PEDIATRIC CARDIAC SURGERY IN DEVELOPING COUNTRIES OF AFRICA: CURRENT STATE AND FUTURE DIRECTION

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Pediatric Cardiac Surgery in Developing Countries of Africa:

Current State and Future Direction

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ABSTRACT:

Surgical services are often the most neglected part of medical care in developing countries of Africa. Cardiac surgical care is even less accessible in comparison due to its need for highly skilled individuals and sophisticated equipment. This lack of proper care places the pediatric population affected by cardiac conditions without much hope for the future. Combining my clinical experience overseas with an extensive literature review, I examined the current state of pediatric cardiac surgery in several developing countries of Africa, and possible future efforts for establishing a viable cardiac surgery centers in low-resource settings. I examined in detail the two most prominent cardiac conditions in the developing world: congenital heart disease and rheumatic heart disease. The review of literature showed that cardiac surgical care is a serious need in many developing countries. It also revealed that with careful long-term international collaboration between institutions, a self-sustainable and economically viable cardiac surgical center with reasonable outcome can be established.

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A healthy population is fundamental to prosperity, security and stability - a cornerstone of economic growth and social development. In contrast, poor health does more than damage the economic and political viability of any one country - it is a threat to the economic and political interest of all countries.

- Her Majesty's Government -

I. Introduction

Even prior to beginning medical school, global health has been my passion. I was lucky enough to be chosen as one of students pursuing their interests in global health through a program called International Medical Exchange Program (IMEP) at UT Southwestern Medical Center. Upon completion of my third year clinical rotations, I embarked on my journey, where I spent six months in France for a clinical rotation, followed by a three-month rotation in Madagascar, then a three-month research elective in South Africa.

Most people are familiar with the medical missions that many people take that often last for 1 to 2 weeks at a time. Unfortunately in this type of aid work, too often there is misallocation of resources, lack of continuity of care, no promotion of self-sustainability, or cultural insensitivity. These are just examples of mistakes inadvertently made by well-meaning individuals lacking information and experience. I wanted more immersive experience where I was able to work with the locals and get a better grasp of the state of healthcare in these particular countries, and identify their true need.

Aside from the required France portion of IMEP, the reasons I chose Madagascar and South Africa were as follows. For the first country, I wanted to go to one of the most resource poor countries in the African continent that was francophone, while free of political unrest or a sense of physical danger to the traveler. This had led me to choose Madagascar. For the second country of choice, I desired to go to a more developed country where it is often thought of as a good example of progress made in healthcare in the African continent. South Africa had comparatively robust resources for providing healthcare to its citizens, but access to the indigent population was an issue, considering the concentration of healthcare facilities in urban areas and the national shortage of physicians. In terms of cardiothoracic surgery, Groote Schuur Hospital under University of Cape Town at one point was one of the pioneers of the field, having

performed the world's first heart transplant. Because of South Africa's involvement with many surrounding countries in the southern African region, my experience there allowed me to understand the state of cardiac surgical care, not only in Western Cape region, but also in its neighboring countries.

II. Cardiac Surgery in Africa

Surgical services are largely absent in poorer parts of the African continent. [1, 2] Cardiac surgery is even less accessible for patients in lesser developed countries because of its necessity for highly sophisticated infrastructure, and trained individuals with expertise. [2, 3] Madagascar, for example, has two large university hospital centers at Antananarivo and Mahajanga. Since both of these centers completely lack the ability to perform cardiac surgeries, cardiac surgery patients are referred to a neighboring island of Réunion (which is an overseas department of France) or France.

The first documented open heart surgery under the principles of modern medicine in the African continent was performed in 1958 by the famed surgeon Christian Barnaard, who also accomplished the even more impressive feat of performing the world's first allotransplantation of human heart. [4, 5] Since then, as early as the 1960s, countries such as Ghana, Nigeria, and Côte d'Ivoire began performing open cardiac procedures, often with the aid of foreign surgeons. [6, 7, 8] These cardiac programs gained momentum and were able to report higher numbers by the 1980s. [6, 7, 8] Throughout history, however,

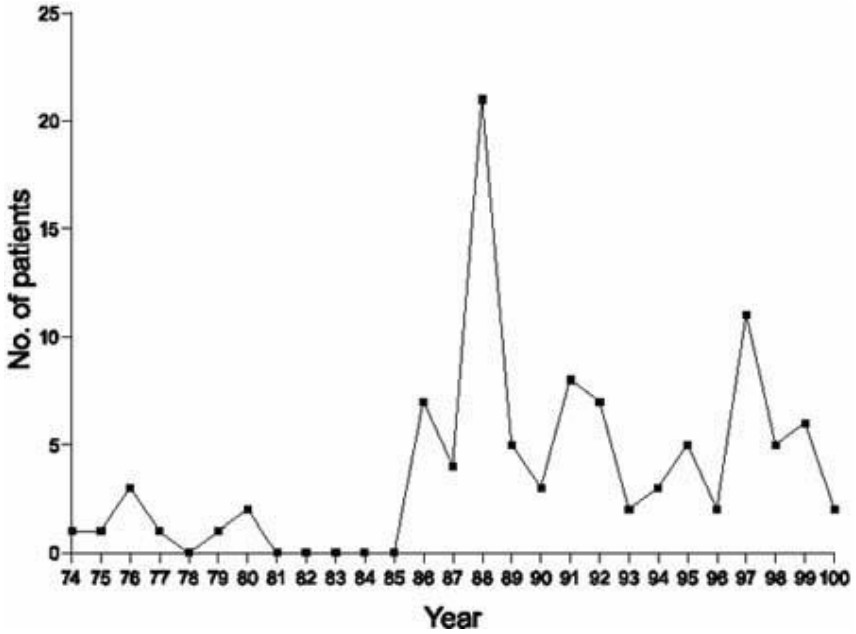

Figure 1: Fluctuation of cardiac case volume from 1974 to 2000 at University of Nigeria Teaching Hospital in Enugu. [9]

many of these programs have failed to maintain their levels of excellence due to economic challenges and civil strife (Figure 1). [6]

Currently there are a handful of countries that are able to perform open heart surgeries in the African continent. Open heart surgery is defined as a surgery which requires an exposure of the internal structure of the heart, requiring cardiopulmonary bypass. South Africa and Egypt historically have been more developed and currently boast multiple cardiac centers that are able to perform open heart surgeries. Several other more industrialized countries in the African continent such as Nigeria, Kenya, Sudan, or Ghana have active cardiac centers that are able to perform high-level open heart surgeries, though not without challenges. [6, 10] When it comes to specialized pediatric cardiac centers, they are only found in South Africa in the entire continent. [2] Many countries that lack the medical capabilities resort to transferring these patients across borders to other countries or rely on foreign aid. Certain centers have been successful in this model, such as The Salam Centre for Cardiac Surgery in Sudan, which is run by an Italian-based humanitarian organization called Emergency.

