ABSTRACT

The Intersections of Neglected Tropical Diseases and Surgical System Strength in Low and Middle Income Countries

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Neglected tropical diseases (NTDs) are a subsection of diseases identified by the World Health Organization (WHO) that burden approximately 1 billion people every year. The majority of the affected individuals live in low and middle-income countries (LMICs). Additionally, these conditions disproportionately affect those in poverty. Three NTDs in particular that can present a need for surgical intervention are Soil-Transmitted Helminthiases, Buruli Ulcer, and Trachoma. Currently, 5 billion individuals lack access to surgical care, of which LMICs also bear the largest gaps in access. A strong surgical system is vital to the success of an overall healthcare system and is a necessary part of relieving the burden of NTDs. Surgical system strengthening intersects with NTDs in such a way that it is impossible to adequately addresses the burden of neglected tropical diseases without also placing focus on strengthening the surgical care system.

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THE INTERSECTIONS OF NEGLECTED TROPICAL DISEASES AND SURGICAL SYSTEM STRENGTH IN LOW AND MIDDLE INCOME COUNTRIES

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements for the

Honors Program

By

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Waco, TX

December 2019

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

To my parents, thank you for believing in me each step of the way. You have heard me run through an endless number of ideas, ramble on about sources, and push through the both the good and the bad days throughout my academic journey. I would not be here without your love and support. Thank you for teaching me to never give up and to chase after each step of my life with everything I have to give.

To Dr. Smith, Thank you for your guidance and mentorship throughout this entire process. Since the first day I sat in your epidemiology class I saw you had a love and passion for your work unlike I had seen in anyone else. I aspire each day to have the love and passion that you display. Thank you for you for pushing me to give my very best and for helping me continue to grow towards the scholar I aspire to be.

To my roommates of LL Sam's apartment #1322, you each have played such a special role in this process and I could not be more thankful for you all. From the late night writing sessions, to proof reading chapters, and reminding me not to skip meals you guys have really kept me sane through this process. You guys are amazing, so thank you.

To my wonderful husband Andrew, thank you for loving me so well through this whole process. You have proof read chapters, gone on late night coffee and ice cream runs, and given me a hug when I truly needed it. This thesis would not have come to completion without your encouragement and support. Thank you and I promise to make it up to you when you get in your writing grind next semester.

CHAPTER ONE

Introduction

Global Health

Global health is an area of study, research, and practice with the goal to improve the health and equality of all people. This movement has been majorly influenced by the United Nations Millennium Development Goals (MDGs) and now by the United Nations Sustainable Development Goals (SDGs). The SDGs were published in 2015 the United Nations (UN). Since the publication of the SDGs they have become a driving force behind global health improvements. Of the Sustainable Development Goals, SDG 3 gives particular attention to the healthcare of the world, stating that the global community should strive to "Ensure healthy lives and promote well-being for all at all ages" (UN, 2015). SDG 3 is aimed at improving global health and specifically targets seven thematic areas as a way to provide meaningful checkpoints that are representative of achieving the larger goal. The seven themes are maternal and infant healthcare, infectious diseases, non-communicable diseases and mental health, injury and violence related healthcare risks, universal healthcare and health systems, environmental risks, and health risks and disease outbreaks (Figure 1) (UN, 2015).

Figure 1: Sustainable Development Goal 3 adapted from, "Goal 3: Good Health and Well-Being" by UN Environment, 2015

According to the World Health Report there has been considerable progress made towards these thematic goals. One example of this progress is the drop in the global infant mortality rate by 44% since 1990 (World Health Organization (WHO), 2018). Additionally, there has been a reduction in the number of individuals who have needed to be treated via mass drug administration (MDA) for NTDs from 2 billion in 2010 to 1.5 billion in 2016 (WHO, 2018). However, even with this progress, there continues to be areas that are lacking and need more development in order to, "ensure healthy lives and promote well-being for all at all ages," (UN, 2015).

A solution is offered in the Lancet 2030 paper on the state of global surgery, *Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development*. This publication argued that in order for there to be a stronger health system, investments need to be made in surgical system strengthening which will

affect multiple avenues of healthcare including diseases treatment, mortality rates, and overall health of the global community (Meara et al, 2015). One of the many avenues that surgical strengthening has the ability to impact is the burden of neglected tropical diseases (NTDs).

Intro to Neglected Tropical Diseases and Global Surgical Access

Neglected tropical diseases were first defined in 2003 by the World Health Organization (WHO, 2010) and then further described in the 2010 first report on neglected tropical diseases. NTDs are a subsection of communicable diseases that impact 149 countries around the world. They are primarily concentrated in tropical and subtropical regions placing the largest burden on a group of developing countries referred to as low and middle income countries (LMICs) (Figure 2).

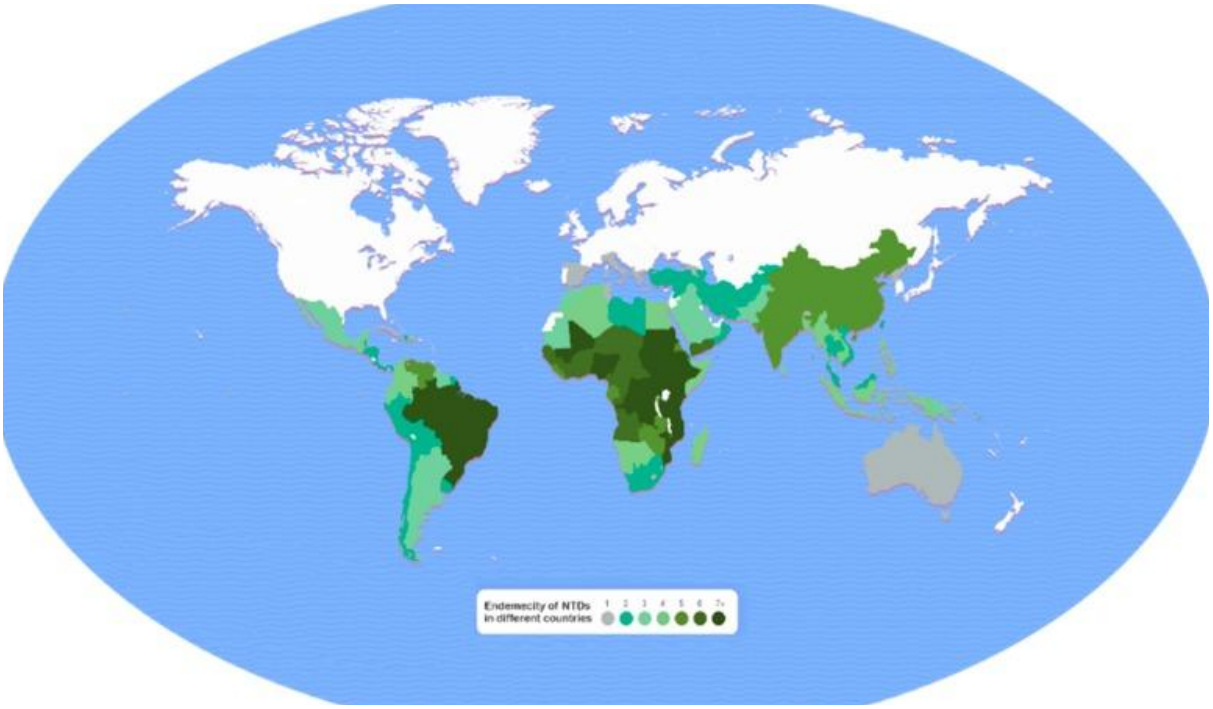

Figure 2: Endemic distribution of neglected tropical diseases Sep. 2017 adapted from "Neglected Tropical Diseases: Epidemiology and Global Burden" by Amal Mitra and Anthony Mawson, *Trop. Med. Infect. Dis*. 2017, *2*, 36

Although there have been many efforts to provide treatment and prevention for these conditions, there are still over 1 billion people affected by the burden of disease from one of the many NTDs (WHO, 2019).

In 2015 it was estimated that 5 billion individuals lacked access to surgical care and that the heaviest burden falls on LMICs. In LMICs specifically, nine out of ten people do not have access to safe affordable surgical care (Figure 3) (Meara et al, 2015).

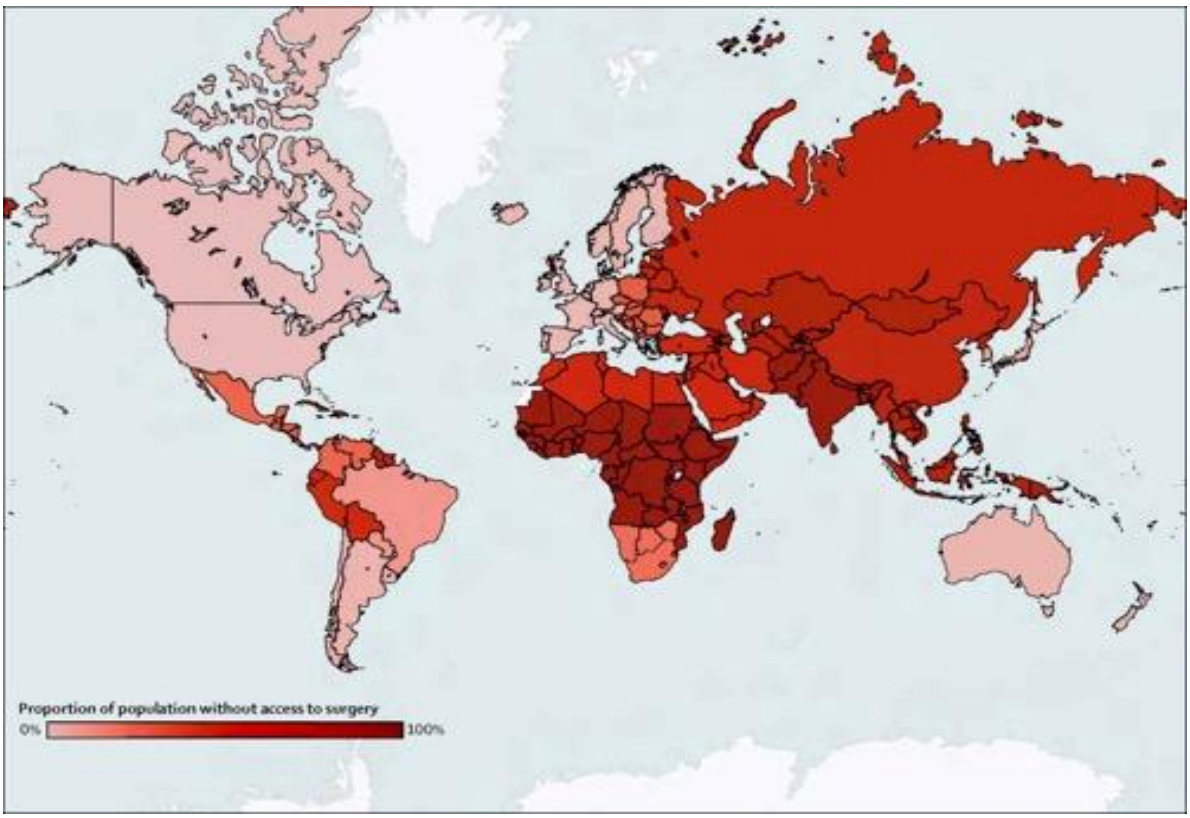

Figure 3: The proportion of population without access to surgery from June 2015, adapted from "Global Access to surgical care: a modeling study" by Alkire Elt. El, *The Lancet Global Health,* 3, 316-323

With surgery being a requirement for treatment of many injuries, obstetric emergencies, and life threatening conditions, the lack of surgical care access leads to major impacts economically for a country. In 2015 is was estimated that LMICs would have an economic loss of $12.6 trillion dollars due to lack of surgical care between 2015 and

2030 if major changes were not made to the existing surgical care system (Meara et al, 2015). Both NTDs and lack of surgical care are placing a large burden on LMICs. This opens the door for potential overlap between NTDs and lack of surgical care access, resulting in compounded health conditions in regions endemic to NTDs as well as lacking in surgical care.

Intersections between Neglected Tropical Diseases and Global Surgery

The WHO defines a well-functioning health system as a system that "responds in a balanced way to meeting a population's need and expectations by improving the health status of individuals, families and communities, defending the population against what threatens its health, protecting people against the financial consequences of ill-health, and providing equitable access to people-centered care". By this definition, the lack of a surgical system that is able to meet everyone's needs, is hindering the ability of the country to have a well-functioning health system. Additionally, the burden that NTDs have on individuals in and of itself hurts the health of those infected, their families, and communities. This burden is not being adequately addressed and therefore hinders the success of a health system. Many NTDs can result in complications that require surgery. However, many of those surgeries are not taking place due to the unavailability of surgical care. Figures 1 and 2 show the burden of NTDs and lack of surgical access respectively. Those figures display that both NTDs and lack of surgical care have the heaviest burden on LMICs. Therefore, providing greater access to surgical care in combination with a robust primary care system will result in an improved and sustainable health system that will alleviate the burden of neglected tropical diseases.

History of Global Health

The foundations of Global Health

Global health has long had a focus on improving the quality and access of primary care to those most underserved. A defining moment for primary care was the Alma-Ata conference in September of 1978. During this conference a statement on primary care was made in regard to the need for primary care around the world declaring the following goal:

> The International Conference on Primary Health Care calls for urgent and effective national and international action to develop and implement primary health care throughout the world and particularly in developing countries in a spirit of technical cooperation and in keeping with a New International Economic Order (International Conference on Primary Health Care, 1978).

