the most recent time you were unable to use it?
 - 4. How frequently is this test unavailable? _____
10. Is there a type of monitoring you would like to do but are unable to do so?
- No, end
 - Yes
 - a. What type of monitoring?
 - b. Why are you unable to do this?

Provider Survey – Airway & Breathing Management for Trauma

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for airway management and breathing management for trauma in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat trauma patients or are you familiar with protocols for trauma treatment in this hospital?
 Yes, skip to next question
 No
 - b. Can you connect me with a provider in the hospital who treats trauma patients or is familiar with the treatment for trauma?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many cases of trauma do you see in a typical month that require airway management or breathing management? _____
3. What is the mortality rate of these cases? _____
4. What is the rate of anoxic brain injury among these cases? _____
5. How is anoxic brain injury diagnosed?

Provider Survey – Airway & Breathing Management for Trauma

6. Are there other health outcomes related to trauma that you track at a facility level?
- No, skip to next question
 - If yes, what?
7. Which of the following are done at this hospital for head injury?
- Airway Management
 - a. How frequently is this done? _____
 - Breathing Management
 - a. How frequently is this done? _____
8. For Airway Management:
- a. What determines the need to place an airway?
 - Visual examination
 - Clinical symptoms
 - i. What symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?
 - b. What is the price to the patient for placing an airway? _____
 - c. What is the cost to the hospital for placing an airway? _____
 - d. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - e. Do you use a suction machine when placing an airway?
 - No, skip to next question
 - Yes
 - i. What kind of suction machine do you use?
 - Electric
 - Non-Electric
 - ii. Have you ever been unable to use a suction machine when indicated?
 - No
 - Yes
 - 1. What is done in this situation?
 - Swab the area
 - Perform a tracheotomy
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when a suction machine is not available?

Provider Survey – Airway & Breathing Management for Trauma

- No
- If yes, what health outcomes/conditions and how?
- 3. Do you know why suction machine was unavailable the most recent time you were unable to use it?
- 4. How frequently does this occur? _____
- f. Do you use a laryngoscope when placing an airway?
 - No, skip to next question
 - Yes
 - i. Have you ever been unable to use a laryngoscope when indicated?
 - No, skip to next question
 - Yes
 - 1. What is done in this situation?
 - Perform a tracheotomy
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when a laryngoscope is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why a laryngoscope was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____
- g. Do you use a capnograph when placing an airway?
 - No, skip to next question
 - Yes
 - i. Have you ever been unable to use a capnograph when indicated?
 - No, skip to next question
 - Yes
 - 1. What is done in this situation?
 - Use color coded flowmeter
 - Perform a tracheotomy
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when a capnograph is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why a capnograph was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____

Provider Survey – Airway & Breathing Management for Trauma

9. Are there additional steps you would like to take for airway management but are unable to do so?
- No, next question
 - Yes
 - a. What steps?
 - b. Why are you unable to do this?
10. For Breathing Management:
- a. What is the procedure to diagnose respiratory distress?
 - i. Clinical Symptoms
 - 1. What Symptoms?
 - 2. How is this measured?
 - ii. Other _____
 - 1. How is this measured?
 - b. What is the price to the patient to treat respiratory distress? _____
 - c. What is the cost to the hospital to treat respiratory distress? _____
 - d. If don't know to both of the above price/cost, who would know:
 - i. Referred to:
 - ii. Title:
 - iii. Cell Phone:
 - e. What form of Oxygen supply is used to treat respiratory distress?
 - Cylinder
 - Concentrator
 - Other _____
 - i. Have you ever been unable to provide oxygen when indicated?
 - No, skip to next question part
 - Yes
 - 1. What is done in this situation?
 - No alternative available
 - Other _____
 - 2. Do you believe patient outcomes are different when an oxygen supply is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - 3. Do you know why an oxygen supply was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____
 - f. Pulse Oximeter
 - i. Have you ever been unable to use a pulse oximeter when indicated?
 - No, skip to next question part

Provider Survey – Airway & Breathing Management for Trauma

Yes

1. What is done in this situation?

a. No alternative available

b. Other _____

2. Do you believe patient outcomes are different when a pulse oximeter is not available?

a. If yes, how?

b. No

3. Do you know why a pulse oximeter was unavailable the most recent time you were unable to use it?

4. How frequently does this occur?

g. Mechanical Ventilator

i. What type of ventilator is used?

ii. Have you ever been unable to use a ventilator when indicated?

No, skip to next question

Yes

1. What is done in this situation?

Bag-mask is used

No alternative available

Other _____

2. Do you believe patient outcomes are different when a ventilator is not available?

No

If yes, what health outcomes/conditions and how?

3. Do you know why a ventilator was unavailable the most recent time you were unable to use it?

4. How frequently does this occur? _____

11. Are there additional steps you would like to take for breathing management but are unable to do so?

No, End

Yes

a. What steps?

b. Why are you unable to do this?

Provider Survey – Equipment Sterilization for Surgery

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master’s student in global health at Duke University. As part of my master’s research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for sterilization of equipment for surgical procedures in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Are you familiar with surgical sterilization techniques at this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with someone at the hospital who is familiar with surgical sterilization procedures?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many surgical procedures are performed in a typical month? _____
3. What is the surgical site infection rate? _____
4. Are there other health outcomes related to surgical infection that you track at a facility level?
 - No, skip to next question
 - If yes, what?