Even in a country with a well-established program like South Africa, patient care does not happen without its struggles. During my research elective at Red Cross War Memorial Children's Hospital (RCWMCH) in Cape Town, I noticed that many of the patients with congenital heart disease presented quite late in the progression of the disease, therefore adding an obstacle to the course of treatment.

TABLE 1. BIRTH INCIDENCE OF DIFFERENT FORMS OF CONGENITAL HEART DISEASE

Disease	*Incidence/million live births*
Structural CHD	10 000–12 000
Bicuspid aortic valve	10 000–12 000
Genetic disorders	776
Dilated cardiomyopathy	6
Hypertrophic cardiomyopathy	50
Neuromuscular dystrophies	300
Connective tissue disorders: large countries, Marfan, mucopolysaccharidoses, etc	420

Table 1: Taken from a study by J. Hoffman. The Global Burden of Congenital Heart Disease [11]

III. Congenital Heart Disease

Congenital heart disease (CHD) is a structural and/or functional problem of the heart that is present at birth. Children with CHD often have good outcomes in developed countries, however many of them are unable to receive care in low and middle-income countries (LMICs). [11, 12, 13, 14] The worldwide incidence of CHD is similar across countries, suggesting no particular environmental factors contributing to the etiology. [11] Current estimate of noteworthy cases of congenital heart disease at birth is 6 to 12 cases per 1000 live births, depending on the method used to evaluate CHD (symptomatic patients vs. screening echocardiography). [11, 13, 15, 16] These are incidences of CHD, which will require some form of intervention or follow-up in the future. The age ranges of patients included in the studies have also varied significantly. Different studies may only include infants and therefore miss the diagnoses on patients who present late. Depending on which sources you observe, if all trivial cardiac lesions without any clinical significance are included, the range of incidence may vary up to 50 per 1000 births. [13]

There are, however, noticeable differences in prevalence of CHD and its subtypes in Africa compared to the Western world. This is likely attributed to the lack of viable patient

databases, as well as the high outpatient mortality in cardiac patients. This is evident by the fact that many cardiac studies in Africa demonstrate a low incidence of patients with more complex cardiac lesions. [3, 6, 16, 17, 18, 19] There are ongoing efforts in several African countries to build more robust databases, and therefore better characterize their patient population. These efforts are likely to improve resource utilization and outcomes for cardiac patients.

In comparison to developed countries where the fertility rate is low, many LMICs in Africa have high fertility rates with large families (Figure 2), meaning that the resources of these families are thinly spread out causing the actual disease burden to be greater compared to developed countries. [11]

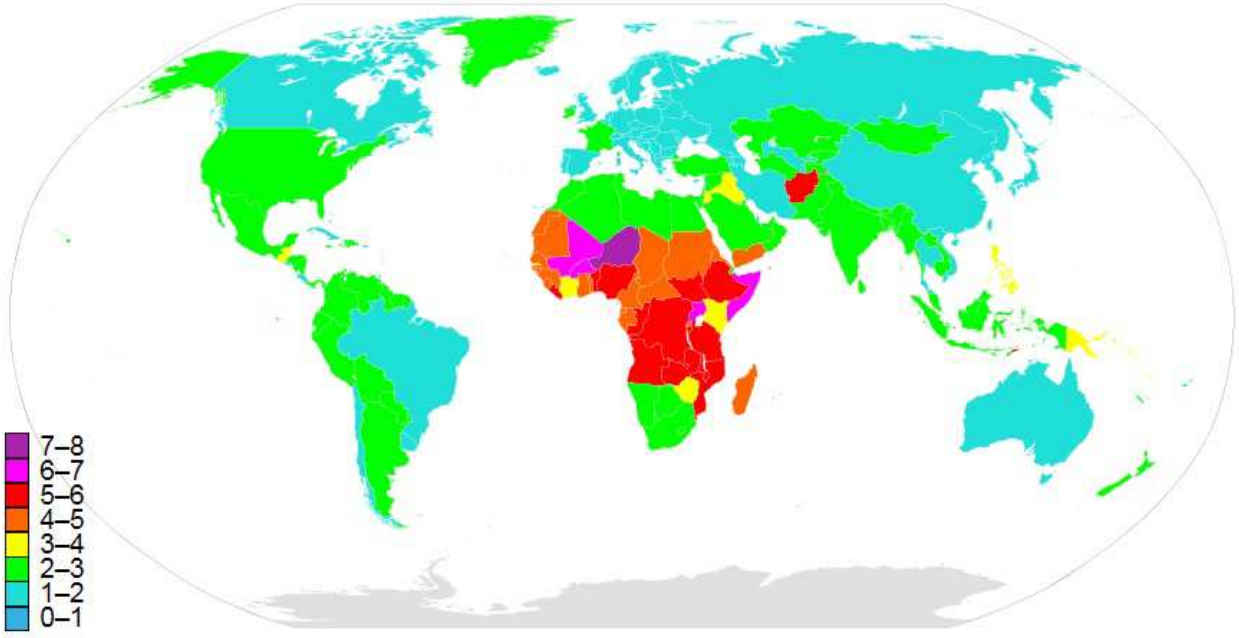

Figure 2: Global mean fertility rate according to Central Intelligence Agency World Factbook 2012. Notice that almost all countries with very high birth rate have been concentrated in the African continent. [20]

As seen on Figure 3, even though the CHD incidence may be similar across the world, the high birth rates observed in African countries (Figure 2) result in a greater number of children born with congenital heart disease compared to North America or Western Europe. Also considering that many countries with high fertility rates are resource-poor in comparison, the governmental resources allocated to treat these patients are much smaller in comparison to the countries of North America and Western Europe. Take for example, the two countries with a similar size population of around 17 million: Netherlands and Niger. Netherlands has 10.85

births per 1000. This means that at population of 16.77 million people, there are roughly 180 thousand live births occurring every year in Netherlands. [21] At 12 congenital heart disease cases per 1000 births, there are roughly 2183 new cases of CHD every year in the Netherlands. Niger has 46.84 births per 1000 people, which at a population of 17.16 million people, there are roughly 800 thousand live births per year. [21] This translates to 9645 new cases of CHD every year in Niger, which is over four times the number of CHD incidence in the Netherlands. Even though the two countries have a very similar current population, the number of new cases of CHD is grossly disproportionate. Not only that, Netherlands boasts a per capita gross domestic product (GDP) of $45,955 according to the World Bank, versus Niger with a per capita GDP of $395. [22] Just for a point of comparison if the ratio of per capita GDP over the number of CHD was taken, Netherlands has $21.05 per CHD case versus Niger with $0.04 per CHD case. Though this number does not necessarily equate the amount of money allocated for a child born with the disease, it is a reasonable representation of discrepancies of available resources.