The target date for completion of this task was the year 2000. Although all of the goals outlined by the conference were not achieved by 2000, the conference's statement set the tone for the work of global health for years to come. For primary care specifically, efforts have been focused on treatment of conditions such as HIV, vaccine delivery, and basic healthcare checkups.

With the passing of the 2000 completion date for the Alma-Ata conference goals, the UN came together to unify the world with a new set of goals everyone was committed to working towards. These new goals were the Millennium Development Goals and had a target completion date of 2015. Two of the eight MDGs were centered on healthcare with goal six being directly related to combating diseases. The MDGs resulted in large improvements for healthcare around the world including reducing the maternal mortality rate by 45% and making significant gains in the fight against diseases such as HIV, tuberculosis, and malaria. However, the MDGs were not enough and in 2015 the

Sustainable Development Goals as mentioned earlier were created in order to further unify us globally on important issues with health being the primary focus of SDG goal three.

Current Health of the World

A 2016 study published in the Lancet measured the 195 countries recognized by the United Nations on their Healthcare Access and Quality (HAQ) index (Fullman et al, 2018). The HAQ index distribution in Figure 4 shows that 69 countries received a HAQ score of 50 or below and 123 countries received a HAQ score of 70 or below.

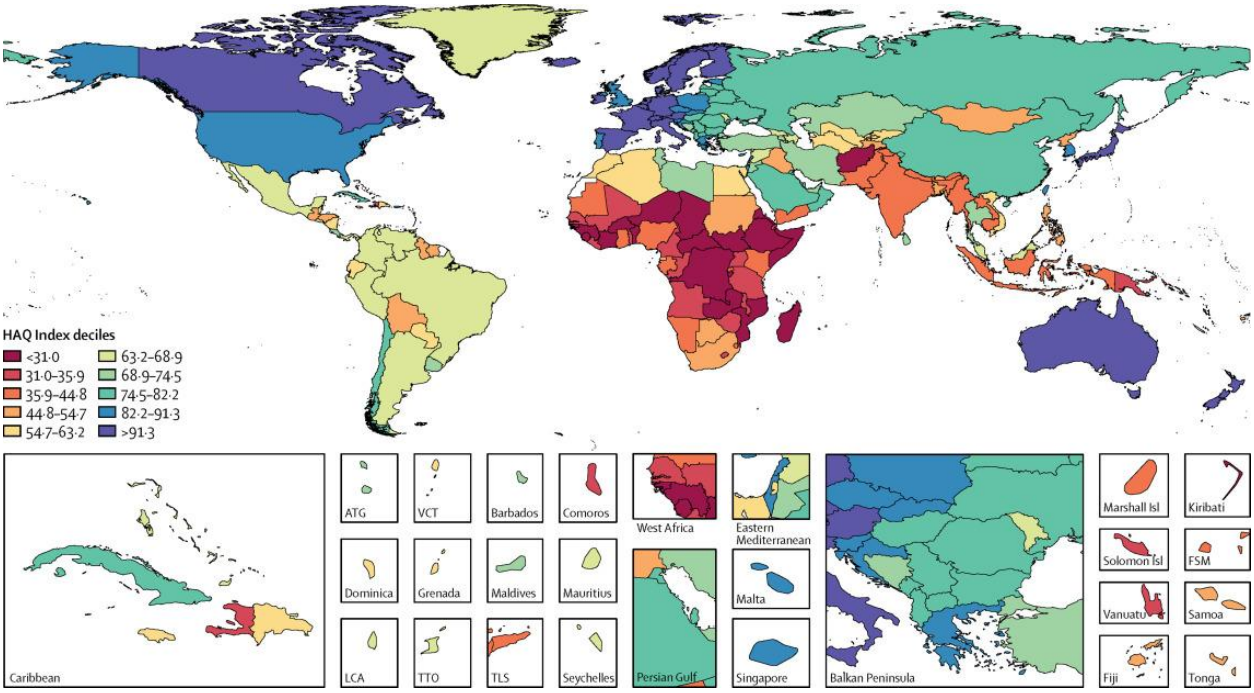

Figure 4: Distribution of HAQ index scores by decile, in 2016. Adapted from "Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016" by GBD 2016 Healthcare access and quality collaborators, *The Lancet,* 391, 2236

Despite all of the efforts to improve the global access and quality of care, 63% of the world is still receiving a failing score for access and quality to healthcare. Many of the strategies to reduce communicable and non-communicable diseases have included

vaccine distribution, mass drug distribution, and health and sanitation education (Fullman et al, 2018). However, these efforts have been largely seen as Band-Aids only reducing prevalence of some conditions but not always helping address the problems associated with those that are living with the long term effects associated with a disease pathway (Fullman et al, 2018). These long term effects such as physical deformities, blindness, and chronic pain have a greater impact on the quality of life and ultimately on a country's economic capacity than the current measures are able to address. In order for there to be true change to a population's health, interventions will have to be implemented that bring strength to a nation's healthcare system outside of the scope of short term non-sustainable interventions.

In-Depth Look at the Surgical Systems of the World

Surgical Systems as a Way to Improve Health Systems

As the global health community has searched for ways to improve healthcare, there has been a rise in the focus on surgical care and the value it brings not only to one's individual health but also the health of a population. Surgery is sometimes thought of being one of the more expensive parts of healthcare when in reality it is very cost effective (Butler et al, 2017). The impact of surgical care is measured in disability-adjusted life years (DALYs). DALYs are a measurement that take into account both the fatal and nonfatal effects of a disease burden. The two metrics that go into calculating the DALY are years of life lost (YLL) and years lived with disability (YLD) (Shrime et al, 2015). In 2010 it was estimated that 16.9 million lives were lost due to surgical conditions, which is 32% of deaths globally that year. Additionally, at least 77.2 million

DALYs could be averted each year if adequate surgical care was available (Bickler et al, 2015). The highest DALY losses are primarily concentrated in LMICS. LMICs are the countries most impacted by the lack of surgical care access while simultaneously are in the greatest need for their population to be productive members of society. This is creating an enduring cycle that must be broken for these countries to be able to grow and function at a sustainable level.

Children and Surgery

Injury related surgical needs as well as congenital abnormalities disproportionately affect children over adults which further exacerbates the healthcare problems persistent in LMICs. In 2017, *Butler Et el*. conducted a survey to measure the burden of surgical care on the children of four LMICs, Rwanda, Sierra Leone, Nepal and Uganda. When examining the impact on the pediatric population, it was estimated that 19% of children had a surgical need and 69% of those needs are not currently being met. This was estimated to be 3.7 million children in just those four LMICs living with a surgical need. With such a large percentage of individuals being impacted at a young age this compounds the economic and lifestyle effects already seen from the lack of surgical care in adults. Having a surgical need beginning in childhood significantly hinders one's ability to contribute to society into adulthood. This affects both the individual and the population as a whole. Similar to the focus of overall global health, the majority of the healthcare improvements centered around children have been focused on infectious diseases, prenatal care, and nutrition. Although these focuses are vitals parts of pediatric healthcare, they are only able to improve a child's well-being to a certain point. A focus

on surgical care specifically at a pediatric level is going to be necessary for ensuring long term success of the global community.

In-depth look at Neglected Tropical Diseases

What are Neglected Tropical Diseases?

The 2010 WHO report on *Working to Overcome the Global Impact of Neglected Tropical Diseases* placed several diseases into a category labeled as neglected tropical diseases defining them as, "a diverse group of communicable diseases that prevail in tropical and subtropical regions of 149 countries- affecting more than one billion people and cost developing economies billions of dollars every year," (WHO, 2010). It was quickly found that this subset of diseases disproportionately affect individuals in poverty. The methods by which the WHO has decided to tackle these diseases thus far have included preventative chemotherapy, earlier diagnosis and detection, increased public knowledge and education, as well as large scale mass drug administration (WHO, 2010).

Long Term Effects of Neglected Tropical Diseases

NTDs have varying long-term impacts on an individual's health and are primarily dependent on the timeliness of treatment implementation. Many NTD conditions have the potential to result in lifelong complications if treatment is delayed. Currently, one of the most common approaches for treatment is mass drug administration or MDA. Although MDA typically reduces the prevalence burden in conditions such as Lymphatic Filariass (LF), it does not help alleviate the burden on those already living with permanent complications from the disease (Mitra & Mawson, 2017).

Economic Impact of Neglected Tropical Diseases

As highlighted in Figure 5, the two NTDs that have the largest impact on a country's DALYs are LF and Soil Transmitted Helminths (Ascariasis, Trichursis, and Hookworm).

Neglected tropical disease	World[b]	WHO region				
		African	Americas	Eastern Mediterranean	South-East Asia	Western Pacific
Human African trypanosomiasis	1 673	1 609	0	62	0	0
Chagas disease	430	0	426	0	0	0
Schistosomiasis	1 707	1 502	46	145	0	13
Leishmaniasis	1 974	328	45	281	1 264	51
Lymphatic filariasis	5 941	2 263	10	75	3 525	65
Onchocerciasis	389	375	1	11	0	0
Leprosy	194	25	16	22	118	13
Dengue	670	9	73	28	391	169
Trachoma	1 334	601	15	208	88	419
Ascariasis[c]	1 851	915	60	162	404	308
Trichuriasis[c]	1 012	236	73	61	372	269
Hookworm disease[c]	1 092	377	20	43	286	364

Figure 5: Impact of Neglected Tropical Diseases on the total global population measured in DALYs by region adapted for the World Health Organization *Report of Neglected Tropical Diseases;* Data on DALY for Buruli Ulcer is not currently available

These conditions also have disproportionately large impacts on pediatric populations as highlighted in Figure 6.

Condition*	Pediatric Global Burden of Disease (per 1,000 DALYs)
Dengue and Chikungunya	1,208
Schistosomiasis	371
Soil Transmitted Helminthiases	1,578
Leishmaniasis	721
Rabies	601
Chagas	3
Scabies and other Ectoparasites	1,507
Trachoma	0
Human African Trypanosomiasis	118
Taeniasis/Cysticercosis	31
Dracunculiasis	0
Echinococcosis	60
Foodborne Trematodiases	139
Leprosy	0
Lymphatic Filariasis	242
Onchocerciasis	273
Total	**6,855**

Figure 6: Table of neglected tropical diseases and its impact on the pediatric global burden of disease measured in DALYs adapted from *Neglected tropical diseases in children: An assessment of gaps in research prioritization* Jan. 2019; DALY Data for Buruli Ulcer is not currently available

In children, both the long term and immediate effects from NTD conditions are often more severe than those seen in adults. This is due to the fact that children are still developing and are much smaller in size than the average adult. Another reason that the DALY impact for NTDs in pediatric populations is so high, is due to that fact that infections can lead to complications that prevent them from walking, seeing, or even attending school, therefore limiting their ability to succeed in society throughout their lifetime (WHO, 2010). An example of this impact is seen in the effects of soil-transmitted helminths. The helminths can grow larger than a child's bowel system resulting in obstructions, which when left untreated can eventually lead to death (Mishra, 2008).

Surgical Interventions are a Necessary Part of Treating Neglected Tropical Diseases

Many NTDs have long term effects that require surgical intervention such as removal of large obstructing worms, reduction of scar tissue, or malformation corrections. The three NTDs with some of the greatest burden, that also have a potential need for surgical intervention, are soil-transmitted helminthiases, Buruli Ulcer, and Trachoma. These three conditions can begin affecting populations during their pediatric and adolescent years, but the long term impact continues to affect these individuals well into adulthood and is continued to be seen in the DALY measurements (Figures 5 and 6). The existing healthcare system needs a stronger surgical care system in order to address the gap in surgical care currently available as well as to adequately reduce the burden seen from neglected tropical diseases.

CHAPTER TWO

Neglected Tropical Diseases with Surgical Applications

Although there are many neglected tropical disease conditions, there are three in particular with some of the largest impact both economically and have a direct relationship with a surgical intervention. These three conditions, Buruli Ulcer, Soil-Transmitted Helminthiases, and Trachoma, all have long term effects such that the full burden of disease cannot be adequately addressed without strengthening the global surgical care system. Although preventative measures have reduced the global incidence, there is a large population that have long term effects not treatable with the current standards of care.

Buruli Ulcer

Burden of Buruli Ulcer Disease

Buruli Ulcer is a condition caused by the bacteria *Mycobacterium ulcerans.* This bacterium will lead to ulcers most commonly found on the arms, legs and affect the bone in extreme cases. Without treatment in a timely manner, it can lead to lifelong deformities and disabilities that prevent individuals from being fully functioning members of their communities (Center for Disease Control (CDC) "*Buruli Ulcer"*, 2019). At the time of diagnosis 28% of individuals already have some form of a disability (WHO "Buruli Ulcer, "*disease profile*", 2018). These disabilities are almost certainly causing economic burden, but unfortunately at this time there has not been an economic study done to quantify the exact DALY loss due to Buruli Ulcer (Ackumy et al, 2011).

Buruli Ulcer has been reported in a total of 33 different countries since the initial case was reported in 1948. From 1948 to 2010 there was a rise in the diagnosis of Buruli Ulcer but since 2010 there has been an unexplained gradual decline in diagnosis (WHO "*Buruli Ulcer"*, 2019; Amofah, 2002). In 2015, 12 of the 15 countries that regularly report information to the WHO regarding Buruli Ulcer, reported new cases as showcased by Figure 7.