Provider Survey – Equipment Sterilization for Surgery

5. What is the cost to the hospital for equipment sterilization?
6. What is the most commonly used method for disinfecting or sterilizing surgical equipment before use?
- Dry-heat sterilization
 - Autoclaving
 - Boiling
 - Steaming
 - Chemical Method
 - Process outside of facility
 - Other _____
7. For Autoclave:
- a. What type of autoclave is used?
 - Electric autoclave
 - Non-electric autoclave
 - b. Has the autoclave ever be unavailable for use?
 - No, skip to next question
 - Yes
 - i. What is done if the autoclave is not available?
 - Other _____
 - No alternative available
 - Cannot perform surgery without this
 - Nonessential
 - ii. Do you believe patient outcomes are different when an autoclave is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why the autoclave was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____
8. For Dry Heat Sterilization:
- a. What type of dry heat sterilizer is used?
 - Electric
 - Non-electric
 - b. Has the dry heat sterilizer ever be unavailable for use?
 - No, skip to next question
 - Yes
 - i. What is done if the dry heat sterilizer is not available?

Provider Survey – Equipment Sterilization for Surgery

- Other _____
- No alternative available
 - Cannot perform surgery without this
 - Nonessential
- ii. Do you believe patient outcomes are different when a dry heat sterilizer is not available?
 - No
 - If yes, what health outcomes/conditions and how?
- iii. Do you know why the dry heat sterilizer was unavailable the most recent time you were unable to use it?
- iv. How frequently does this occur? _____

9. For Boiling:

- a. What type of boiler is used?
 - Electric
 - Non-electric
- b. Has the boiler ever be unavailable for use?
 - No, skip to next question
 - Yes
 - i. What is done if the boiler is not available?
 - Other _____
 - No alternative available
 - Cannot perform surgery without this
 - Nonessential
 - ii. Do you believe patient outcomes are different when a boiler is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why the boiler was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____

10. For Steaming:

- a. What type of steamer is used?
 - Electric
 - Non-electric
- b. Has the steamer ever be unavailable for use?
 - No, end
 - Yes
 - i. What is done if the steamer is not available?

Provider Survey – Equipment Sterilization for Surgery

- Other _____
- No alternative available
 - Cannot perform surgery without this
 - Nonessential
- ii. Do you believe patient outcomes are different when an steamer is not available?
 - No
 - If yes, what health outcomes/conditions and how?
- iii. Do you know why the steamer was unavailable the most recent time you were unable to use it?
- iv. How frequently does this occur? _____

Provider Survey – General Anesthesia for Surgery

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for general anesthesia for surgery in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Are you familiar with surgical anesthesia techniques at this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with someone at the hospital who is familiar with surgical anesthesia techniques?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many surgical procedures are performed in a typical month? _____
3. How many surgical procedures require general anesthesia in a typical month? _____
4. What is the preferred method of inducing anesthesia?
 - a. Inhalation: Agent _____
 - b. Injection: Agent _____
5. Oxygen Provision
 - a. How is oxygen delivered during surgery?

Provider Survey – General Anesthesia for Surgery

- Cylinder
- Concentrator
- Other _____
- b. Have you ever been unable to provide oxygen when indicated?
 - No, Skip to next question
 - Yes
 - i. What is done in this situation?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - ii. Do you believe patient outcomes are different when an oxygen supply is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why an oxygen supply was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____
- 6. Is continuous electrocardiograph (ECG) monitoring done during anesthesia?
 - No, skip to next question
 - Yes
 - a. Is ECG ever not available?
 - No, skip to next question
 - Yes
 - i. What is done if continuous ECG is not available?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - b. Do you believe patient outcomes are different when ECG monitoring is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - c. Do you know why ECG monitoring was unavailable the most recent time you were unable to use it for a surgical procedure?
 - d. How frequently does this occur? _____
- 7. Is pulse oximetry done during anesthesia?
 - No, skip to next question
 - Yes
 - a. Is pulse oximetry ever not available?

Provider Survey – General Anesthesia for Surgery

- No, skip to next question
 - Yes
 - i. What is done if pulse oximetry is not available?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - ii. Do you believe patient outcomes are different when pulse oximetry is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why pulse oximetry was unavailable the most recent time you were unable to use it for a surgical procedure?
 - iv. How frequently does this occur? _____
8. Is blood pressure monitoring done during anesthesia?
- No, skip to next question
 - Yes
 - a. What method is used?
 - Blood pressure cuff
 - Non-invasive blood pressure monitoring
 - Invasive blood pressure monitoring
 - b. Is blood pressure monitoring ever not available during surgical procedures?
 - No, skip to next question
 - Yes
 - i. What is done if blood pressure monitoring is not available?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - ii. Do you believe patient outcomes are different when blood pressure monitoring is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why blood pressure monitoring was unavailable the most recent time you were unable to use it for a surgical procedure?
 - iv. How frequently does this occur? _____
9. Is capnography done during anesthesia?
- No, skip to next question
 - Yes
 - a. What method(s) are used?

Provider Survey – General Anesthesia for Surgery

- Capnograph
 - Color coded flowmeter
 - Other _____
- b. Is capnography ever not available during surgical procedures?
- No, skip to next question
 - Yes
 - i. What is done if capnography is not available?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - ii. Do you believe patient outcomes are different when capnography is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why capnography was unavailable the most recent time you were unable to use it for a surgical procedure?
 - iv. How frequently does this occur? _____
10. Is a ventilator available during anesthesia?
- No, next question
 - Yes
- a. Is a ventilator ever not available during surgical procedures?
- No, next question
 - Yes
 - i. What is done if a ventilator is not available?
 - No alternative available
 - Local anesthesia used
 - Other _____
 - ii. Do you believe patient outcomes are different when a ventilator is not available?
 - No
 - If yes, what health outcomes/conditions and how?
 - iii. Do you know why a ventilator was unavailable the most recent time you were unable to use it for a surgical procedure?
 - iv. How frequently does this occur? _____
11. Is any additional monitoring essential when administering general anesthesia?
- No, End
 - Yes
 - a. What monitoring?