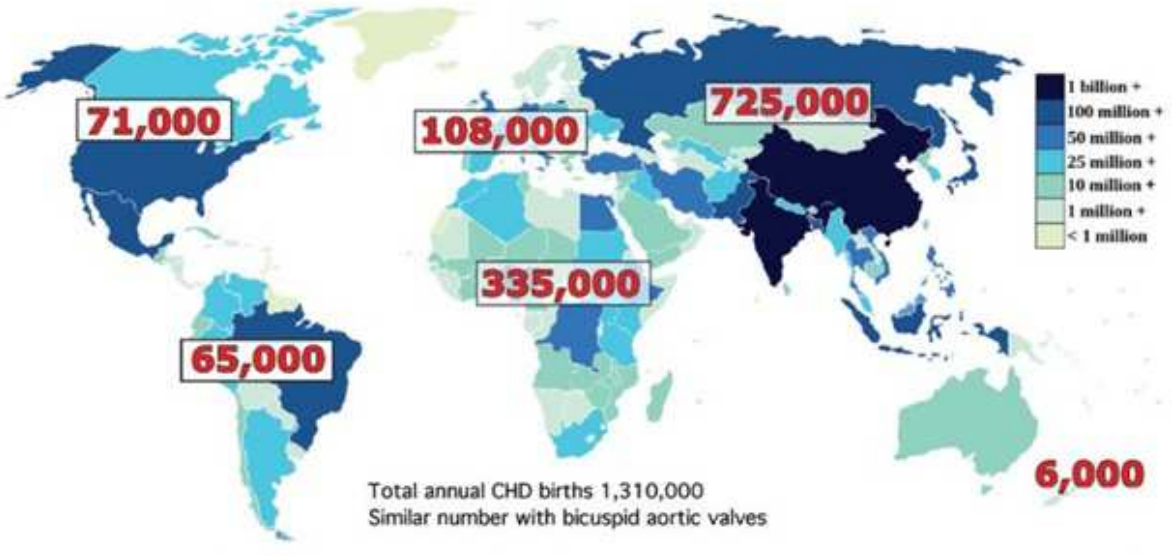

Figure 3: Total annual births of children with CHD by continent. Panel on the side indicates the population range of designated countries. [11]

So what does it all mean for these children who are born with congenital heart diseases? Though many will need medical intervention, some trivial lesions such as small ventricular septal defects (VSD) will often close spontaneously and many of these patients will progress without any hindrance into adulthood. Julien Hoffman's group at University of California at San

Francisco illustrates the prevalence of congenital heart disease very well in his study. He classified the congenital heart diseases in three separate categories depending upon the level of care that patients will require: simple, moderate, and complex lesions. Simple lesions include small VSDs, small or spontaneously closed atrial septal defects (ASD), small or treated patent ductus arteriosus (PDA), mild or treated pulmonary stenosis (PS), bicuspid aortic valve, and treated total anomalous pulmonary venous connection (TAPVC). Moderate lesions include large ASDs and VSDs, non-critical coarctation of aorta, moderate PS, and congenital aortic stenosis (AS). Severe lesions include all cyanotic heart diseases as well as very large VSDs, PDA, atrioventricular septal defect (AVSD), critical AS, severe PS, and critical coarctation of aorta. [12] According to the study by Hoffman, from the year 1940 to 2002, there were about 1.2 million patients with simple cardiac lesions, and 500,000 cases of moderate, and complex lesions each. If all of these patients were treated, there would be 750,000 patients with simple cardiac lesions, 400,000 patients with moderate lesions, and 180,000 patients with complex lesions still alive today. Conversely, if none were treated, there would be 400,000 simple lesions, 220,000 moderate, and only 30,000 patients with complex lesions still alive today. [12] This shows that untreated CHD has a dismal survival rate.

IV. Surgical Treatment of Children with Congenital Heart Disease

Even after these patients have been diagnosed and identified within the population, they are met with quite a large challenge. First, many patients with cyanotic heart disease or other complex cardiac lesions are simply not able to receive the necessary intervention in time, and will die within the first month of life. [2] This also includes premature newborns with cardiac lesions who often die during birth. Even when the patients are able to receive the necessary care in these countries in low resource settings, the survival rates are low compared to developed countries. Many industrialized countries report overall mortality rates of 3% to 7%, in patients with CHD, regardless of intervention, compared to lesser developed countries, with rates in the ranges of 20%. [1] A Tunisian study by Hammami et al reports overall mortality of their patients with CHD at 23.8% over a 9-year period. [23]

Select patients who are referred to an institution in another country, due to the delays from the time of diagnosis to intervention, patients are still subjected to a high mortality rate of 18.8% [24]. There are a select number of hospitals such as Sudan Heart Centre, which report comparable post-operative mortality rate of 8.3%. [10] However, this does not include about 42% of patients with unfavorable pre-operative conditions (low weight) or complex cardiac lesions (Rastelli repair, Ross-Konno procedure, arterial and atrial switch), who were treated by a visiting surgical team. The mortality for this particular group of patients was 17.3%. [10] Mortality rate is not excessively high in all parts of Africa however. Our retrospective study at Red Cross War Memorial Children's Hospital (RCWMCH), we examined the patients who had presented with cyanotic congenital heart diseases (Tetralogy of Fallot - TOF, Transposition of Great Arteries - TGA, single ventricle, Pulmonary Atresia - PA, PS, AVSD, Double Outlet Right Ventricle - DORV) who were operated on from year 2007 and 2013, which revealed in hospital mortality of 11.2% and late mortality of 15.2%.[1] In several single center studies carried out in the United States, mortality rates for patients with similar cardiac conditions range from 11% to 16%. [25, 26, 27, 28, 29, 30] The largest study amongst them showed a mortality rate of 14% in over 2,000 patients, which is comparable to the outcome at RCWMCH. [29]

V. Rheumatic Heart Disease

Rheumatic heart disease (RHD) results from repeated acute rheumatic fevers following Group A streptococci (GAS) infections. In a study commissioned by the World Health Organization (WHO), it estimated that there are 471,000 new cases of acute rheumatic fever (ARF) every year. [31] Excluding a few isolated outbreaks, ARF and RHD are rather uncommon in the West. However, in many African countries, RHD still poses to be an important public health issue. [14] According to the report by WHO, acute rheumatic fever is 100 fold more prevalent in Sudan than Western Europe or North America. [32] The overall disease burden of RHD worldwide was estimated to be 15.6 million prevalent cases with more than 233,000 deaths per year, the majority of which occur in sub-Saharan Africa and parts of Asia Pacific. [33] This figure, however, is likely an underestimate of true mortality because it is suspected that many