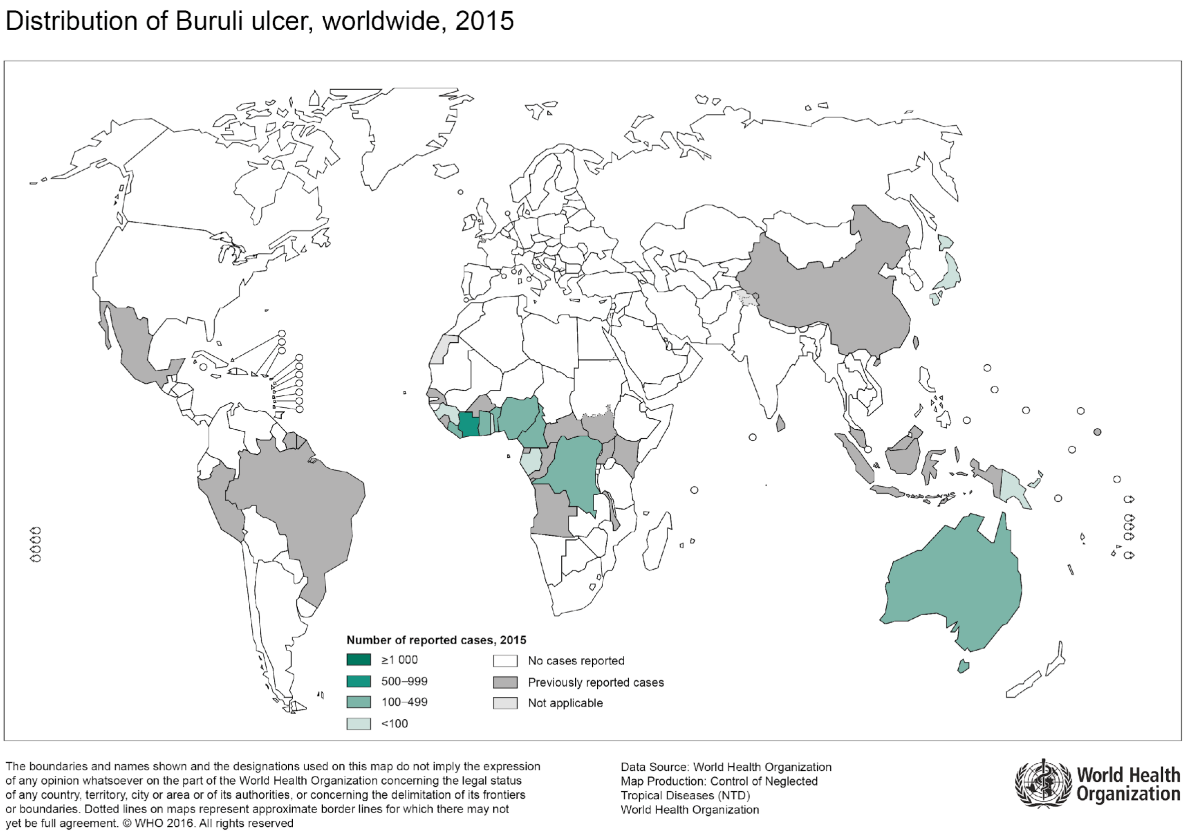

Figure 7: Distribution of the Buruli Ulcer worldwide 2015 adapted from "Epidemiology of Buruli Ulcer" by World Health Organization

From this map, it is seen that the prevalence of Buruli Ulcer is concentrated in central Africa, Australia, and Papua New Guinea. The population at greatest risk of infection is children under the age of 15 with the peak age of diagnosis being in children between the

ages of 10-14 years old followed by a secondary peak in diagnosis seen in those over 75 years old (Portaels, Silva, and Meyers, 2009).

Following a 2 – 14 week incubation period, Buruli Ulcer will cause an initial nodule which is typically painless but will ulcerate within four weeks of initial development (Merritt, 2010). The WHO claims that approximately 70% of Buruli Ulcer cases are diagnosed in the ulceration stage with the remaining 30% being diagnosed during the initial nodule stage. Once the nodule ulcerates, typically within four weeks of the initial nodule formation, there are three categories of classification. Category 1 is as a lesion with a cross sectional area of less than 5cm. Category 2 is a lesion with a cross sectional area of 5-15cm. Category 3 is a lesion with a cross sectional area greater than 15cm, multiple lesions, or a lesion located in a critical area such as the eyes, breasts or genital region (WHO "*Buruli Ulcer",* 2019). The progression of disease through the various categories can range from weeks to months depending on the health of the infected individual especially dependent upon nutritional state and co-morbidity of other infections (Merritt, 2010). At this time there is no known mode of transmission, but studies have shown a strong link between Buruli Ulcer diagnosis and water sources (Debacker et al, 2006). Due to the lack of known transmission, the only current method by which efforts are being made to decrease the burden of the disease are early detection and treatment.

Treatment of Buruli Ulcer

Up until 2004, the only way to treat Buruli Ulcer was surgical care involving skin grafts and reconstruction of tissue. Surgery had long been the only option for providing healing to those that were suffering from Buruli Ulcer but that began to change in 2004.

In 2004, the WHO introduced an 8-week antibiotic standard of care for those with the *Ulcerans* bacterium. The introduction of antibiotic use as a treatment for Buruli Ulcer is thought by some to render surgical treatment completely unnecessary. However, antibiotics have been insufficient in treating those that are in the late stages of category 2 or in category 3. Additionally, concerns have been raised around the difference in healing times and toxicity associated with antibiotic treatment. Antibiotic treatment is still a great option for early stages, but for those that have delayed diagnosis or have significant progression of disease, surgery is one of the only options for treatment (O'Brien et al, 2018). Even with antibiotic and surgical intervention, the disease can take a significant period of time to recover from and requires an average of 3 months in the hospital if the disease is diagnosed at the ulceration stage (Brown and Altman, 2017).

Currently, there is debate over when in the course of the disease surgical intervention is most effective or if a combination of surgical and antibiotic treatment is the best way to accomplish positive results. A 2018 study in the *Infectious Disease Lancet* looked at the pro and cons regarding delayed use of surgical interventions as an adjunct treatment to antibiotics for Buruli Ulcers in Benin. This study concluded that although delayed surgical intervention had better outcomes for decreased time spent in the hospital and overall treatment of condition, it did not affect the outcome on the number of individuals that eventually needed surgery (Wadagni et al, 2018). This study shows that although antibiotic treatment is helpful in addressing the needs of small lesions, once the disease has progressed to a certain state, surgical intervention is still a necessary part of treatment to regain full functionality and prevent long term deformities.

Soil Transmitted Helminths

Burden of Soil-Transmitted Helminth Disease

Soil Transmitted Helminths are populations of worms that grow in the intestinal lining (WHO "*Intestinal Worms"*, 2019). The three main species of worms in this category are roundworm (*Ascaris lumbricoide),* whipworm *(Trichuris trichiura),* and hookworms *(Ancylostoma duodenale)* (WHO "*Intestinal Worms"*, 2019). These conditions have symptoms of diarrhea, abdominal pain, weakness, and malnutrition. Soil-transmitted helminths are a unique classification of diseases in which the severity of the condition is determined by the physical number of worms present inside of the individual (WHO "*Intestinal Worms, disease"*, 2019). Inside of one individual, thousands of eggs can be laid each day resulting in the condition growing exponentially in a short period of time. Transmission of the disease is through feces that contaminate soil and effect unwashed fruits and vegetables (WHO *"Intestinal Worm, disease",* 2019). Larvae take an average of three weeks to mature in the soil prior to being infective to humans so there is no direct person to person transmission (WHO *"Soil transmitted helminths, key facts",* 2019). Following the beginning of the infection, the worms will begin to reproduce within an average of 5-10 days (Jourdan, Lamberton, Fenwick, & Addiss, 2018). The severity increases the more the worms are able to reproduce and within months can lead to severe complications. In the most severe cases, Soil-transmitted Helminths can result in bowel obstruction or perforation, bile duct obstruction, and appendicitis. The full progression of the disease to this point can range from weeks to months depending on the size of the individual infected (Jourdan et al, 2018).

Additionally, Soil- Transmitted Helminths can cause severe malnutrition which in children can lead to stunting, delayed educational access, and potentially even death. Figure 8 shows the distribution of Soil-Transmitted Helminths in its most endemic locations, Africa, Southeast Asia, and South America. It is estimated that currently 1.5 billion people are infected with Soil-Transmitted Helminths (USAid, 2019).

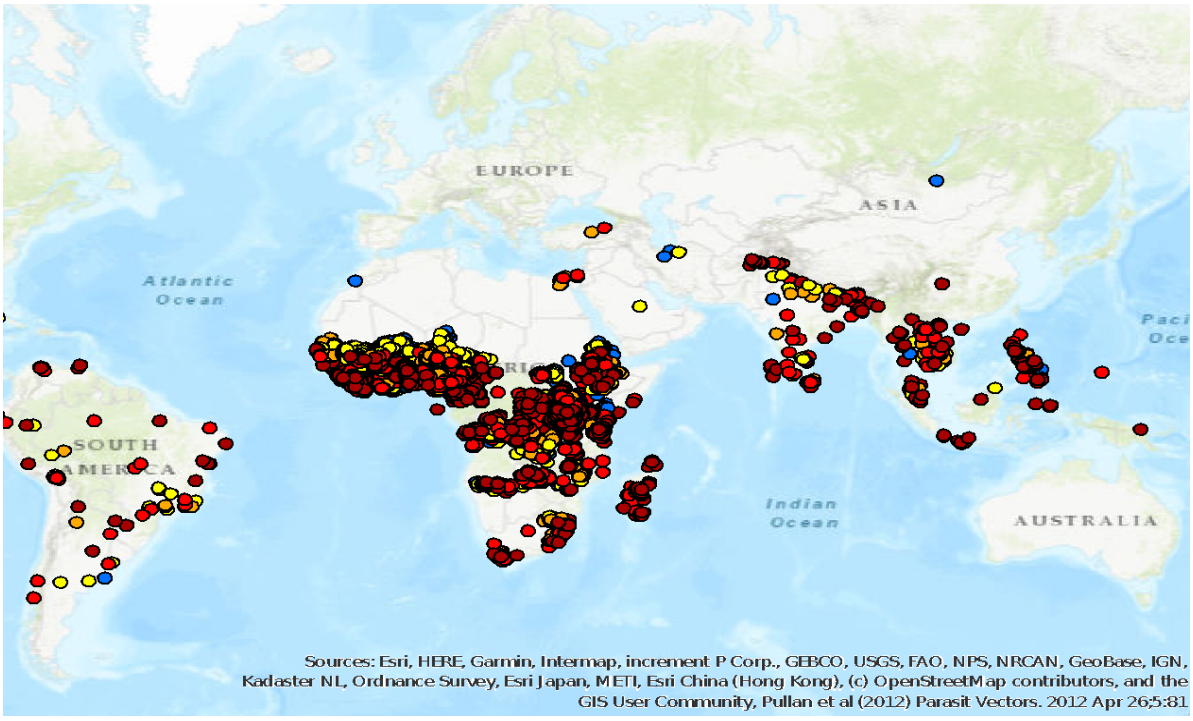

Figure 8: Distribution of Soil- Transmitted Helminths 2012 adapted from "This is my World" by Global Atlas of Helminth Infections London School of Tropical Medicine

Treatment of Soil-Transmitted Helminths

The non-severe cases of Soil-Transmitted Helminths are typically treated with antibiotics that kill off the worm population infesting the individual. However, in extreme cases surgical treatment is required to remove the worms and repair the tissue damage that has been done. The current treatment model has included control through routine drug treatment for those classified as at risk populations. The most at risk populations include pre-school aged children, school aged children and women of child bearing age

(WHO "*Intestinal Worms, disease"*, 2019). The WHO recommends that in communities with 20-50% prevalence, treatment is received once a year and in communities with 50% prevalence or above, treatment is received twice a year (WHO "*Intestinal Worms, strategy"*, 2019). In 2011, over 300 million preschool and school aged children received treatment which cover about 30% of the global at risk pediatric population (WHO "*Intestinal Worms, strategy"*, 2019). Although at least 30% (300 million) of children have received treatment, that means there are approximately 700 million children suffering from prolonged infection of soil-transmitted helminths that could put them at risk for needing emergency surgical intervention.

Trachoma

Burden of Trachoma Disease

Trachoma is the world's leading cause of preventable blindness. Trachoma is caused by the bacterium *Chlamydia trachomatis* and is currently endemic to 57 countries (Rajak, Collin, and Burton, 2012). The World Health Organization's April 2018 data stated that 158 million people live in Trachoma endemic areas and are at risk for developing blindness due to a Trachoma infection (WHO "*Trachoma Fact Sheet",* 2019). Currently 2.2 million people have blindness or visual impairment due to trachoma infection (WHO *"Trachoma, epidemiology",* 2019). One positive aspect of Trachoma treatment is that the visual impairment caused by the diseases is reversible if caught before corneal opacity through the use of both antibiotics and surgical care. The *Chlamydia trachomatis* bacterium is spread through personal contact and those most at risk are women and children between the age of 1-9 years (WHO *"Trachoma,*

epidemiology", 2019). Women are at a higher risk compared to men due to the increased exposure from being in close contact with children (Gebre, 2014). Once infected it only takes five to 12 days for the initial symptoms to begin however it generally takes years for the disease to progress to permeant vision loss (American Academy of Ophthalmology "What is Trachoma?", 2019). In between the time of initial infection and permanent vision loss, antibiotics and surgery are sued to correct the vision loss. In 2014 it was established that cases of vision impairment associated with Trachoma attribute to a loss of 39 million DALYs. This DALY loss has resulted in a loss of productivity equivalent to between US$2.3 billion and US$5.3 billion dollars (Gebre, 2014). Trachoma is a highly treatable disease that has an extremely large impact on the global population.