Technician and Equipment Survey

Date:

Time:

Name:

Title:

Cell Phone:

Email:

Facility Name:

District:

Province:

Type of facility:

Managing Authority:

Referral hospital

Government public

District hospital

Government non-public

Health center

Private

Clinic

NGO/Community

Other _____

Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about the availability and repair status of certain pieces of equipment. In addition, I would like to photograph the equipment. I have spoken with the hospital administrator and received permission to conduct this survey. I know my colleague, Lillian Gu, was here earlier this year, so I will try to be brief. Does that sound okay? Do you have any questions before we begin?

1. Flow cytometer

No

Yes _____ (amount)

2. PCR machine

No

Yes _____ (amount)

3. Phototherapy lights

No

Yes _____ (amount)

4. Fluid pump

No

Yes _____ (amount)

5. Blood typing test

No

Yes _____ (amount)

6. Blood filtration machine

No

Yes _____ (amount)

7. Cardiac monitor for infants

No

Yes _____ (amount)

8. Respiratory monitor for infants

No

Yes _____ (amount)

9. Infant incubator

No

Yes _____ (amount)

10. Infant warmer

No

Yes _____ (amount)

11. Suction machine

No

Yes _____ (amount)

12. Laryngoscope

No

Yes _____ (amount)

Technician and Equipment Survey

- | | |
|--|--|
| <p>13. Capnograph
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>15. Oxygen concentrators
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>17. Non-invasive blood pressure monitor
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>19. Pulse oximeter
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>21. Autoclave
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>23. Boiler for sterilization of equipment
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>25. Anesthesia machine
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> | <p>14. Oxygen cylinders
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>16. Blood pressure cuffs
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>18. Invasive blood pressure monitor
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>20. Ventilator
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>22. Dry heat sterilizer
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>24. Steamer for sterilization of equipment
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> <p>26. ECG machine
 <input type="checkbox"/> No
 <input type="checkbox"/> Yes _____ (amount)</p> |
|--|--|

For each piece of equipment:

Type:

Manufacturer:

Model:

Serial Number:

Photo Number:

Date:

Time:

When this piece of equipment is broken, who is responsible for fixing it?

- In-house tech
 Outside, no warranty/contract
 Under warranty
 Under service contract
 Don't know

Is this piece equipment working? Fully in service Partially in service Out of service

How much did this piece of equipment cost? Donated Leased Purchased

How much does it cost to maintain per year? Consumables _____ Spare Parts _____

How many hours per year are spent on? Preventative maintenance _____ Repairs _____

Have you touched this machine or trained others how to use it in the past 12 months?

- Yes No

Based on a preliminary analysis, three focus areas and several pieces of equipment were rejected from further field study

Of HIV treatment monitoring equipment, both CD4 flow cytometers and PCR machines, were not serviced by BMET technicians. Equipment for acute airway management, including suction machines, laryngoscopes, and pulse oximeters were rarely found to be unavailable. Equipment for sterilization of surgical equipment, including autoclaves, steamers, and dry heat sterilizers, were also found to be rarely unavailable. In addition, no clear and measureable health outcome was identified.

In addition to these focus areas, several specific pieces of equipment in other health areas were also rejected from further field study. Exchange transfusion is not used as a treatment for neonatal jaundice and was therefore not pursued. No clear and measureable health outcome was identified to be indicative of infant warmer use for neonatal thermoregulation. Pulse oximeters for acute respiratory management were rarely found to be unavailable and also not critical to treatment. Finally, for patient monitoring during general anesthesia, pulse oximeters, blood pressure monitoring, and capnographs were all found to be rarely unavailable. Surveys were updated accordingly.

For the health areas, equipment and health outcomes that were not rejected, additional details regarding health outcomes and treatment protocols were included as well.

The modified surveys are provided here, including:

1. Director Survey
2. Provider Surveys:
 - a. Neonatal Jaundice Treatment
 - b. Neonatal Thermoregulation
 - c. Emergency Breathing Management
 - d. General Anesthesia for Surgery
3. Technician and Equipment Survey

These surveys were used at 4 hospitals:

1. Nyanza District Hospital
2. Gitwe District Hospital
3. Nyagatare District Hospital
4. Kiziguro District Hospital

Director Survey

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I know that my colleague Lillian Gu spoke with you earlier this year. I will be as brief as possible. I do not anticipate spending more than 20 minutes with you. At your hospital, we are hoping to:

1. Speak with you
2. Speak with hospital technicians about equipment availability and survey equipment status
3. Speak with clinicians and hospital staff about select conditions including:

Infant Jaundice

1. Referred to:
2. Cell Phone:
3. Title:

Breathing Management (Trauma)

1. Referred to:
2. Cell Phone:
3. Title:

Infant Hypothermia

1. Referred to:
2. Cell Phone:
3. Title:

General Anesthesia (Surgery)

1. Referred to:
2. Cell Phone:
3. Title:

Does that sound okay? With you, I would specifically like to discuss if health outcomes are available at the facility level for certain key indicators. Do you have any questions before we begin?