[1] Unpublished data from South African study on pediatric patients with congenital heart diseases post systemic to pulmonary shunts.

patients who die from cardiac diseases have undiagnosed RHDs that have caused their cardiac condition in the first place. [34] The mortality figure does not include many patients who may die from long-term sequelae of RHD such as congestive heart failure, arrhythmia, infective endocarditis, atrial fibrillation, and stroke. [34] RHD complications such as infective endocarditis can also pose a large burden on the patient and the hospital system due to its need for long-term hospitalization and treatment. In one study of all the newly diagnosed RHD patients, 26% were readmitted within 30 months of initial diagnosis for suspected bacterial endocarditis. [35] Though the suspected mortality rate according to WHO is at roughly 1.5%, the prospective multicenter observational survey of 9 sub-Saharan countries called Sub-Saharan Africa Survey of Heart Failure (THESUS-HF) noted that 180-day mortality rate of patients presenting with acute heart failure was 17.8%, and rheumatic heart disease is one of the top three etiological factor of acute heart failure in these countries. [36] In addition, from the same study, it showed that acute heart failure from endemic causes had higher mortality rate of 20.5% compared to the emerging causes of heart failure such as hypertension or ischemia. [36] In rural parts of Ethiopia, mortality rate of patients with RHD reaches up to 12.5%. [37]

RHD poses great risk to the entire population, but more severely in the younger population. [38] In parts of Africa, prevalence of chronic RHD has been estimated to be between 2.7 and 20 per 1000 school-aged children. [32, 39] Congestive heart failure in the United States is often perceived as the disease of advanced age. In Africa, post rheumatic valvulopathies and congenital heart diseases are the most common etiological factor of congestive heart failure (CHF) in young patients. In a single center study from Cameroon, patients aged 8 - 20 years old made up 14.6% of all CHF patients, all attributable to valvulopathies secondary to RHD. [40]

RHD also poses a great amount of maternal-fetal risk. During pregnancy, there is a 30% to 50% increase in circulating blood volume, 30% to 50% increase in cardiac output, and 10 to 20 beats per minute increase in basal heart rate due to increased cardiac demand. [41] This hemodynamic change can exacerbate, or even at times bring an onset of cardiac symptoms in a previously stable woman. [42] In a study by University of Dakar, Senegal, pregnant women with RHD reached a mortality rate of 34%. [43] Not only that, the same group of women had a 7.6% neonatal mortality rate, 12% fetal deaths, and 10% required therapeutic abortions during the second trimester. [43]

VI. Surgical Treatment of Rheumatic Heart Disease

Rheumatic heart disease is preventable if the patient is treated with antibiotics at the acute phase of rheumatic carditis. [33] However, if the disease progresses further, a number of these patients will require surgical or percutaneous intervention for valve repair or replacement. A South African single center study showed that 75 (22%) patients out of 344 new RHD diagnoses required valve replacement or repair. [35] As discussed previously, open or percutaneous valve repair/replacement procedures require sophisticated surgical equipment and highly trained individuals, which are often unavailable in many African countries. Additionally, patients post-valve replacement require long-term follow-up and close adherence to anti-coagulation therapy, which may be difficult to do in a population that already has enough difficulty with very basic access to healthcare.

VII. Initial Steps for Improving Management of CHD and RHD

There are several tasks that need to be accomplished in order to make progress in delivering better cardiac surgical care to the underserved population of the African continent. First, it is necessary to better understand the disease. In both realms of CHD and RHD, there is great need for more comprehensive epidemiologic studies. [34] Some countries have already shown signs of collaboration in certain subregions of West Africa, East Africa, and South Africa with its neighbors, but this requires a concerted effort using standardized guidelines. Without standardized guidelines, the information is likely to be inconsistent, and less valuable for statistical analysis.

In addition to the characterization of the disease, better screening guidelines are necessary. In terms of CHD, given the limited resources, the usage of routine prenatal ultrasound screening is probably not the right answer at LMICs. Though prenatal ultrasound screening is often a normal practice in many institutions in the United States, routine ultrasound has never been proven to be effective in reducing adverse outcomes for babies. [44, 45] Prenatal ultrasound is highly variable in sensitivity for CHD, with several studies reporting detection rate ranging from 15 to 80 percent dependent on operator experience, ultrasound technique, gestational age, maternal weight, fetal position, and type of defect. [46, 47, 48, 49] In the settings of LMICs,

better solutions to this problem are improved access to prenatal care, careful patient history and physical, followed by a pulse oximetry CHD screening for asymptomatic newborns 24 hours after birth. One study has shown that this screening cost was roughly $5 per child in the US, and this screening method could be broadly implemented at a further reduced cost in developing countries. [50] This has been shown to have sensitivity of 76.5% with specificity of 99.9% for detecting critical congenital heart defects. [51] For those patients who are discharged without diagnoses, their parents must be well-educated on alarming signs so that if patients become symptomatic, they can be promptly returned to the hospital for diagnosis and treatment.

Management of RHD and CHD differ greatly because RHD is a preventable disease. There are two parts to prevention of RHD: public health and medical intervention. The most important part is the public health efforts by the government in improving the standard of living and general public hygiene. [52, 53] This should be the number one driving factor in decreasing the prevalence of RHD in LMICs. Though early treatment of streptococcal infection is preventative, the overall reduction of incidence of RHD in the western world is largely attributable to less overcrowding and improved public sanitation. [26]

The other important method in reducing the number of RHD cases is primary and secondary prevention of ARF via antibiotic treatment. [33, 54] Primary prevention or prophylaxis involves early antibiotics treatment of a Group A Streptococcus (GAS) pharyngitis within nine days of onset, which is thought to prevent most cases of ARF. [33] Unfortunately, this is not as simple as it appears. It has not been clear in literature whether primary prevention is effective in population at high risk for ARF. [33] Clinical diagnosis of GAS has been shown to be inherently difficult, and using the currently accepted method of GAS rapid antigen test or microbiological culture confirmation in LMICs is impractical due to the cost and the delay of results. [54, 55] The main support for the primary prophylaxis came from several studies done from 1950s to 1970s as part of intensive school-based sore throat screening programs, which have shown that primary prophylaxis reduced ARF incidence [33, 56, 57]. Meta-analysis of aforementioned trials and another meta-analysis of studies done on mostly military personnel also suggested that primary prophylaxis effectively reduced incidence of ARF. [58, 59] None of the studies included in the meta-anlysis, however, are randomized controlled trials and it is acknowledged by their authors that the methodological qualities are poor. [58, 59] The only

randomized controlled trial of primary prevention was a New Zealand study by Lennon et al with 22,000 school children, which showed no significant reduction in incidence of ARF. [60]