Classification of Disease

There are five grades of classification of the disease; Trachomatous inflammation – follicular, Trachomatous inflammation- intense, trachomatous scarring, Trachomatous Trichiasis, Corneal Opacity. Visual impairment is caused by all stages of the condition however, Trachomatous Trichiasis is the stage at which the disease requires corrective eyelid surgery to fix the vision impairment done to the eye. The three previous stages necessitate only tropical and systemic interventions (WHO *"Trachoma, disease",* 2019).

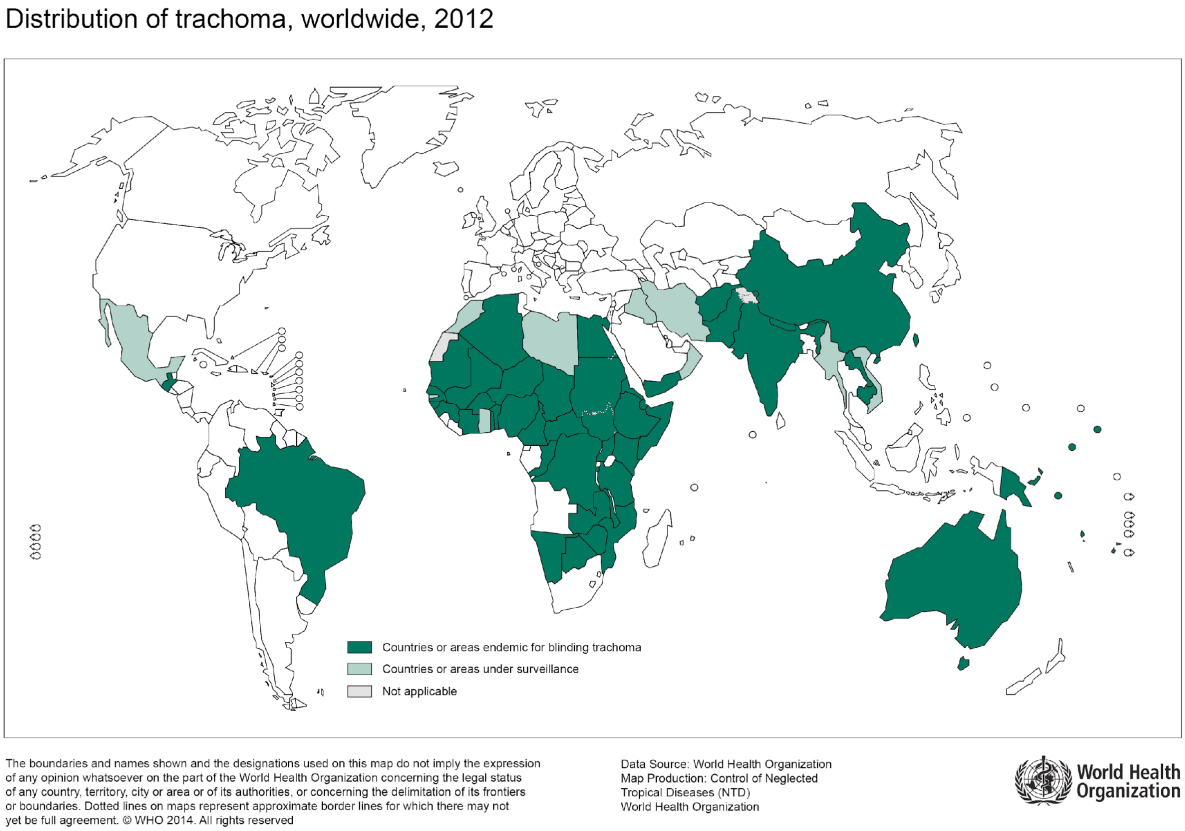

Figure 9: Distribution of Trachoma 2012, "Distribution of Trachoma worldwide: adapted from *World Health Organization*

Treatment of Trachoma

In 1993 the WHO adopted what is known as the SAFE strategy in its approach to treating Trachoma. SAFE stands for "**S**urgery to treat the blinding stage, **A**ntibiotics to clear infection, particularly mass drug administration of the antibiotic azithromycin though the International Trachoma initiative, **F**acial cleanliness, and **E**nvironmental improvement, particularly improving access to water and sanitation" (WHO "*Trachoma Fact Sheet",* 2019). In 1997 the WHO Alliance for the Global Elimination of Trachoma was formed and in 1998 there was a goal set for Trachoma to be eliminated by 2020 (WHO *"Trachoma, strategy",* 2019). In addition to the SAFE program implementation,

there has been increased awareness towards the importance of facial cleanliness specifically in children, and controlling bug populations that fly (Frik et al, 2003). Since the SAFE program was initiated, there has been significant progress in suppressing the burden of Trachoma on endemic populations with a reduction in the population at risk dropping from 190.2 million in 2016 to 157.7 million in 2018 (WHO, *"93rd Weekly Epidemiological Record*", 2018). One study published in 2011 describing the impact of the SAFE strategy in Ethiopia over a three-year period showed that with the implementation of SAFE resulted in a drop from 4.6% to 2.9% prevalence of Trachoma Trichiasis (blinding trachoma) (Roba et al, 2011). In this strategy the goal has been to provide antibiotics to those that do not yet need surgery, get the surgery to those patients that are in the near blindness stage, and to prevent new individuals from acquiring the disease. With the implementation of SAFE, also came a shift in the type of antibiotic used from tetracycline to azithromycin (WHO "*Trachoma, SAFE",* 2019). All Trachoma treatment strategies are implemented to be community based approaches (WHO "*Trachoma, SAFE",* 2019). Despite all of these strategies, one of the major problems has been extremely high rates of recurrence.

Surgical Impact

Impact of a Stronger Surgical Care System on Buruli Ulcer Disease Burden

Although antibiotics have changed the way that Buruli Ulcer care is conducted, surgical care is often times still necessary. Surgery is necessary for those that have significant tissue, muscle, nerve, or bone damage that have not been able to promote healing through antibiotic use. In 2018 the ANZ Journal of Surgery published a study

examining the use of exclusive antibiotics in 600 patients presenting with Buruli Ulcer disease in Australia, an endemic area. The study concluded that aggressive surgical resection which impacts uninfected tissue and other extensive surgical treatments should be avoided whenever possible, especially in small lesions. However, the use of surgery as the predominant treatment for slightly larger more aggressive cases of disease progression has shown increased rates of wound healing, reduced antibiotic related toxicity, and reduction of tissue damage due to severe paradoxical reactions (O'Brien, 2019). From an economics perspective, a study looked at the economic burden on the population in Ghana and estimated that the treatment of Buruli Ulcer can alleviate both direct and indirect costs. The study showed that that the high indirect costs equal to a 45% economic burden. In a 2013 study done in Ghana it was estimated that both the direct and indirect costs resulted in a loss of $35,915.98 per person (Amoakoh and Aikins, 2013). Also, children in this study missed an average of 19 days of school if infected with the disease. This puts a damper on the economic potential of the children affected by this disease and is only worsened through repeated infection.

Children are a subpopulation of individuals that are more susceptible to the disease than others. Additionally, the disease tends to be more severe in children with greater tissue damage than it is in adults. This results in the need to provide surgical intervention with a greater importance placed on not impacting uninfected tissue due to the overall lower amount of healthy tissue available in children than in adults. This requires high precision and therefore a greater level of surgical expertise.

Increasing surgical system strength in countries endemic with Buruli Ulcer will help not only provide increased access to care for those that have long term disabilities,

therefore improving their quality of life, but will also alleviate both the direct and indirect economic burden that many countries are facing as a result of the spread of Buruli Ulcer. Additionally, increasing the surgical strength will allow a higher level of surgical precision to be obtained resulting in better patient outcomes especially in the pediatric population. Alieving the burden of Buruli Ulcer will promote individual, national, and international growth and development.

Impact of a Stronger Surgical Care System on Soil-Transmitted Helminth Disease Burden

Although efforts are being made to expand preventative treatment for all at risk regions of Soil-Transmitted Helminth Diseases, there are adults and children in those regions already suffering and dying due to the unavailability of a surgical intervention. Currently, it is estimated that 60,000 deaths are linked to ascariasis alone which could be avoided if there was an increased surgical system in the endemic regions (Khan and Ghauri, 2016). In children the burden of disease is more much severe. It is estimated that 2 per 1,000 infected children will result in a bowel obstruction that would necessitate an emergency surgical intervention (Haburchak, 2018). This means that of the 804 million cases of ascariasis in 2013, an estimated 1,608 needed a surgical intervention and depending on their access to surgical care might have died due to their infection (Haburchak, 2018). Children are in the greatest need for a surgical intervention due to the smaller size of their intestinal tract. However, pediatric surgery requires a higher level of surgical expertise and further necessitates the need to increase the surgical system strength. For this reason, it is necessary to increase surgical system strength in the endemic areas to provide a more adequate treatment of this condition.

Intestinal worm obstruction not only impacts the individual but the entire community. If deaths and the presence of Soil-Transmitted Helminths are reduced, then the functionality of the community as a whole will improve, allowing it to focus more on aspects of development. Overall it is a necessity, along with the expansion of treatment to all at risk populations, that surgical system strength be a priority in order to reduce the burden for those with the most severe infections. Through the continued use of antibiotics, early detection, and increased surgical system strength there will be a reduction in the physical and economic burden of soil-transmitted helminths.

Impact of Stronger Surgical Care System on Trachoma Long-Term Burden of Disease

Surgery has been demonstrated by the World Health Organization as being a primary means to reduce the long term burden of Trachoma on an individual and therefore on the global community. This has been demonstrated through surgery's integration into the SAFE global treatment strategy. Although surgery is a major part of the SAFE treatment strategy, one of the major issues seen in patients that have received surgery for their Trachomatous Trichiasis, is an extremely high rate of recurrence. In patients diagnosed with Trachomatous Trichiasis there has been a recurrence rate ranging from 7.4% after one year and 62% after three years in patients (Rajak et al, 2012). There has been research into looking at what could be causing the widespread reoccurrence seen in surgical patients and the two main contributors have been narrowed down to surgical technique and skill of the provider performing the surgery (Rajak et al, 2012). In many of the Trachoma endemic regions the surgical procedures are primarily performed by nurses and eye-care workers who have very limited training in surgery (Rajak et al, 2012). Surgeries performed by these healthcare team members have received training in a

short intensive period of time which includes very little follow up or continued education. This short training period and lack of follow up on standards is cited as a major contributor to trachoma recurrence rates in these patients (Rajak et al, 2012). In order to address this problem, an increased regulation and education system for these surgical procedures needs to be implemented.

However, even amongst surgeries performed by trained surgeons there are studies showing anywhere form 0-83% rates of recurrence using the current surgical approach. This is credited to the fact that although performing the same method there are variations in technique within the standardized method. These differences include subtle variation in the length of incision, placement and tightness of sutures, and postoperative follow up practices (Rajak et al, 2012). These small differences have played a large role in patient outcomes and have been correlated with increased recurrence rates (Rajak et al, 2012). There has been little research thus far in how to improve the official technique used to perform these surgeries, but evidence suggests that more research should be done in this area. In order to address the concerns on differences in technique, there will need to be a more robust surgical care system and training.

In children, the inflammation of the eye lid and therefore the scaring associated with the infection is more severe than in adults. Due to this, children tend to progress to the state of needing a surgical intervention faster than their adult counterparts. Additionally, they need a more rigorous course of antibiotics and require a more delicate surgical procedure (Lansingh, Callahan, and Emerson, 2017). In order to meet the need of the children progressing through the disease at a faster rate as well as having smaller

more delicate structures necessitating very little surgical error, the current system will need to be strengthened to make a meaningful impact.

Overall having a stronger surgical system for the treatment of Trachoma can improve access and availability of surgery to the 2.2 million individuals living with visual impairment due to the disease. Additionally, improving the surgical system would increase the consistency and guidelines for training and performance of trachoma surgery overall reducing the rate of recurrence. By cutting down on the prevalence of trachoma and reducing the recurrence rate, the overall physical and economic burden of trachoma will be reduced.

Summary of the impact of NTDs in need of surgical intervention

Diseases	Summary of Epidemiology	Surgical Intervention	Surgical Need
Buruli Ulcer	~2200 new cases/year [a]	Adjuvant to antibiotic treatment and typically not seen as necessary until category two or three	Depending upon the practitioner's belief in regards to antibiotic and surgical effectiveness between 50-100% of those diagnosed will need some form of surgical intervention. Estimations of those that have received a surgical intervention for their infection is not available [d]
Soil Transmitted Helminths	1.5 million people infected globally at any given time, 800 children are currently estimated to be in need of treatment [b]	Severe cases, most commonly Ascariasis, to prevent bowel obstruction which can be life threatening	Mainly needed for pediatric population. 2 per 1,000 infected children with ascariasis need surgery. 2013 ~ 1608 new surgical cases emerged in just 2013 [e]

Trachoma	2.2 million individuals living with visualizing impairing trachoma [c]	To correct blindness due to the disease, happens primarily in very aggressive or untreated infections	~ 5 million individuals are in need of a surgical intervention due to trachoma infection [f]

Table 1: Summary of NTDs and surgical intervention; a – WHO "Epidemiology of Buruli Ulcer", 2019, b – WHO "Epidemiology of Soil Transmitted Helminths", 2018, c - WHO *"Trachoma, epidemiology",* 2019, d- Ackumy et al, 2011, e - Haburchak, 2018, f - WHO *"Trachoma, disease",* 2019

A Stronger Surgical Care System is Necessary to Treat Neglected Tropical Diseases

Conclusion

Buruli Ulcer, Soil Transmitted Helminths, and Trachoma are all three conditions that with the improvement of the global surgical healthcare system would have a reduced burden of disease. These conditions are hurdles to the growth of countries, as seen through the loss of DALYs decreasing economic growth in impacted regions. However, once these burdens are relieved through increased surgical system strength, areas endemic for these NTDs will be able to return focus towards growth and development with stronger productivity.