Referred to:

Cell Phone:

Title:

From Lillian Gu's survey on _____ (date)

Director Survey

1. The hospital serves a population of _____ people
2. The hospital has _____ beds
3. The usual occupancy rate is _____ % of beds filled
4. _____ inpatients are seen in a year
5. _____ outpatients are seen in a year
6. _____ operating beds are in use
7. _____ ICU/NICU beds are in use

1. Infant Jaundice

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many cases of infant jaundice are seen monthly?
- b. What is the mortality rate of infant jaundice patients?
- c. Are there other health outcomes related to infant jaundice tracked at the facility level?
 No
 If yes, what?

2. Infant Hypothermia

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many cases of infant hypothermia are seen monthly?
- b. What is the mortality rate of these cases?
- c. Are there other health outcomes related to infant hypothermia tracked at the facility level?
 No
 If yes, what?

3. Trauma

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many injury cases are seen monthly?
- b. What is the mortality rate of these cases?
- c. What is the rate of anoxic brain injury among these cases?
- d. Are there other health outcomes related to injury tracked at a facility level?
 No
 If yes, what?

Director Survey

4. General Anesthesia

Referred to:

Cell Phone:

Title:

Records: Written OR Oral

- a. How many general anesthesia procedures are performed each month?
- b. How many adverse events due to general anesthesia?
- c. Are there other health outcomes related to patients who receive general anesthesia tracked at a facility level?
 - No
 - If yes, what?

Provider Survey – Neonatal Jaundice Treatment

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for infant jaundice in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat infant jaundice or are you familiar with infant jaundice treatment protocols in this hospital?
 - Yes
 - No
 - a. Can you connect me with a provider in the hospital who treats infant jaundice or is familiar with the treatment for infant jaundice?
 1. Name:
 2. Cell Phone:
 3. Title:
2. How many cases of infant jaundice are treated in a typical month?
3. How many of these cases progress to Kernicterus?
4. What is the mortality rate of infant jaundice patients?
5. Do you track infection rates in infant jaundice cases?
 - No, skip to next question
 - Yes

Provider Survey – Neonatal Jaundice Treatment

1. How is infection diagnosed?
 2. What is the infection rate among infant jaundice cases?
 3. Does infection affect duration of therapy? If so, how?
 4. Does infection affect jaundice recovery time? If so, how?
6. Are there other health outcomes related to infant jaundice are tracked at the facility level?
- No, skip to next question
 - If yes, what?
7. Which of the following treatments are used for infant jaundice?
- Phototherapy
 - Other _____
8. On what basis is the decision to start phototherapy made?
- Bilirubin level
 1. What threshold? _____
 2. How is this measured?
 - Clinical symptoms
 1. What symptoms?
 2. How are these measured?
 - Other _____
 1. How is this measured?
9. What percent of infant jaundice cases require phototherapy? _____
10. How do you determine duration of therapy?
11. How is recovery defined?
12. Equipment:
1. What type of phototherapy is used?
 - Conventional
 - Fiberoptic
 - Sunlight
 - Don't know
 2. What type of light source is used?
 - Fluorescent
 - Blue Bulbs
 - White Bulbs

Provider Survey – Neonatal Jaundice Treatment

- LED
- Other _____

13. Do you use the Ministry of Health price list for this treatment?

- Yes
- No:
 1. What is the price to the patient for phototherapy treatment? _____
 2. What is the cost to the hospital for phototherapy treatment? _____
 3. If don't know to both of the above price/cost, who would know:
 1. Referred to:
 2. Title:
 3. Cell Phone:

14. Do you ever place more than one infant under the same set of phototherapy lights?

- No
- Yes
 1. How frequently do you place 2 infants under the same lamp? _____
 2. How frequently do you place 3 infants under the same lamp? _____
 3. How frequently do you place 4 infants under the same lamp? _____
 4. Does this extend recovery time? If yes, can you estimate the difference?
 5. Does this extend duration of therapy? If yes, can you estimate the difference?
 6. Does this increase infection rates? If yes, can you estimate the difference?

15. Have you ever been unable to use phototherapy when it was indicated?

- No, ask hypothetical
- Yes
 1. What is done in this situation?
 - Refer to another hospital
 1. How frequently does this occur? _____
 - Sunlight
 1. How frequently does this occur? _____
 - No alternative available
 1. How frequently does this occur? _____
 - Other _____
 1. How frequently does this occur? _____
 2. Do you believe patient outcomes are different when phototherapy is not available?
 - No

Provider Survey – Neonatal Jaundice Treatment

- If yes, what health outcomes/conditions and how? How is this measured?
- 3. Do you know why phototherapy was unavailable the most recent time you were unable to use it?
- 4. How frequently does this occur? _____

Provider Survey – Neonatal Hypothermia Treatment

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for infant hypothermia in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat infant hypothermia or are you familiar with infant hypothermia treatment protocols in this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with a provider in the hospital who treats infant hypothermia or is familiar with the treatment for infant hypothermia?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many cases of infant hypothermia are treated in a typical month?
3. What is the mortality rate of infant hypothermia patients?
4. Do you track infection rates in infant hypothermia cases?
 - No, skip to next question
 - Yes
 1. How is infection diagnosed?
 2. What is the infection rate among infant hypothermia cases?