	Dose	Frequency	Duration
Primary prophylaxis (treatment of group A streptococcal pharyngitis)			
Benzathine penicillin G	1·2 million units intramuscularly (600 000 units if bodyweight <27 kg)	Single dose	Single dose
Phenoxymethylpenicillin (penicillin V) or amoxicillin	Children: 250 mg orally Adolescents and adults: 500 mg orally	Two to three times daily	10 days
First generation cephalosporins or erythromycin (only if allergic to penicillin*)	Orally: dose varies with drug and formulation	Varies with agent and formulation	10 days
Secondary prophylaxis (long-term preventive therapy in patients with a history of ARF or RHD)			
Benzathine penicillin G	1·2 million units intramuscularly (600 000 units if bodyweight <20 kg)	Every 3–4 weeks	5 years since last episode or age 18 years (whichever is longer) 10 years since last episode or age 25 years (whichever is longer) if mild or healed carditis Lifelong if more severe carditis or valve surgery†
Phenoxymethylpenicillin (penicillin V)	250 mg orally	Twice daily	
Erythromycin	250 mg orally	Twice daily	

Table 2: WHO recommendations for Primary and Secondary Prevention of ARF. [33]

Despite the controversy over how primary prophylaxis should be implemented, one thing holds true: there needs to be a cost-effective strategy in diagnosis and treatment of patients with GAS pharyngitis. In terms of diagnosis, many physicians are advocating a locally adapted, risk stratified adjunct to the current diagnostic criteria. [54] Brazillian study incorporated a pragmatic scoring system (See Table 3) for pharyngitis diagnosis, which was able to maintain 88% specificity while safely reducing 35 to 55% of antibiotics use. [61] This is a reasonable option that can be implemented in other developing countries for improving diagnosis and treatment of GAS pharyngitis. It is also important to acknowledge other LMICs such as Cuba, Martinique, and Guadeloupe that successfully reduced their incidences of RHD. [62, 63] These countries were more successful in their efforts by employing multi-modal strategy in the community. These programs approached the problem in primary prevention, maintenance of ARF/RHD registry with secondary prevention, personnel training, health education at all levels, public campaign, community participation, and epidemiological surveillance. [62, 63]

		X	Value
Age?	≤35 mo		1
	36 - 59 mo		2
	≥60 mo		3
			+ Number of signs
Bacterial Signs?	Tender cervical nodes		
	Headache		
	Petechiae on the palate		
	Abdominal pain		
	Suddeon onset (<12H)		
			- Number of signs
Viral Signs?	Conjunctivitis		
	Coryza		
	Diarrhea		
			=
Total Score			

Treatment Decision Rule According to Total Clinical Scores in 2 Different Situations of Availability of Microbiologic Resource.

Total Score	RADT*	Treatment
Bacteriologic diagnosis unavailable		
≤2		Symptomatic
≥3		Antibiotic
Limited bacteriologic diagnosis available		
≤2	No	Symptomatic
3	Yes	Antibiotic if RADT +
≥4	No	Antibiotic

*RADT = Rapid Antigen Detection Test

Table 3: GAS Pharyngitis diagnostic scoring system used by Joachim et al. [61] The score is calculated by the value assigned for age group plus the number of bacterial signs designated above, then subtracting the number of viral signs listed above. Treatment options are selected according to the total score.

Secondary prevention or prophylaxis is used in patients with history of ARF in order to reduce repeated bouts with ARF that may eventually lead to RHD. Secondary prophylaxis has been clearly shown to be effective when implemented in a community-based registry programs, where patient compliance can be strictly controlled. [33, 52, 62, 63] However, identification and surveillance of the patients with undocumented bout with ARF or RHD in the community is controversial particluarly given the category of subclinical RHD. [52] These asymptomatic

patients demonstrate findings of RHD on echocardiogram only. [64] Various studies from different regions of Africa showed that 5.1 to 30.4 cases per 1000 asymptomatic patients were diagnosed with RHD [64]. Some studies have examined this issue, and in a long term follow-up, the available data suggests that subclinical carditis occurs in 15% - 20% of cases of ARF and that 30% to 50% of patients with subclinical carditis develop RHD. [65] Unfortunately, our current understanding of this disease category is still limited and will require further study.

Echocardiography can be a useful tool providing many necessary information regarding prognosis and treatment. For example, in patients who present with acute rheumatic carditis and mitral regurgitation, 9% to 30% of patients also had documented mitral valve prolapse on echo, which denotes a worse prognosis. [66, 67] The recent data from Dakar indicated that adolescents in their late teens should be screened by echocardiography in light of the high prevalence of the disease in that particular age group and the geographical setting. [68] Though widespread use of echocardiography will help diagnose all of the asymptomatic cardiac diseases, studies have also shown that echocardiographic detection of morphologically abnormal valves or significant valvular regurgitation does not guarantee a prgression to advanced valvular disease. [14] Efforts to screen all of these asymptomatic patients, then placing them on antiobiotic prophylaxis may be a gross misallocation of resources. [14]

A study by Liesel Zuhlke of South Africa called for a need for a longitudinal study of patients with subclinical RHD and see whether secondary prophylaxis would change the disease progression and outcome. [34] This longitudinal study would also provide information regarding the natural progression of disease and help us better understand this sub-category of RHD and its true impact on patient survival.

It is also imperative that whatever improvements and options discussed above do not halt simply as resources available only to the elite few. Currently, South Africa is the only country in the African continent with a national guideline for RHD prevention. [52, 69] Considering the prevalence of the disease on the continent, every country should have a plan on approaching the treatment of this disease. More men and women should be educated on these conditions in order to offset the skew of distribution of diseases in patients with low educational level. A study of pregnant women with RHD showed that forty-five women (90%) had low educational status (no

school or primary school only) and low socioeconomic status (income less than $2.5 per day), compared to only three women (6%) who were engaged in any professional occupation. [43]