CHAPTER THREE

Confounding and Modifying Variables

Variables

Although there is a link between neglected tropical disease burden and access to surgical care there are confounding and modifying variables that play a role in complicating this relationship. These variables include socioeconomic status, healthcare infrastructure, cultural beliefs regarding medicine, conflict and war, population density and age distribution. Socioeconomic status, infrastructure, cultural beliefs regarding medicine, and conflict are classified as confounders because they can distort the relationship seen between neglected tropical disease burden and surgical system strength. Specifically as confounders these variables could be seen as competing explanations for how to reduce the burden of NTDs. However, the variables population density and age distribution are classified as modifying variables because these variables identify subpopulations that are impacted by the NTD and surgical system strength relationship differently. Individuals in various population densities and age ranges may be more or less impacted by NTDs but cannot alone be used as an explanation to reduce the burden. Overall, these variables make it more difficult to draw connections regarding the direct relationship between neglected tropical disease burden and surgical system strength, therefore contributing to the health disparities seen around the world.

Confounding Variables

Socioeconomic Status

Socioeconomic status presents as a confounding variable due to the monetary cost associated with both treatment for NTDs and surgical care. Figure 10 shows the classification of countries by income per capita.

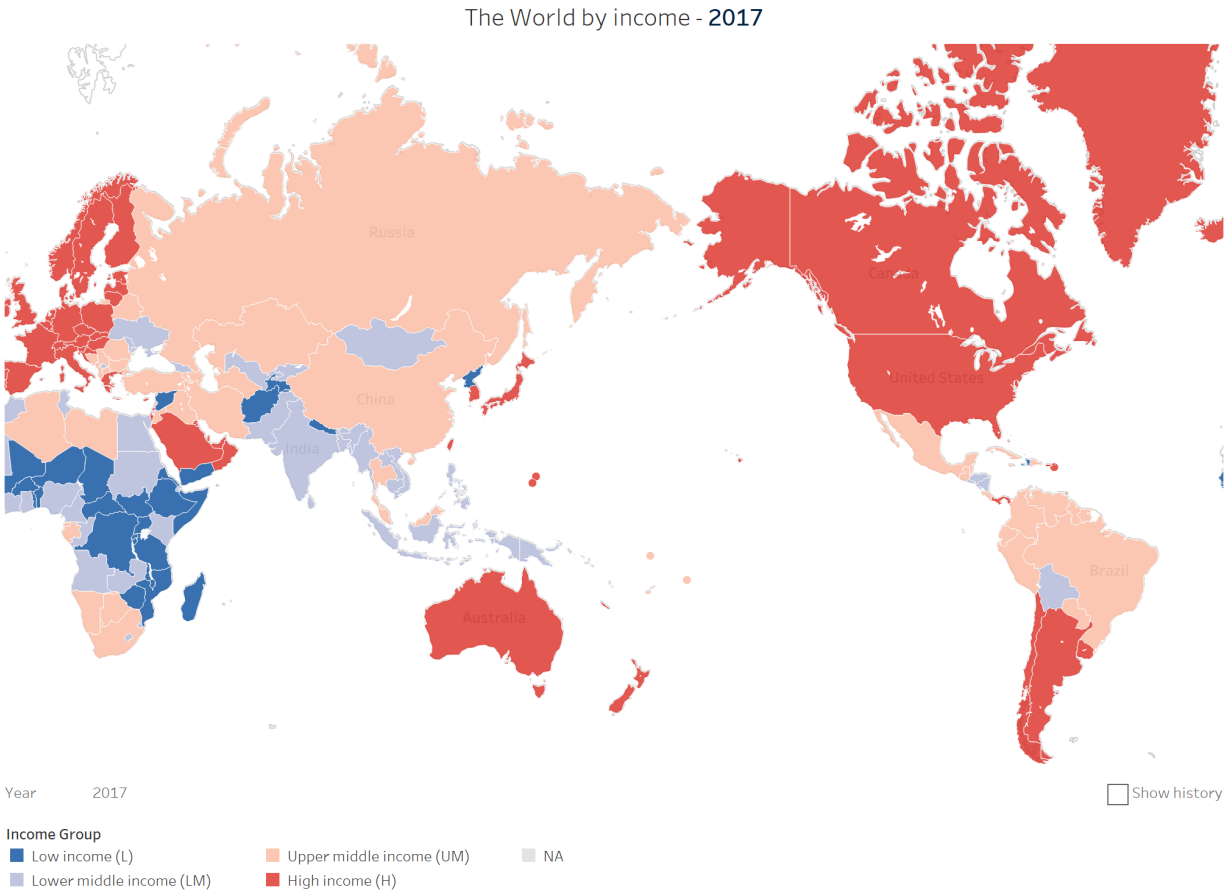

Figure 10: The World by Income, adapted from the World Bank

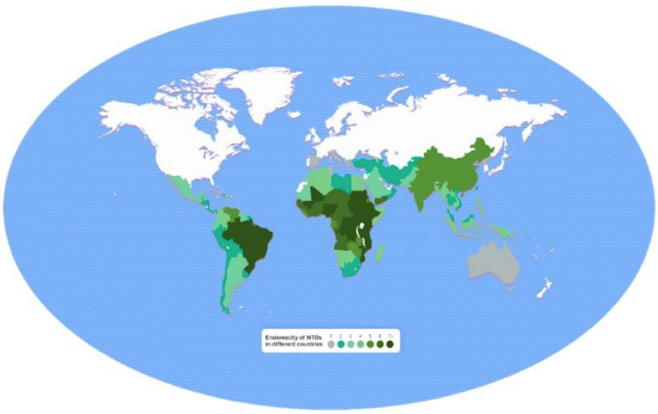

Figure 1: Endemic distribution of neglected tropical diseases Sep. 2017 adapted from "Neglected Tropical Diseases: Epidemiology and Global Burden" by Amal Mitra and Anthony Mawson, *Trop. Med. Infect. Dis.* 2017, *2*, 36

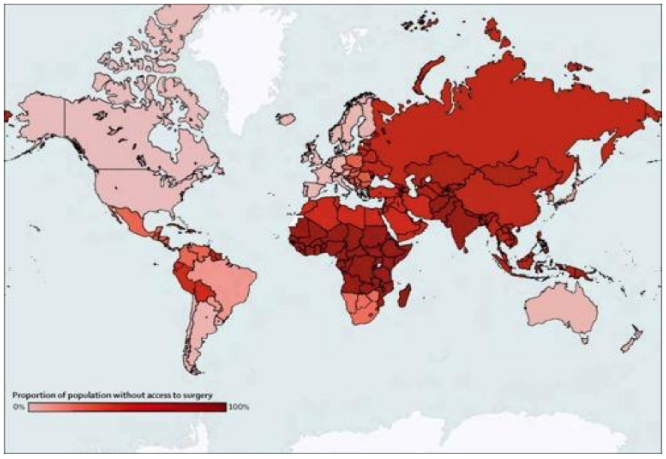

Figure 2: The proportion of population without access to surgery from June 2015, adapted from "Global Access to surgical care: a modeling study" by Alkire Elt. El, *The Lancet Global Health,* 3, 316-323

When compared with the burden of NTDs and the access to surgical care in Figures 1 and 2 respectively, there is significant overlap in regions that are labeled as low income and lower middle income countries that are being affected by NTDs as well as struggling with inadequate surgical care. The countries that are most in need of treatment for NTDs are also the countries with some of the lowest income availability per capita. This means that not only is obtaining surgical care difficult, but the costs associated with treatment for an NTD could be contributing to the overall lack of ability to receive care in a timely manner.

Infrastructure

An additional confounding variable is healthcare infrastructure in those places with an NTD burden. For healthcare specifically, a value for examining a country's infrastructure is the number of hospitals per 100,000 people. Figures 11a-11c display the WHO's global data observation collection on the number of hospitals for every 100,000 people. For this measurement, the data includes all rural and district hospitals, specialized hospitals, provincial or second level hospitals, teaching and research hospitals and private hospitals. Although the WHO data does not include measurements from all countries, it does include countries from all three income levels (low, middle, and high) as well as is inclusive of multiple regions. Figures 11a-11c highlight how a large number of countries have fewer than 10 hospitals with only Guinea-Bissau and Micronesia having more than 10 hospitals per 100,000 people and majority of countries falling below even 2 hospitals per 100,000 people. This measurement however can be looked at a bit deeper by examining the hospital beds per 10,000 people. The number of hospital beds per 10,000 people gives an idea of the number of individuals in each country that could receive tertiary care at one time if needed. Figures 12a-12c show the number of hospital beds for each country as a measurement per 10,0000 people. These figures shows that the majority of countries with high numbers of hospital beds are also high income countries. Low and middle income countries that neglected tropical diseases are most impacting have an average of 10 or less hospital beds per 10,000 individuals. The lack of hospitals or hospital beds could be a confounding variable representing lack of access to treatment and even lower access to higher level interventions such as surgery.

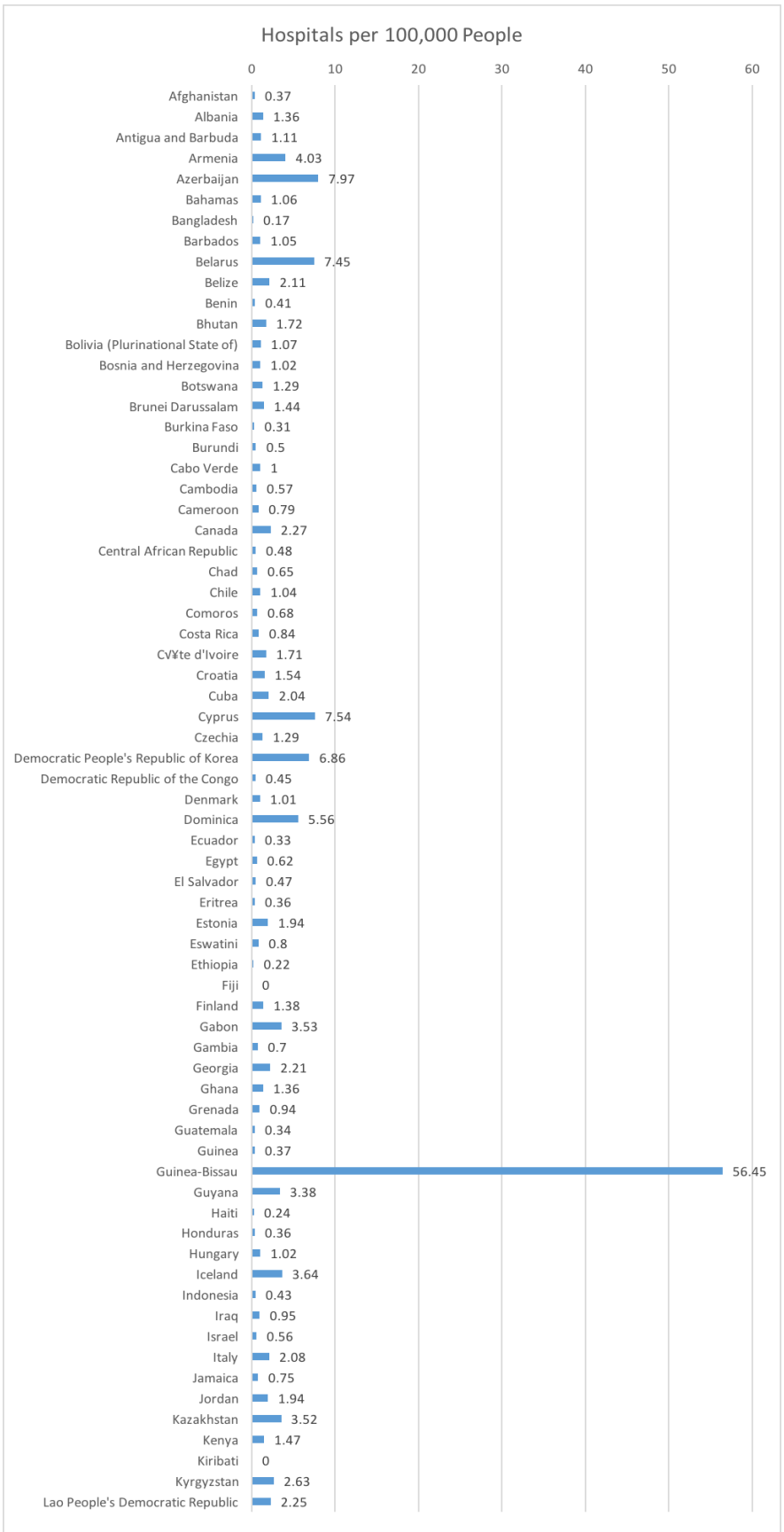

Figure 11a: World Health Organization, Global Health Observatory Data *Hospital per 100,000 individuals*, 2013