Provider Survey – Neonatal Hypothermia Treatment

3. Does infection increase duration of therapy? If yes, can you estimate the difference?
4. Does infection affect hypothermia recovery time? If yes, can you estimate the difference?
5. Are there other health outcomes related to infant hypothermia that you track at the facility level?
 - No, skip to next question
 - If yes, what?
6. Which of the following treatments are used for infant hypothermia?
 - Infant incubator
 - Infant warmer
 - Kangaroo care
 - Swaddling
 - Other _____
 - Don't know
7. How do you define recovery?
8. How do you determine duration of treatment?
9. What determines the use of an infant incubator?
 - Temperature
 - i. What temperature range or threshold? _____
 - ii. How is this measured? _____
 - Prematurity
 - i. What gestation period range or threshold? _____
 - Low birth weight
 - i. What weight range or threshold? _____
 - Stability
 - i. What clinical symptoms?
 - ii. How are they measured?
 - Other _____
 - i. How is this measured?
10. Do you use the Ministry of Health price list for this treatment?
 - Yes
 - No:
 1. What is the price to the patient for phototherapy treatment? _____

Provider Survey – Neonatal Hypothermia Treatment

2. What is the cost to the hospital for phototherapy treatment? _____
3. If don't know to both of the above price/cost, who would know:
 1. Referred to:
 2. Title:
 3. Cell Phone:

11. Do you ever place more than one infant in the same incubator?

- No
 Yes

1. How frequently do you place 2 infants in the same incubator? _____
2. How frequently do you place 3 infants in the same incubator? _____
3. How frequently do you place 4 infants in the same incubator? _____
4. Does this extend duration of therapy? If yes, can you estimate the difference?
5. Does this extend recovery time? If yes, can you estimate the difference?
6. Does this increase infection rates? If yes, can you estimate the difference?

12. Have you ever been unable to use an incubator when it was indicated?

- No, ask hypothetical
 Yes

i. What is done in this situation?

- Refer to another hospital

1. How frequently does this occur? _____

- Infant warmer

1. How frequently does this occur? _____

- Kangaroo care

1. How frequently does this occur? _____

- Swaddling

1. How frequently does this occur? _____

- No alternative available

1. How frequently does this occur? _____

- Other _____

1. How frequently does this occur? _____

ii. Do you believe patient outcomes are different when an incubator is not available?

- No

- If yes, what health outcomes/conditions and how? How is this measured?

iii. Do you know why an incubator was unavailable the most recent time you were unable to use it?

iv. How frequently does this occur? _____

Provider Survey – Breathing Management for Trauma

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master’s student in global health at Duke University. As part of my master’s research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for breathing management for trauma in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Do you treat trauma patients or are you familiar with protocols for trauma treatment in this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with a provider in the hospital who treats trauma patients or is familiar with the treatment for trauma?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many cases of trauma do you see that require breathing management in a month? _____
3. What is the mortality rate of these cases? _____
4. What is the rate of anoxic brain injury among these cases? _____
5. How is anoxic brain injury diagnosed?

Provider Survey – Breathing Management for Trauma

6. Are there other health outcomes related to trauma that you track at a facility level?
- No, skip to next question
 - If yes, what?
7. What is the procedure to diagnose respiratory distress?
- Clinical Symptoms
 1. What symptoms?
 2. How is this measured?
 - Other _____
 1. How is this measured?
8. Do you use the Ministry of Health price list for this treatment?
- Yes
 - No:
 1. What is the price to the patient for treatment of respiratory distress? _____
 2. What is the cost to the hospital for treatment of respiratory distress? _____
 3. If don't know to both of the above price/cost, who would know:
 1. Referred to:
 2. Title:
 3. Cell Phone:
9. What form of Oxygen supply is used to treat respiratory distress?
- Cylinder
 - Concentrator
 - Other _____
 - i. Have you ever been unable to provide oxygen when indicated?
 - No, ask hypothetical
 - Yes
 1. What is done in this situation? (Ask if both cylinder and concentrator are unavailable)
 - No alternative available
 - a. How frequently does this occur? _____
 - Prioritize patients
 - a. How frequently does this occur? _____
 - Other _____
 - a. How frequently does this occur? _____
 2. Do you believe patient outcomes are different when an oxygen supply is not available?
 - No

Provider Survey – Breathing Management for Trauma

- If yes, what health outcomes/conditions and how? How is this measured?
- 3. Do you know why an oxygen supply was unavailable the most recent time you were unable to use it?
- 4. How frequently does this occur? _____

b. Ventilator

- i. Have you ever been unable to use a ventilator when indicated?
 - No, ask hypothetical
 - Yes
 - 1. What is done in this situation?
 - Bag-mask is used
 - a. How frequently does this occur? _____
 - No alternative available
 - b. How frequently does this occur? _____
 - Other _____
 - 2. Do you believe patient outcomes are different when a ventilator is not available?
 - No
 - If yes, what health outcomes/conditions and how? How is this measured?
 - 3. Do you know why a ventilator was unavailable the most recent time you were unable to use it?
 - 4. How frequently does this occur? _____

Provider Survey – General Anesthesia for Surgery

Date:	Time:
Name:	Title:
Cell Phone:	Email:
Facility Name:	
District:	Province:
Type of facility:	Managing Authority:
<input type="checkbox"/> Referral hospital	<input type="checkbox"/> Government public
<input type="checkbox"/> District hospital	<input type="checkbox"/> Government non-public
<input type="checkbox"/> Health center	<input type="checkbox"/> Private
<input type="checkbox"/> Clinic	<input type="checkbox"/> NGO/Community
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____

I am a master’s student in global health at Duke University. As part of my master’s research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about clinical protocols for general anesthesia for surgery in order to understand how medical equipment is used. I have spoken with the hospital director and been given permission to conduct this survey. I will try to be brief and hope to take no more than half an hour of your time.

Does this sound okay? Before we begin, do you have any questions about the project?