VIII. Challenges in Delivery of Cardiac Surgical Care

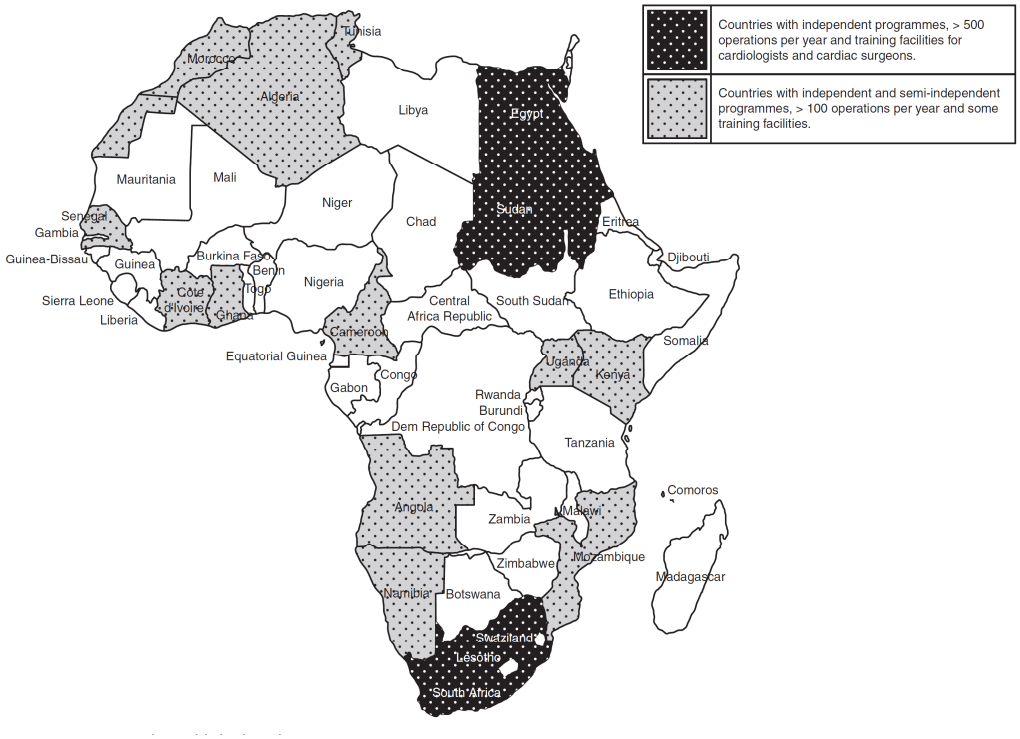

Figure 4: African countries with cardiac surgery capabilities. (11)

The World Society for Paediatric Heart Surgery noted that about 75% of the world's population has absolutely no access to cardiac surgery. [3] In North America and Western Europe, the ratio of number of cardiac surgeons to the general population is 1 to 3.5 million people. In the African continent, that ratio is 1 to 38 million people. [11] In addition to a sheer lack of cardiac surgeons, they are also concentrated in select parts of the continent and many sick children lack the reliable means of transportation. [70] As seen in figure 4, Egypt, Sudan, and South Africa are the only three countries in the entire African continent with highly trained cardiac surgeons and robust cardiac surgery programs. Some of the others marked on this map have well-functioning independent surgical programs, but many operate under foreign management. [14] These centers, though they can be very well-run, rely heavily or entirely on

foreign cardiac surgeons. [2, 10, 70] Programs that are completely independent are met with even more challenges. Kenya has a self-sustained program at Aga Khan University (AKU) Nairobi Heart and Cancer Center, which had only begun their cardiac surgery program in 2011. Since then they have performed roughly 100 operations by the year 2013, which is rather a low volume despite the need in the country. As reported by the chief surgeon and director of the center, Dr. Raj Jutley, the limiting factors are that they are perpetually understaffed, and because patients are unable to afford the surgery. [71, 72]

Affordability of care is a major challenge in many African countries, and it reserves cardiac surgery as a luxury item for select patients. [2] In the case of the Western Africa region, the cost of treatment is largely beyond the means of the indigent population. In a single center study in Ghana, only 20% of the parents of children less than 15 years-old requiring correction of CHD were able to pay for the operation within 12 months of diagnosis. [18] In Sudan, only 69% of the patients requiring surgery could ultimately be treated due to the socioeconomic status of the family. [10] The delay that occurs in order to accrue enough funds to finance the surgery can adversely affect the condition of the child or delay the operation until the child is out of the optimum age for correction. In a report from AKU Heart and Cancer Center, it is stated that nearly 70% of their potential cardiac surgery candidates die waiting. [71] Additionally, many patients may present with malnutrition, which not only creates an obstacle in successfully performing the surgery but hinders the healing process post-operatively as well. [70]

IX. Other Challenges in Delivery of Cardiac Surgical Care: Delayed Presentation

It is very likely in the setting of developing countries that the surgeon may see a congenital pathology presenting as an adolescent or an adult. [19, 70] Patient delays in presentation are likely multifactorial in origin: lack of funding, transportation, or poor patient education. [2, 70] A delay of patient presentation can complicate his or her condition and create an additional obstacle that hinders patient care. For many, this begins even prior to birth. In various parts of Africa, overwhelming numbers of pregnant women do not receive proper prenatal care. [2, 14] For this reason, CHDs that may have been detected prenatally are not diagnosed early on.

CHD, when delayed in diagnoses, can manifest complicated sequelae that may be irreversible, which may mean a worse prognosis for patients. Some of the possible conditions include VSD with Eisenmenger's syndrome, TOF in adults, VSD with pulmonary atresia and aortopulmonary collateral arteries, and subaortic VSD with aortic insufficiency. [19, 70] These conditions not only complicate the cardiac management, but can also present along with other associated conditions such as polycythemia or stroke. [70] In studies done in Zimbabwe, Sudan, and Djibouti, the median age at initial diagnosis or a referral to a cardiologist of patients with CHD are 2, 4, and 5 years old respectively. [10, 73, 74] In the Sudan study, 5% of the patients were simply ruled as inoperable because they had already progressed too far in their disease and were managed conservatively. [10] Studies by Mocumbi et al and Sani et al had 6.9% and 11% of patients present with Eisenmenger's syndrome. [17, 19] In South Africa, with its more robust medical resources and a better referral system, the median age of patients with CHD who were referred for surgery at Red Cross War Memorial Children's Hospital (RCWMCH) was 4 months old.[2] However, it was still not uncommon to see patients referred at much older ages for we had patients upwards of 15 years old at their initial visit. These older patients are often far-progressed in their diseases and are difficult to treat. Nevertheless, at a hospital center that is serving a very large region, including its neighboring countries that are unable to treat these patients internally, this type of patients will be unavoidable. It is described in a Ghanaian study as well that they also serve the West Africa sub-region with 17% of their patients consisting of non-Ghanaians, as well as 36.3% of their patients with congenitally malformed hearts presenting for surgical repair in their 30s. [18] Similar observations of delayed presentation can be seen in RHD patients. The difficulties of treating these patients are evident in the study done by Silwa et al in South Africa. The study showed that majority of the patients presenting for the first time with symptomatic RHD had impaired systolic function, elevated right ventricular systolic pressure greater than 35 mmHg, and atrial fibrillation, which are all significant for negative prognosis. [35]