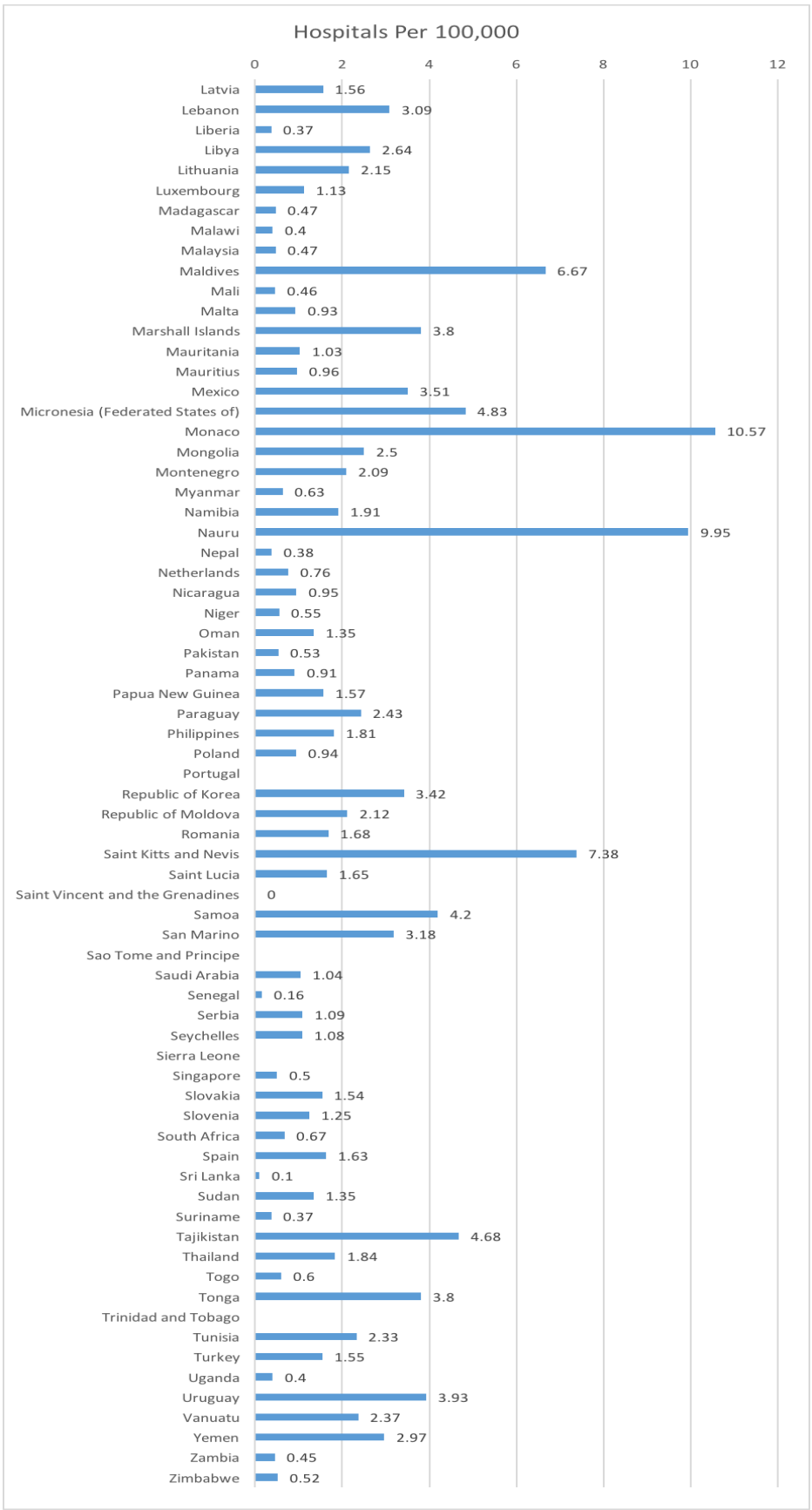

Figure 11b: World Health Organization, Global Health Observatory Data *Hospital per 100,000 individuals*, 2013

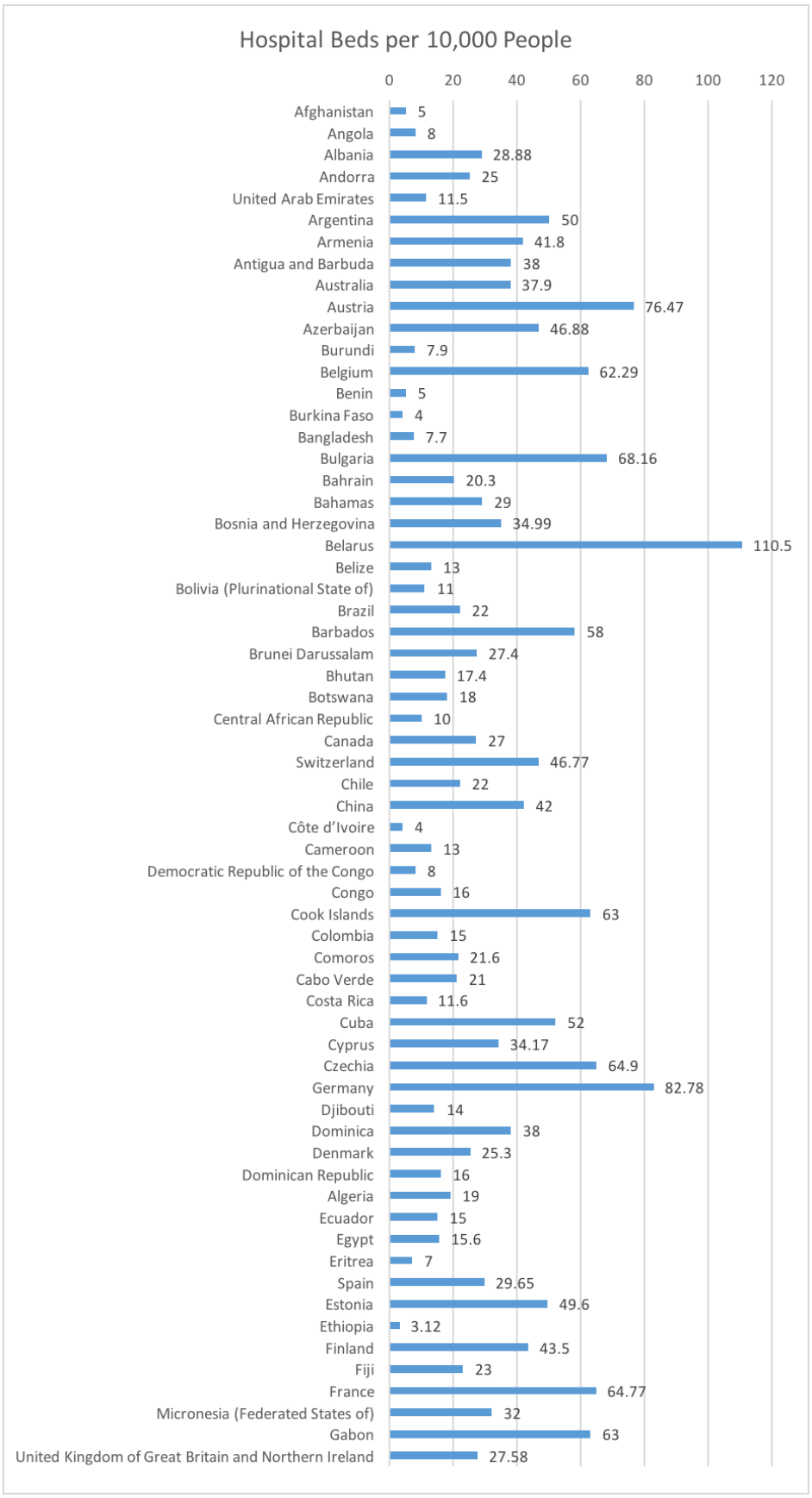

Figure 12a: World Health Organization, Global Health Observatory Data *Hospital Beds per 10,000 individuals*,

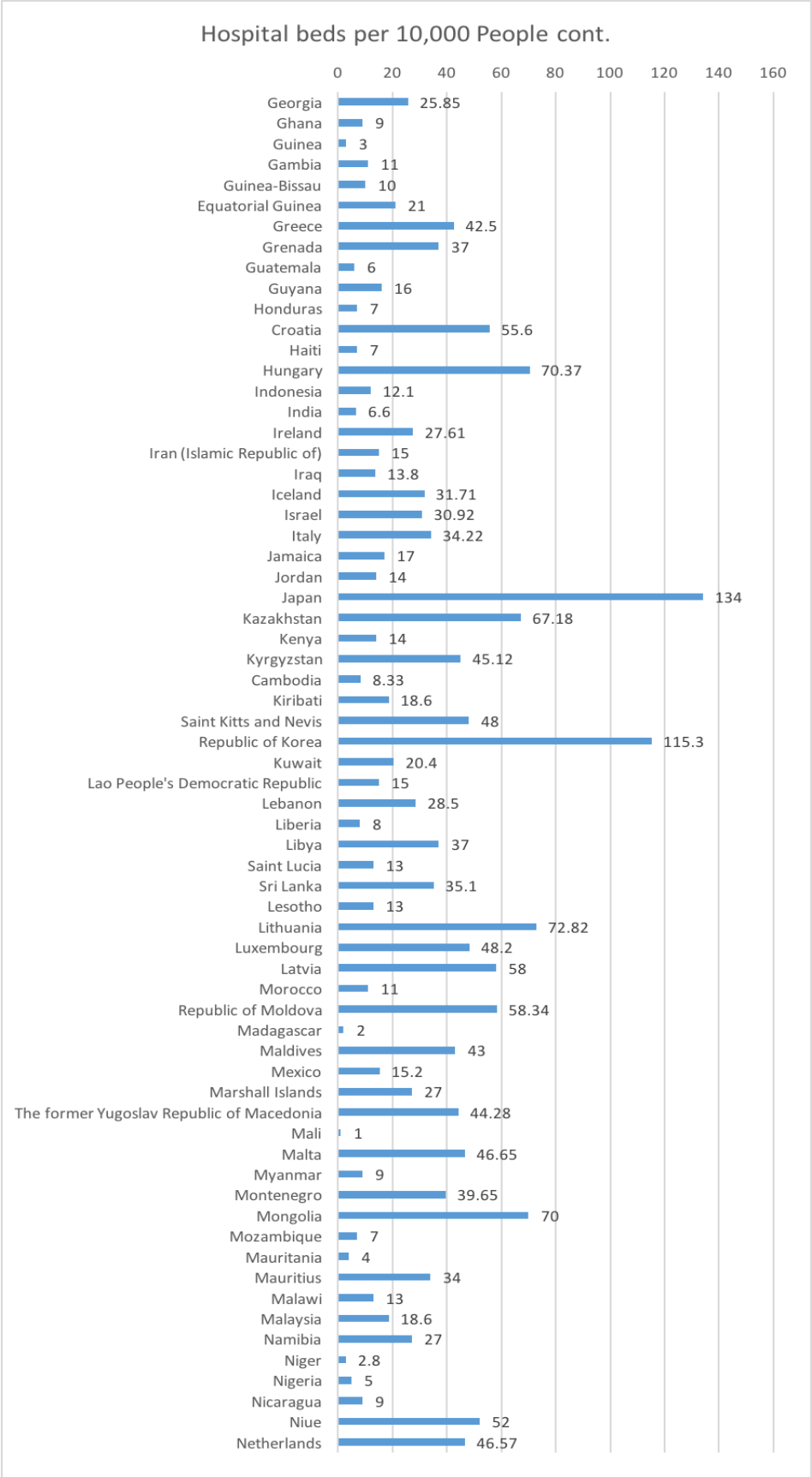

Figure 12b: World Health Organization, Global Health Observatory Data *Hospital Beds per 10,000 individuals*,