1. Are you familiar with surgical anesthesia techniques at this hospital?
 - Yes, skip to next question
 - No
 - a. Can you connect me with someone at the hospital who is familiar with surgical anesthesia techniques?
 - i. Name:
 - ii. Cell Phone:
 - iii. Title:
2. How many surgical procedures are performed in a typical month? _____
3. How many surgical procedures require general anesthesia in a typical month? _____
4. What is the preferred method of inducing anesthesia?
 - a. Inhalation: Agent _____
 - b. Injection: Agent _____
5. Sedation
 - a. How do you determine if the patient is properly sedated?

Provider Survey – General Anesthesia for Surgery

- b. How is this measured?
6. Blood loss
- a. Do you monitor for severe blood loss?
 - b. How is this diagnosed?
7. Oxygen Provision
- a. How is oxygen delivered during surgery?
 - Cylinder
 - Concentrator
 - Other _____
 - b. Have you ever postponed a surgery due to a lack of oxygen provision?
 - No
 - Yes
 - i. How frequently does this occur? _____
 - ii. How does this impact the patient's health outcomes? How is this measured?
 - c. Have you ever been unable to provide oxygen when indicated?
 - No, ask hypothetical
 - Yes
 - i. What is done in this situation?
 - No alternative available
 - a. How frequently does this occur? _____
 - Local anesthesia used
 - a. How frequently does this occur? _____
 - Other _____
 - a. How frequently does this occur? _____
 - ii. Do you believe patient outcomes are different when an oxygen supply is not available?
 - No
 - If yes, what health outcomes/conditions and how? How is this measured?
 - iii. Do you know why an oxygen supply was unavailable the most recent time you were unable to use it?
 - iv. How frequently does this occur? _____
8. Is continuous electrocardiograph (ECG) monitoring done during anesthesia?
- No
 - i. Is ECG not done because it is unavailable? Or because it is not necessary?
 - Yes

Provider Survey – General Anesthesia for Surgery

- a. Is ECG ever not available?
 - No, ask hypothetical
 - Yes
 - i. What is done if continuous ECG is not available?
 - No alternative available
 - i. How frequently does this occur? _____
 - Local anesthesia used
 - i. How frequently does this occur? _____
 - Other _____
 - i. How frequently does this occur? _____
 - b. Do you believe patient outcomes are different when ECG monitoring is not available?
 - No
 - If yes, what health outcomes/conditions and how? How is this measured?
 - c. Do you know why ECG monitoring was unavailable the most recent time you were unable to use it for a surgical procedure?
 - d. How frequently does this occur? _____
9. Is a ventilator used during anesthesia?
- No
 - i. Is this because a ventilator is not available? Or because it is not necessary?
 - Yes
 - a. Is a ventilator ever not available during surgical procedures?
 - No, ask hypothetical
 - Yes
 - i. What is done if a ventilator is not available?
 - No alternative available
 - i. How frequently does this occur? _____
 - Local anesthesia used
 - i. How frequently does this occur? _____
 - Other _____
 - i. How frequently does this occur? _____
 - ii. Do you believe patient outcomes are different when a ventilator is not available?
 - No
 - If yes, what health outcomes/conditions and how? How is this measured?
 - iii. Do you know why a ventilator was unavailable the most recent time you were unable to use it for a surgical procedure?
 - iv. How frequently does this occur? _____

Technician and Equipment Survey

Date:

Time:

Name:

Title:

Cell Phone:

Email:

Facility Name:

District:

Province:

Type of facility:

Managing Authority:

Referral hospital

Government public

District hospital

Government non-public

Health center

Private

Clinic

NGO/Community

Other _____

Other _____

I am a master's student in global health at Duke University. As part of my master's research work, I am here to understand how medical equipment repair impacts health outcomes. I would like to speak with you about the availability and repair status of certain pieces of equipment. In addition, I would like to photograph the equipment. I have spoken with the hospital administrator and received permission to conduct this survey. I know my colleague, Lillian Gu, was here earlier this year, so I will try to be brief. Does that sound okay? Do you have any questions before we begin?

1. Phototherapy lights (neonatology)

No

Yes _____ (amount)

2. Infant incubator (neonatology)

No

Yes _____ (amount)

3. Oxygen concentrators (trauma, surgery)

No

Yes _____ (amount)

4. Oxygen cylinders (trauma, surgery)

No

Yes _____ (amount)

5. Ventilator (trauma, surgery)

No

Yes _____ (amount)

6. ECG machine (surgery)

No

Yes _____ (amount)

7. Anesthesia machine (surgery)

No

Yes _____ (amount)

Technician and Equipment Survey

For each piece of equipment:

Type:

Manufacturer:

Model:

Serial Number:

Photo Number:

Date:

Time:

When this piece of equipment is broken, who is responsible for fixing it?

In-house Outside, no Under Under service Don't
tech warranty/contract warranty contract know

Is this piece equipment working? Fully in service Partially in service Out of service

How much did this piece of equipment cost? Donated Leased Purchased

_____ How much does it cost to maintain per year? Consumables _____ Spare Parts _____

How many hours per year are spent on? Preventative maintenance _____ Repairs _____

Have you touched this machine or trained others how to use it in the past 12 months?

Yes No

Appendix B: Summary of Findings of Rejected Areas, Equipment, and Health Outcomes

This appendix contains the details of findings for areas that were studied in the field but ultimately rejected for the reasons explained in section 4.2.