X. Issues in Continuity of Care

Even after a patient is able to recover well after a successful surgical intervention, cardiac procedures require extensive follow-up, which is not well achieved in many developing countries. In a study of cardiac patients done in Cameroon, over the course of study in six years, there was

[2] Unpublished data from ongoing study.

loss of follow-up of 32.1%, and late at follow-up of 40.1%. [75] This loss of follow-up was attributed to financial limitations, and distance between the patients' homes to the hospital. [75] In our study at RCWMCH, 28.8% of patients were lost to follow-up.[3] About one-third of these patients who were lost to follow-up were referred from a far away region of South Africa, mostly from Eastern Cape, or from neighboring countries. One study notes that this loss of continuity often occurs due to parents lacking understanding of the condition or parents refusing treatment. [19]

XI. Ethical Dilemma of Investment in Cardiac Surgery

There are opposing views as far as making investments in cardiac surgery is concerned. Some view that due to other dire issues that require more attention, investment in cardiac surgery is impractical and not a priority. [76] As far as medical issues are concerned most countries believe that those of infectious diseases are much more pressing issues. [6] In Ghana, 42.1% of deaths in 2009 were attributed to malaria, diarrhea, HIV, and respiratory infections, which are a much larger percentage than all of the patients who died from congenital issues and RHD combined. [77] Some see the cardiac interventions a futile effort in this low-resource setting and have even suggested that promotion of birth control and decreasing the fertility rate may be a more effective way of decreasing overall incidence of CHD. [11] This places us in an ethical conundrum of deciding whether it is right or wrong to make heavy financial investments in treating these patients when there is a greater need elsewhere.

I personally find this to be a rather short-sided view of the situation. I believe that the opponents of investment in cardiac surgical care are discounting the amount of future loss of work force. Surveys revealed that surgical disease is among the top 15 causes of disability. [78] Surgical conditions also account for 15% of total disability adjusted life years lost worldwide. [79] Though the number of cases is comparatively lower for cardiac cases, the potential gains in life years are high considering the high mortality of non-intervened patients. When considering the potential gains, we can start viewing healthcare expenditures less as costs and more as investments for the future. [80] In addition, the current model of out-sourcing cardiac surgeries is not a financially advantageous one. Though investment in cardiac surgery is difficult and fiscally

[3] Unpublished data from ongoing study

demanding, a successful establishment of a cardiac surgery program will have a financial gain and will benefit the country in the long run.

For those placing such heavy emphasis on infectious diseases as the number one target, one must also remember that the reason why industrialized countries are no longer heavily affected by these infectious diseases is not as much a result of advancement in modern medicine but more attributable to improvement in public sanitation and personal hygiene. [53, 80] It is having access to clean water and adequate nutritional intake that can really improve these conditions and decrease people's suffering from infectious diseases. This is more of a social and governance issue that requires a systematic change opposed to a medical intervention. When there is a clearly identifiable cause such as congenital heart disease, a deferment of intervention, which essentially denies a patient a fundamental right to life, would be unethical.

XII. Locally Conscientious Practice Modifications

It is important to recognize that progress has been made and they are not not always modeled on the method of practice in North American or European hospitals. When an individual is placed in a resource poor setting, he or she will have to adapt and make the best use of the available tools. In developed countries, percutaneous approach is the gold standard in treating certain conditions such as PDA closure or valvular stenosis repair. In a recent study done in Rwanda, a group of physicians were able to perform diagnostic and interventional cardiac catheterization procedures, including closure of ASD, PDA, and ballooning of valvular pulmonary stenosis without using an access to a catheterization lab, but only using conventional C-arm X-ray and ultrasound. [81] All of their patients were successfully treated this way without any major complications.

Another example is palliative versus definitive correction. In most developed countries, early primary repair of TOF was favored over staged palliative shunts followed by permanent repair due to the initial outcomes. [82] However, in lesser developed countries, palliative procedures may play a larger role. As reasons stated previously, many patients in these settings present extremely late or present emergently, which may necessitate a shunt as a better option instead of a primary repair. Depending on the socioeconomic status of the family paying for the

surgery, sometimes a Blalock-Taussig shunt is offered as a palliative therapy until they are able to pay for the total repair [18]. Alternatively, if a patient is suspected to have very poor follow-up or is from another country and is expected to not return for a total repair, even if it may be slightly less favorable under medical grounds at the time, it may be best for the patient to perform a full repair.

XIII. Role of Foreign Aid

International collaborative efforts definitely have a place in solving this problem. It is important, however, that this is accomplished in a manner most respectful to the recipient of foreign aid. Too often, foreign aid is done by independent organizations that do more harm than good, accomplishing no more than short-term missions, only to evoke that "feel-good" emotional response from the participants. [83] For successful foreign aid to work, it is crucial that there is an open line of communication established where the leaders of the developing countries can explicitly express their needs and the collaborators of foreign powers help identify the cause of the problem. The goal is not to fix the problem ourselves but to help build a framework or a platform that makes it easier for these countries to fix the problem more or less independently. [80, 83]

Because self-sustainability should always be the goal, education is the most effective avenue of providing aid. [2] There are some successful examples of this in other countries such as The Shanghai Children's Medical Center who have collaborated with Philadelphia and Boston Children's Hospitals and were able to train a number of competent physicians who have returned and established surgical programs in their home institutions. [76, 84] Until the programs can be fully sustainable there will need to be a gradual transition to complete independence. As reported by a hospital in Sudan in 2007, it only performed definitive intracardiac repair of CHD in patients weighing greater than six kilograms and the rest of the patients either received palliative procedures or were operated on by a visiting pediatric cardiac specialist. [10] In a study by Dearani et al, this concept is described as a "twinning program." [85] In essence, a twinning program pushes for improvement in pediatric cardiac surgical care in a developing country by establishing a partnership between two programs, with commitment to collaboration, building

community support, and research. [85] The program development is done in five phases, which are site selection, medical team assessment, education of staff, provision of assisstance, and establishing new goals (See Figure 5). [85]