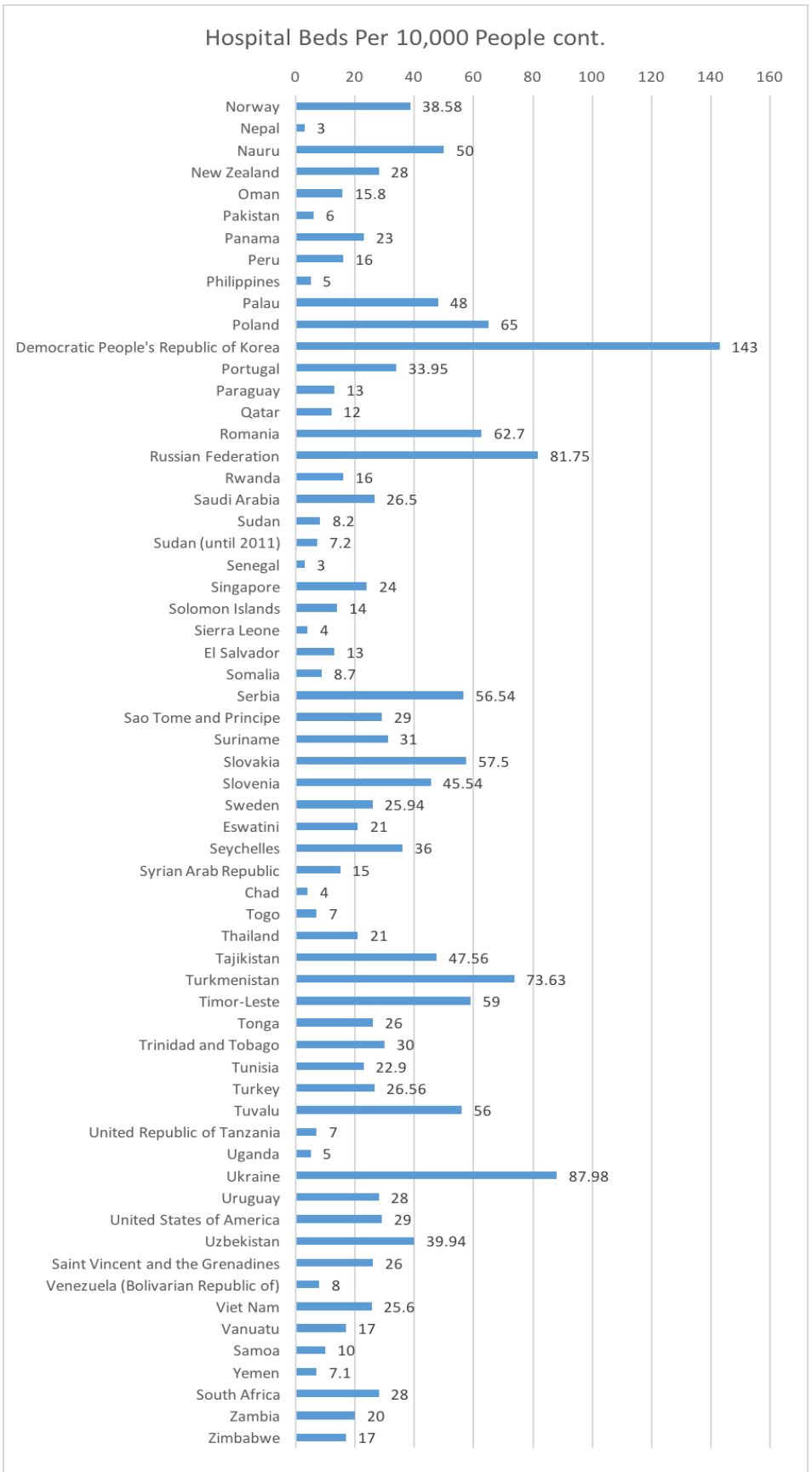

Figure 12c: World Health Organization, Global Health Observatory Data *Hospital Beds per 10,000 individuals*,

Cultural Beliefs

Cultural beliefs of the country's most greatly burdened by NTDs play an important role in the treatment of these conditions. In Ethiopia for example, which has a high burden of trachoma endemic throughout the population, there is a large emphasis on utilizing traditional medicine practices prior to any sort of westernized medical help (Kassaye et al). This comes out of the tribal emphasis that the country has specifically regarding their practice with spirits (Skolnik, 2019). This cultural difference often results in delayed medical treatment resulting in a much more severe burden of disease (Kassaye et al). Cultural opinions towards medical practice can serve as a barrier not only in Ethiopia, but also in many of the countries that are fighting NTD presence. Additionally cultures such as those in Peru, Kenya, and India have traditional beliefs regarding sickness. These cultures typically believe there is a spiritual element to their condition and that treatment or surgery alone will not heal them or if it does, there is still a societal hesitation towards those individuals in case they can pass off their negative spirits (Lawrence, 2013). Lastly a cultural belief that can be a barrier to care is the mistrust of a culture's existing healthcare system. One study from Ghana showed that depending on what part of the country one is in, up to 50% of individuals reported not seeking surgical care for a problem they were having because of their fear or distrust of healthcare professional (Stewart et al, 2015). This was also the case in a study done in Nepal (Stewart et al, 2015). Mistrust of the healthcare system is a cultural belief that impedes the relationship between the NTD burden and surgical system strength. A culture's various beliefs surrounding healthcare are vital to understanding and appropriately

addressing a culture's healthcare needs. Therefore, cultural beliefs can be a confounding variable between the NTD burden and surgical system strength relationship.

War and Regional Conflicts

War and conflict in a region can act as a major inhibitor to the access of medical treatment for NTDs and ultimately for surgical care. War and regional conflicts often lead to the destruction of buildings, government materials, and result in public safety concerns. Both intentional and unintentional destruction of medical facilities or supplies, prevent early treatment from taking place for neglected tropical diseases or for a surgical intervention to take place due to the lack of facilities and supplied. Additionally, for the concern of safety, citizens may be fearful of attempting to access medical care therefore disrupting the correlation between our two variables (Levy and Sidel, 2016). Figure 13 shows the United States travel advisory warnings based on a country's current conflict situation.

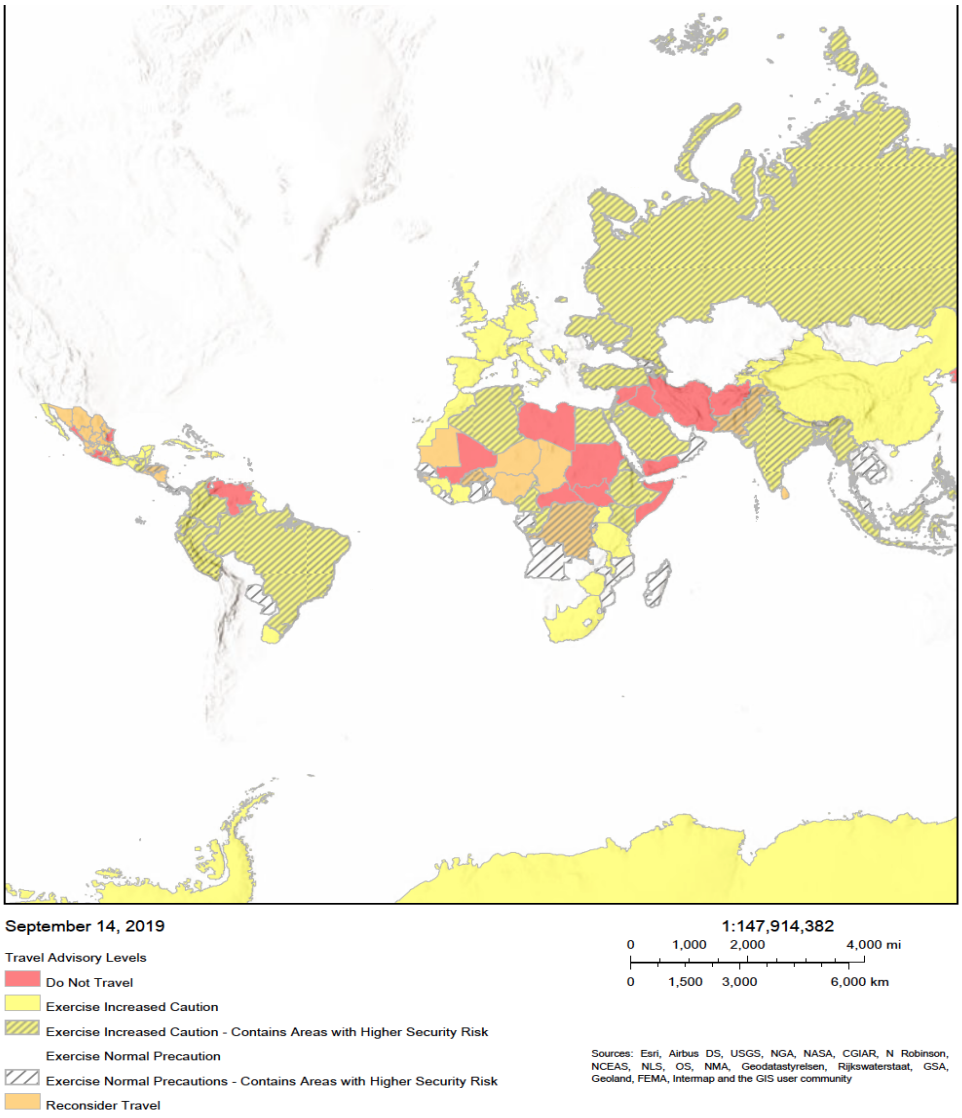

Figure 13: US State Department Travel Advisory Map Sept. 2019 adapted from United States State Department

When compared to Figure 1 displaying the burden of NTDs and Figure 2 showing the global surgical care access there is a correlation between increased burden of NTDs and decreased access to surgical care with the increased risk of travel due to conflict. For this reason, war and regional conflicts may be a confounder to the overall relationship being described.

Modifying Variables

Population Density

Population density may be a modifying variable. When countries focus efforts on healthcare improvement, they typically first address the needs of the highly populated areas which often includes those of a higher economic status in the country (Yegorov, 2015). This may result in many countries' resources having focus on highly populated wealthy regions. Those in the lower populated areas, which are commonly of lower socioeconomic status, as well as often home to many of those infected with neglected tropical diseases, are not able to access care for a disease or surgery when needed if efforts are centered on their higher populated counterparts. However, too high of a population density can result in a breeding ground for lots of infections and contribute to the burden of neglected tropical diseases. Those individuals may have an easier time accessing care due to efforts to address the disease being focused in areas that will provide the greatest impact to the most individuals. In both of these cases, population density can be helpful or hurtful towards the relationship between neglected tropical disease and surgical system strength but is impacting the overall outcomes. The differences in population density globally are shown through Figure 14 and play an important role in understanding the NTD and surgical system relationship.

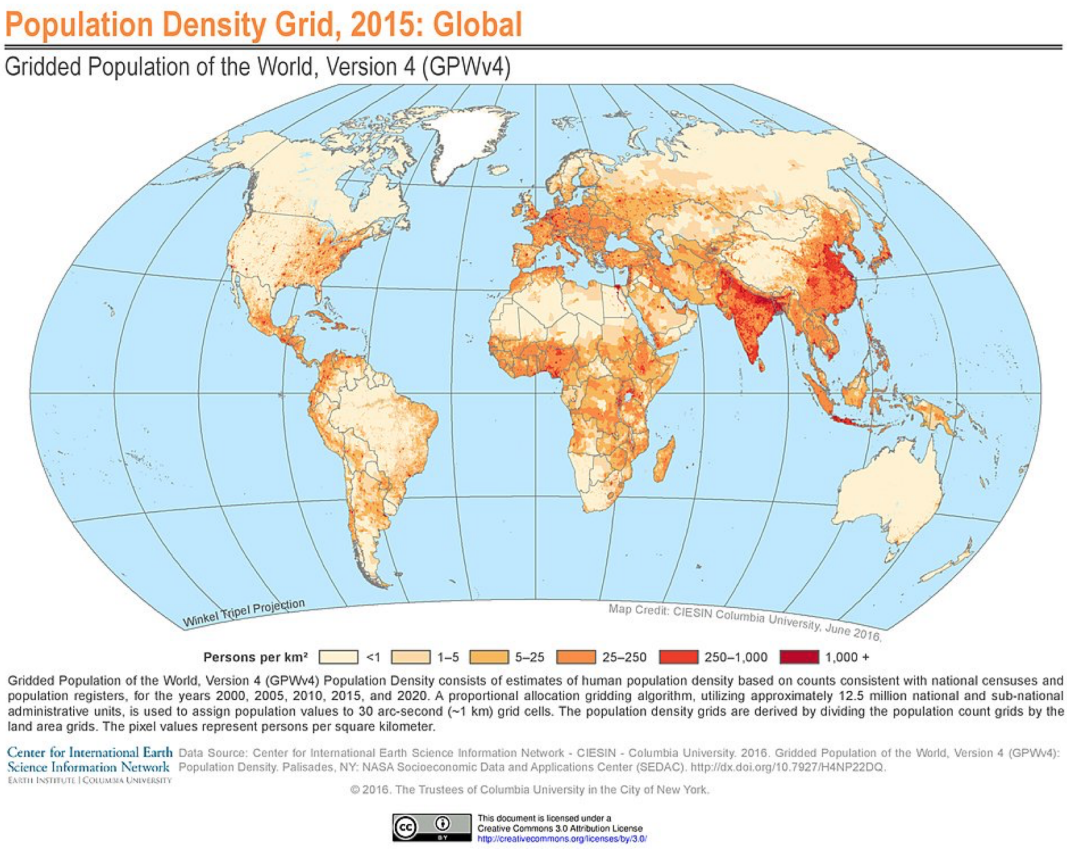

Figure 14: Population Density Grid, 2015:Global, Center for International Earth Science Information Network

The map in Figure 14 displays that when overlapped with Figures 1 and 2 showing NTD burden and lack of surgical care respectively, there is a correlation between low population density and disease concentration in the previous two maps. This is interesting due to the fact that regardless of the lower population density in these regions, the DALY impact of NTDs and surgical care access are still both very large and is most likely due to how large of an area is affected. Population density can be a modifier in the NTD and surgical system relationship contributing to the healthcare needs of those in largely populated areas as opposed to those that are in rural regions.

Age Distribution

Lastly, age distribution of the infected population may also be a modifying variable to the relationship between NTDs and surgical system strength. Research on the immunological system tells us that the young and the old are more susceptible to illnesses and NTDs are no exception (Parham & Janeway, 2015). Younger and older populations also are often dependent on someone else around them to order to receive their basic needs, meaning they are typically limited in their independent survival abilities. For example, in an older population even though they may have a health facility within their town or village, they might not have the physical ability to leave their home in order to receive the necessary care. Another example includes a young child who is sick. The child may be unable to receive healthcare because their parents work during the day and cannot take them to the clinic during the hours they are open. In both of these cases it is the patient's age that affected their ability to receive care. Figure 15 shows the median age of each country.