Table 11: Summary of Findings on Suction for Acute Airway Management

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Frequency of Unavailability
Rwamagana District Hospital	Physician	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Electric suction machine	Never faced equipment shortage
University Central Hospital of Kigali	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Electric suction machine	Never faced equipment shortage
Kibilizi District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Electric suction machine	Never faced equipment shortage
Ruhengeri District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Electric suction machine	Never faced equipment shortage
Nemba District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Electric suction machine	Never faced equipment shortage

Table 12: Summary of Findings on Laryngoscope Use for Acute Airway Management

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*
Rwamagana District Hospital	Physician	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Laryngoscope		Never faced equipment shortage	
University Central Hospital of Kigali	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Laryngoscope	None	1 per month	Insufficient number of laryngoscopes
Kibilizi District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Laryngoscope		Never faced equipment shortage	
Ruhengeri District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Laryngoscope	Refer within hospital	Never faced equipment shortage	
Nemba District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Laryngoscope		Never faced equipment shortage	

Table 13: Summary of Findings on Oxygen Saturation Monitoring for Acute Respiratory Management

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	Notes
Rwamagana District Hospital	Physician	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Pulse oximeter		Never faced equipment shortage		
Kibagabaga District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Pulse oximeter	Borrow from another department	1 per 6 months	Battery low	No major trauma
University Central Hospital of Kigali	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Pulse oximeter	No alternative	Never faced equipment shortage		
Kibilizi District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Pulse oximeter	No alternative	Never faced equipment shortage		
Ruhengeri District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Pulse oximeter	No alternative	Never faced equipment shortage		
Nemba District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Pulse oximeter	Refer out	Never faced equipment shortage		

Table 14: Summary of Findings on Ventilation for Acute Respiratory Management

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Rwamagana District Hospital	Physician	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Ventilator	Bag-valve-mask	1 per month	Insufficient number of ventilators, and equipment not working	2	
Kibagabaga District Hospital	Physician	Survey A (page 105)	O ₂ saturation	Bag-valve-mask					No major trauma
University Central Hospital of Kigali	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Ventilator	Bag-valve-mask	5 per month	Insufficient number of ventilators	0	Borrow from ICU as needed
Kibilizi District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Bag-valve-mask					
Ruhengeri District Hospital	Nurse	Survey A (page 105)	<ul style="list-style-type: none"> • O₂ saturation • Respiratory rate 	Bag-valve-mask					
Nemba District Hospital	Physician	Survey A (page 105)	O ₂ saturation	None					
Nyanza District Hospital	Nurse	Survey B (page 132)	<ul style="list-style-type: none"> • Respiratory rate • Cardiac rate • Blood pressure 	Bag-valve-mask					No major trauma

Hospital	Interviewee	Survey	Treatment Indicators	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*	No. of Units	Notes
Nyagatare District Hospital	Nurse	Survey B (page 132)	• O ₂ saturation Respiratory rate	None					
Kiziguro District Hospital	Nurse	Survey B (page 132)	Respiratory rate	Compressions					

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative

Table 15: Summary of Findings for Equipment Sterilization for Surgery

Hospital	Interviewee	Survey	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*
Rwamagana District Hospital	Technician	Survey A (page 110)	Autoclave, dry heat sterilizer and steamer		Never faced equipment shortage	
Muhima Mother & Child Hospital	Nurse	Survey A (page 110)	Autoclave and dry heat sterilizer	Outside sterilization service	1 per year	Equipment out of service
Kibagabaga District Hospital	Nurse	Survey A (page 110)	Dry heat sterilizer	Postpone surgery (1 day), outside sterilization service		Insufficient number of sterilizers
University Central Hospital of Kigali	Nurse	Survey A (page 110)	Autoclave	Outside sterilization service	Never experienced equipment shortage	
Kibilizi District Hospital	Nurse	Survey A (page 110)	Autoclave, dry heat sterilizer and steamer	Refer out	Never experienced equipment shortage	
Kigeme District Hospital	Nurse	Survey A (page 110)	Autoclave	Refer out	Never experienced equipment shortage	
Ruhengeri District Hospital	Nurse	Survey A (page 110)	Autoclave, dry heat sterilization, and chemical sterilization	Refer out	Never experienced equipment shortage	
Nemba District Hospital	Anesthetist	Survey A (page 110)	Autoclave, dry heat sterilization, and chemical sterilization	Use disposable surgical equipment	1 per 3 months	Equipment was out of service

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative.

Table 16: Summary of Findings on Oxygen Provision for General Anesthesia for Surgery

Hospital	Interviewee	Survey	Cases	Anesthesia Agent	Primary Option	Alternative Option	Frequency of Unavailability
Rwamagana District Hospital	Anesthetist	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	Cylinder		Never faced equipment shortage
Muhima Mother & Child Hospital	Anesthetist	Survey A (page 114)	20 per month	Ketamine, thiopental	Cylinder		Never faced equipment shortage
Kibagabaga District Hospital	Nurse	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	Cylinder		Never faced equipment shortage
University Central Hospital of Kigali	Nurse	Survey A (page 114)	120 per month	<ul style="list-style-type: none"> • Ketamine, thiopental, or propofol (induce) • Halothane, or isoflurane (maintain) 	Wall concentrator	Bag-valve-mask	Never faced equipment shortage
Kibilizi District Hospital	Physician	Survey A (page 114)	10 per month	Ketamine, propofol, or thiopental	Cylinder	Concentrator	Never faced equipment shortage
Kigeme District Hospital	Anesthetist	Survey A (page 114)	4 – 8 per month	Ketamine	Cylinder	Concentrator	Never faced equipment shortage
Ruhengeri District Hospital	Nurse	Survey A (page 114)	100 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	Cylinder, Concentrator	Refer out	Never faced equipment shortage
Nemba District Hospital	Anesthetist	Survey A (page 114)	8 – 10 per month	Halothane	Cylinder, Wall concentrator	Ketamine	Never faced equipment shortage
Nyanza District Hospital	Anesthetist	Survey B (page 135)	90 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	Cylinder, Concentrator	Postpone surgery	Never faced equipment shortage
Gitwe District Hospital	Nurse	Survey B (page 135)	110 per month	Ketamine	Cylinder, Concentrator	None	Never faced equipment shortage
Kiziguro District Hospital	Nurse	Survey B (page 135)	7 – 8 per month	Ketamine	Concentrator	Postpone surgery	Never faced equipment shortage

Table 17: Summary of Findings for Cardiopulmonary Monitoring for General Anesthesia for Surgery

Hospital	Interviewee	Survey	Cases	Anesthesia Agent	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*
Rwamagana District Hospital	Anesthetist	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	ECG, pulse oximeter, and BP monitor		Never faced ECG shortage	
Muhima Mother & Child Hospital	Anesthetist	Survey A (page 114)	20 per month	Ketamine, thiopental	ECG, pulse oximeter, and BP monitor	Pulse oximeter, and BP monitor	ECG previously unavailable	
Kibagabaga District Hospital	Nurse	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	ECG, pulse oximeter, and BP monitor		Never faced ECG shortage	
University Central Hospital of Kigali	Nurse	Survey A (page 114)	120 per month	<ul style="list-style-type: none"> • Ketamine, thiopental, or propofol (induce) • Halothane, or isoflurane (maintain) 	ECG, pulse oximeter, and BP monitor	Pulse oximeter, and BP monitor	2 per week	Equipment was not working
Kibilizi District Hospital	Physician	Survey A (page 114)	10 per month	Ketamine, propofol, or thiopental	ECG, pulse oximeter, and BP monitor	Pulse oximeter, and BP monitor	2 per year	Equipment was not working
Kigeme District Hospital	Anesthetist	Survey A (page 114)	4 – 8 per month	Ketamine	Pulse oximeter, and BP monitor			

Hospital	Interviewee	Survey	Cases	Anesthesia Agent	Primary Option	Alternative Option	Frequency of Unavailability	Reason for Unavailability*
Ruhengeri District Hospital	Nurse	Survey A (page 114)	100 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	ECG, and pulse oximeter	Pulse oximeter	Never faced ECG shortage	
Nemba District Hospital	Anesthetist	Survey A (page 114)	8 – 10 per month	Halothane	Pulse oximeter, and BP monitor			
Nyanza District Hospital	Anesthetist	Survey B (page 135)	90 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	ECG, pulse oximeter, BP monitor	Pulse oximeter, and BP monitor	4 per year	Equipment was not working
Gitwe District Hospital	Nurse	Survey B (page 135)	110 per month	Ketamine	Pulse oximeter, and BP monitor			
Kiziguro District Hospital	Nurse	Survey B (page 135)	7 – 8 per month	Ketamine	Pulse oximeter, and BP monitor			

* Providers were asked for the reason the primary treatment option was unavailable the most recent time they used an alternative

Table 18: Summary of Findings for Ventilation for General Anesthesia for Surgery

Hospital	Interviewee	Survey	Cases	Anesthesia Agent	Primary Option	Alternative Option	Frequency of Unavailability	Notes
Rwamagana District Hospital	Anesthetist	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	Ventilator		Never faced equipment shortage	
Muhima Mother & Child Hospital	Anesthetist	Survey A (page 114)	20 per month	Ketamine, thiopental	Ventilator		Never faced equipment shortage	
Kibagabaga District Hospital	Nurse	Survey A (page 114)	70 per month	<ul style="list-style-type: none"> • Ketamine (induce) • Halothane (maintain) 	Ventilator		Never faced equipment shortage	
University Central Hospital of Kigali	Nurse	Survey A (page 114)	120 per month	<ul style="list-style-type: none"> • Ketamine, thiopental, or propofol (induce) • Halothane, or isoflurane (maintain) 	Ventilator	Bag-valve-mask	Never faced equipment shortage	
Kibilizi District Hospital	Physician	Survey A (page 114)	10 per month	Ketamine, propofol, or thiopental	Ventilator	Bag-valve-mask	Never faced equipment shortage	
Kigeme District Hospital	Anesthetist	Survey A (page 114)	4 – 8 per month	Ketamine	None			

Hospital	Interviewee	Survey	Cases	Anesthesia Agent	Primary Option	Alternative Option	Frequency of Unavailability	Notes
Ruhengeri District Hospital	Nurse	Survey A (page 114)	100 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	Ventilator	Bag-valve-mask	Never faced equipment shortage	
Nemba District Hospital	Anesthetist	Survey A (page 114)	8 – 10 per month	Halothane	Ventilator	Bag-valve-mask	Never faced equipment shortage	
Nyanza District Hospital	Anesthetist	Survey B (page 135)	90 per month	<ul style="list-style-type: none"> • Ketamine or thiopental (induce) • Halothane (maintain) 	Bag-valve-mask			
Gitwe District Hospital	Nurse	Survey B (page 135)	110 per month	Ketamine	Ventilator	Refer out	Never faced equipment shortage	Not always used – only one trained staff member
Kiziguro District Hospital	Nurse	Survey B (page 135)	7 – 8 per month	Ketamine	Ventilator	Refer out	Never faced equipment shortage	

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