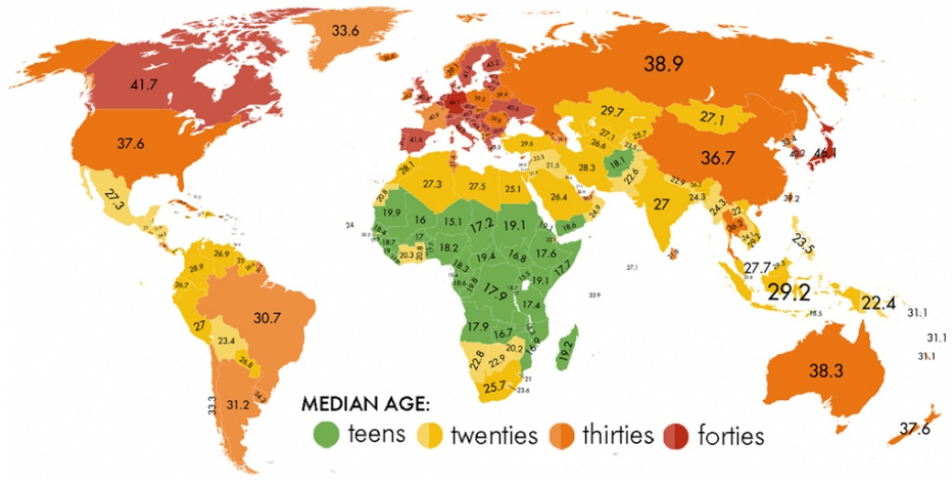

Figure 15: World Map of Median Age adapted from CIA World Factbook (2018)

When looking at Sub Saharan Africa, Southeast Asia, and South America, the median age ranges from 15-27 years old. This is a low median implying that much of the population

in these areas are of young age and are therefore more susceptible to illness. These regions also correlate with Figure 1 showing NTD burden. Ultimately, age distribution of an infected region can modify and complicate the NTD and surgical system relationship. As the world's population continues to age, this variable will become more and more important in addressing the NTD burden and surgical care system globally.

Conclusion

NTD and Surgical System strength relationship has confounders and modifiers

The relationship between neglected tropical diseases and surgical system strength may be confounded by socioeconomic status, infrastructure, cultural beliefs, war and regional conflict. It may also be modified through population density, and age distributions. All of these variables can play a role in affecting the overall result, both positively and negatively, of surgical system strength and the desired outcome of reducing neglected tropical disease burden. Further study of these variables is necessary as it may reveal a unique connection vital to the success of addressing both surgical need and disease burden of NTDs in their endemic regions.

CHAPTER FOUR

Potential Solutions and Conclusion

Summary

Since 2007 with the identification of the neglected tropical disease targets by the WHO, there has been a push to decrease the burden of NTDs in affected regions. Up to this point, the primary focus has been on prevention of disease as well as getting treatment to those that are actively infected. However, although these methods are helping to alleviate the burden, they are not fully addressing the problem. There is a subsection of people, particularly those that have been infected with Buruli Ulcer, Soil-Transmitted Helminths, and Trachoma, that due to delayed treatment of the condition are developing long term effects that only surgery can help address. These individuals are suffering from physical deformities, chronic pain, and in some cases blindness that is preventing them from being fully functioning members of society and adding an extra burden upon their families. If the global community truly intend to alleviate the burden that these NTDs have on individuals and communities, implementing a more robust surgical care system is going to be necessary. However, in order to strengthen a surgical care system, there must be a plan in place that will enable countries to move forward in addressing the issues of their current surgical system.

How to Strengthen the Surgical System

In order for the surgical system to be improved upon, there must first be benchmarks in place as a means of a strength measurement. The World Health

Organization uses six core indicators, demonstrated in Figure 16, as their means of measuring the strength of a country's surgical system; access within two hours, surgical anesthetic and obstetric provider density, surgical volume, perioperative mortality rate, protection against impoverishing expenditures, and protection against catastrophic expenditures (WHO, 2015).

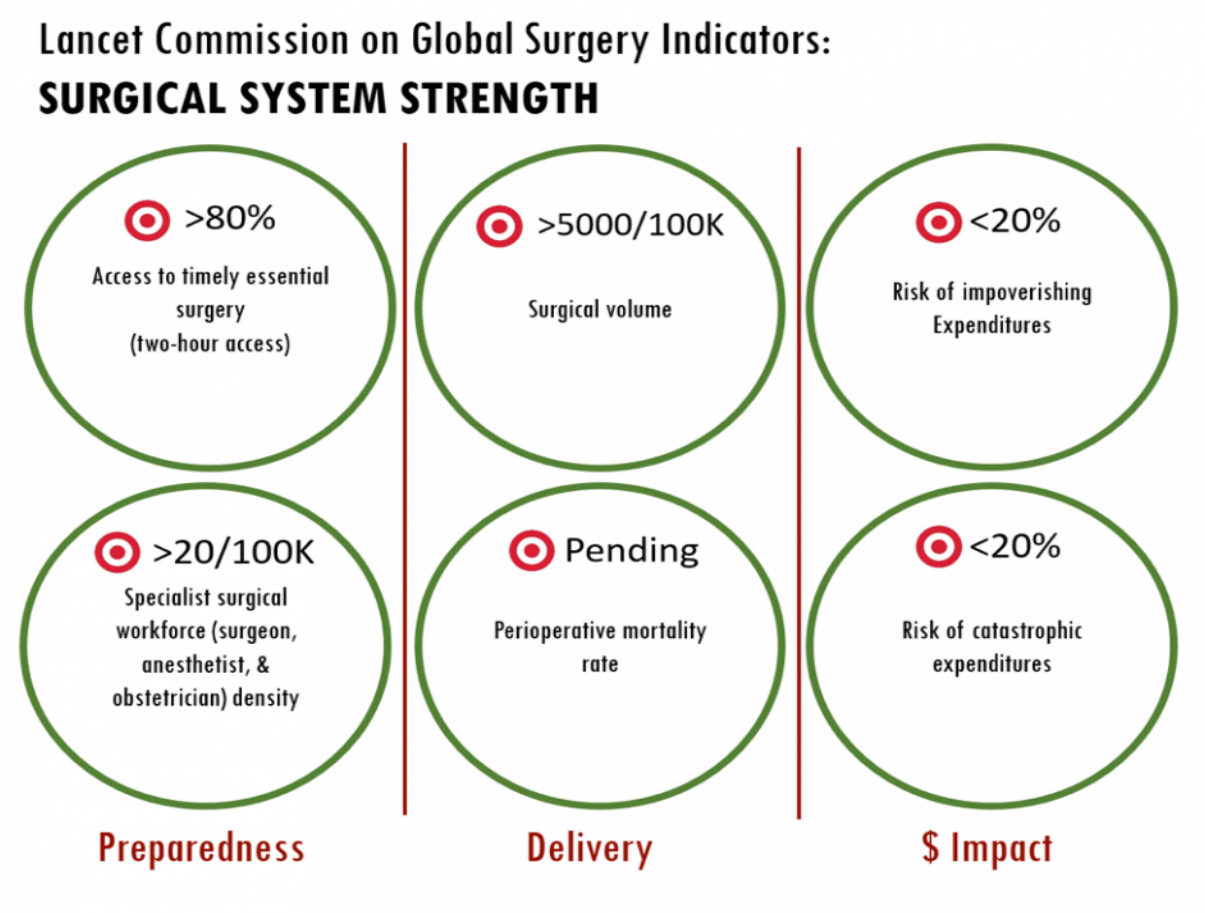

Figure 16: The Lancet Commission *Surgical Care Systems Strengthening*, 2017

These core indicators serve as target measurements to track the improvement of the overall surgical system.

According to the WHO 2017 publication on *Surgical Care Systems Strengthening,* three of the key pieces of a successful plan for system strengthening are

integrating a plan of action into the overarching health care plan for the nation, including all relevant parties to the conversation about said plan, and providing adequate training and then retention of surgical workers. Additionally, there needs to be a level of accountability for transparency on progress towards these surgical goals. This means that there needs to be a centralized tracking system that functions as a baseline measurement. Therefore, the first step in improving a country's overall surgical system strength is to first have adequate health data measurements in these six core areas (WHO, 2017). In 2015 there was a push towards improving the collection and utilization of health data as a means to direct health policy and guide potential improvements (Bram, Warwick-Clark, Obeysekare, and Mehta, 2015). Having baseline data for the six core surgical indicators mentioned earlier is vital to the ability of a country to improve its current system. Without health data and long-term data tracking there is no way for a country to identify its particular problem and address it effectively (Bram et al, 2015). Having the access, workforce, and funding to obtain and track this data can be difficult, so it is vital for the central government to place a level of importance on surgical system strength in order to accomplish the goal of improvement (WHO, 2017).

After gathering the data and identifying the areas of greatest weakness, a task force should be formed to tackle what needs to be done to address that country's specific problems. This group needs to be made up of individuals from all entities that would be impacted by surgical care changes such as the ministry of health, citizens, and policymakers.

One avenue that can be explored in order to strengthen the surgical system of a country is to look into partnerships with NGOs that could meet the need for training or be

able to provide resources outside of those the national government is able to contribute. One example of this kind of partnership is between Mercy Ships and the Republic of Madagascar (WHO, 2017). Mercy Ships has partnered with Madagascar to help train and provide resources for surgical care in portions of the country's most underserved areas. However, one of Mercy Ships' main roles in Madagascar was to help establish baseline data for the WHO core surgical indicators (WHO, 2017). When Mercy Ships left Madagascar, they passed off the work they had been doing to another NGO that was well established in Madagascar, and in conjunction with the Ministry of Health, they have continued to collect data, train, and work to strengthen the surgical care of Madagascar (WHO, 2017). Through partnerships with international NGOs like Mercy Ships and locally established NGOs, countries are often able to train and equip an underserved surgical region more quickly than if the government was responsible for funding all training by themselves (WHO, 2017).

One key aspect of growing a surgical care system is training and retaining surgical workers. Globally only 12% of surgical workers practice in low and middle-income countries which account for one-third of the world's population (Meara, 2015). Additionally, within countries there is not an equal distribution of surgical care workers leading to a further disparity (Meara, 2015). There needs to be an emphasis on not only training more surgical workforce but also to incentivize them to work and serve in the areas with the lowest density. This incentivizing could be done through increasing training of providers who are from that area, encouraging them to stay due to family ties or financial incentivizing them to practice in the more remote areas. A third way to encourage and promote surgical workers to practice in these remote areas is by focusing

on increasing the rural rotation and training options so that the surgical workers are exposed and practiced in that type of region during their training which increases the likelihood they would return to that location in the future (Meara, 2015).

Overall, to strengthen the surgical healthcare system of a country, the three main barriers that are going to have to be overcome are creating a system for health data tracking in order to establish a surgical strengthening plan, creating a task force of involved individuals who can come up with culturally relevant solutions to their particular areas of weakness, and training and retaining surgical workers in the areas most unreached. The greatest success in overcoming these goals, as seen through the case studies provided in the WHO 2017 publication on *Surgical Care Systems Strengthening,* has been when all of those affected including the ministry of health, native individuals, and local NGOs work together to fight for the improvement of surgical care.

Integration of NTD Treatment and Surgical Care as One Plan of Action

In an effort to strengthen the surgical care system as a means of addressing the larger burden of neglected tropical diseases, it will be necessary to integrate surgical care into the existing model of treatment for NTDs. In order to do so, similar to how surgical system strengthening has to take place, it is going to be necessary to have combined efforts and support from all those involved, particularly NGOs and governmental agencies currently tackling the NTD burden.

The WHO current strategy for addressing the burden of NTDs is oftentimes associated with periodic mass drug administration (MDA) for the most at-risk regions (WHO, 2019). MDA is typically given out by health workers and short term traveling clinics that come into unreached regions (WHO, 2019). The places that MDA is

implemented can also serve as a point of first integration for surgical care treatment. When MDA is taking place, those healthcare workers may be coming in contact with individuals suffering from long term deformities due to an NTD that received delayed treatment. These workers can then begin documenting and tracking the areas of most need for surgical care intervention as a means to alleviate the NTD burden. The regions with the highest concentration of NTD related surgical cases can then be used as the first places to focus on surgical strengthening efforts. Those efforts will have to be done in coordination with the surgical system task force described early when discussing how to strengthen a surgical system. Additionally, the teams assigned with providing MDA administration and preventative measures can be partnered with surgical workers who can address some of the longer-term issues they are seeing and create a plan to help get those individuals the surgeries that they need. However, in order to integrate surgical care as a part of the NTD treatment plan, it is going to take the coordination of all impacted parties including healthcare workers, surgical care workers, government officials, and health agencies in order to coordinate effective care and treatment.

Surgical Care Strengthening is Necessary to Adequately Treat the Burden of NTDs

NTDs impact over one million people a year and result in a large burden in many low and middle-income countries, placing unnecessary burdens economically, socially, and politically on the citizens. The efforts currently are focused on treatment through mass drug administration and prevention techniques, but this is not enough to reduce the burden. NTDs such as Buruli Ulcer, Soil-Transmitted Helminths, and Trachoma often result in permanent physical deformities if surgical intervention is not provided. These deformities are then preventing individuals from being able to return to their daily

activities, often resulting in their families and communities having to provide increased or full-time care. However, these lifestyle changes and the excess family burden are not a necessary reality if surgical care is introduced as a part of NTD Treatment. Strengthening the surgical care system is a necessary part of integrating surgery into NTD care and is going to be the only way to adequately address the global burden of neglected tropical diseases.

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