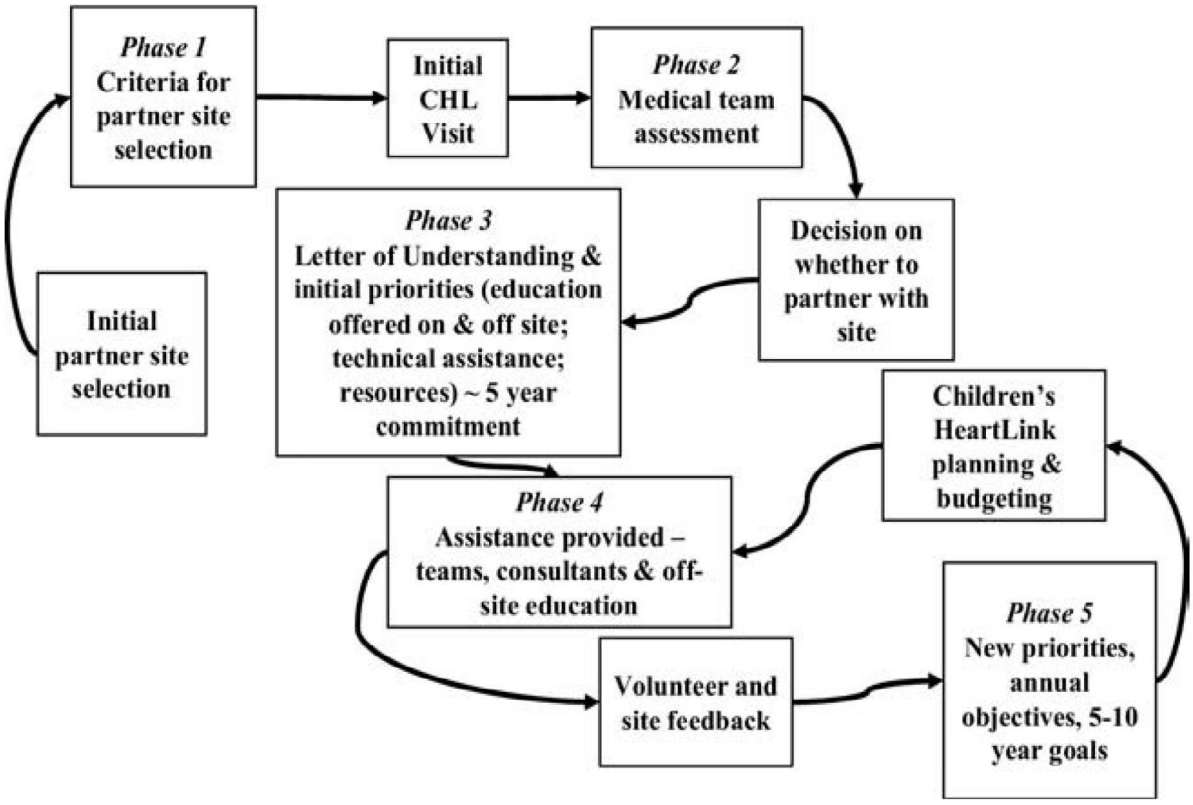

Figure 5: Twinning program relationship cycle outlined by Children's Heart Link (CHL) [82]

XIV. Building a Successful Surgical Program

Building or improving a cardiothoracic program that is sustainable in a developing country is indubitably a difficult task. There are certain key elements that will require a significant amount of effort for the parties involved. It must all begin with identifying the perfect site for this development (Figure 5, phase 1). [2] There needs to be adequate research done in consideration of the current state of infrastructure, patient population, epidemiology, and the ease of transportation for the indigent population. [2, 86] The hospital will need to be a larger volume center with operating rooms large enough to accommodate a perfusionist and the cardiopulmonary bypass pump in addition to standard surgical teams and their equipment. [85]

The hospital also must be equipped with intensive care unit capabilities for proper post-operative care. [72] When the site is selected, it must be evaluated to identify the site's current resources and needs (Figure 5 phase 2). [85]

When the infrastructure is in place, the program is able to accommodate a proper staff (Figure 5 Phase 3). Cardiac surgery requires a number of highly trained personnel. As it is outlined in an article by Probal Ghosh who has worked extensively in the developing world, the minimum number of staff needed for a cardiac surgery team is seven: one surgeon, two assistants, one circulating nurse, one scrub nurse, one perfusionist, and one anesthetist. [72] For a country without a functioning cardiac surgery program, it is likely that these personnel may have to be trained overseas. [2] An annual reported cost for training a specialist surgeon in Uganda is approximately $5,000 per year. [86] It is important to identify aspiring and motivated surgeons who are willing to take on this task.

I have worked with Dr. Jithan Koshy, a Zambian native, who has been selected by the Zambian government in such manner and was sent to Cape Town, South Africa to receive training in cardiothoracic surgery as part of a project sponsored by John Hewitson and Peter Zilla of University of Cape Town cardiothoracic surgery department. The Zambian government is financially supporting Koshy while he trains in Cape Town. In the mean time, the government is acquiring all the equipment that will be needed by the newly established cardiothoracic department, which must all be approved by Koshy under the advice of the cardiothoracic department at Cape Town. At the end of his training, Koshy will return to Zambia to head the only cardiothoracic surgery department in Zambia.

In the case of Botswana, the University of Toronto partnered with the University of Botswana to train their surgeons on location year-round. There were dedicated members of the team from Toronto who traveled to Botswana for a combined 3 months of on-site teaching. In the remaining 9 months, the fellows had video teaching of various types. [87]

Once the partnership goes smoothly past phase 3, more dynamic interaction between the two programs can take place where now the two programs can engage in more intensive education and training, funding support, and technical assistance. This essentially establishes the program as a fully functioning cardiac surgical program. [85]

It is one of the most frustrating but possible outcomes to have spent years worth of effort in establishing a program just to watch it deteriorate. [70] In the 1980s, a surgery group in Abidjan, Cote d'Ivoire led by H. Yagni-Angate had performed over 200 cases per year. Recently, due to economic difficulty and civil unrest, the program has declined. [88] Sustainability is crucial in seeing that the people of that particular region will continue to receive surgical care in the future, as well as those who had already received surgical intervention are properly followed up. This is phase 5 where it is crucial to self-evaluate and carefully audit the program and identify the areas for improvement. [85] The new center must have constant inflow of patients that requires the trust of the community as well as the other referring physicians. Though the goal is to make the care as accessible as possible to all those in need, in order to establish a program and sustain a certain level of quality, the new program will have to charge for procedures at a sufficient rate per procedure. [70] Ideally, the center will have minimum volume of 100 surgical cases per year with the goal of 300 to 500 cases per year. [85, 89] Most likely in the beginning, it will have to rely partially on government subsidy, philantrophic non-governmental organization (NGO) or become an accessory department of a high volume adult cardiac unit. [70, 89] Past programs that have succeeded in establishing itself have required three to five years of commitment to this cause. [2, 5, 84, 85, 90] It is not uncommon in certain developing countries for surgeons to pay the primary care physician or cardiologists in order to get referrals. [72] Unfortunately, in order for a program to have sustainability, it may be necessary for the parties involved to take part in such local practices. Hospitals should also put forth every effort to keep costs down and make sure that it will stay afloat. Hospitals must ensure that patient does not overstay in the intensive care unit, keep the total days of hospitalization down, and prevent iatrogenic causes that may keep the patient in the hospital. [91] Considering that many patients will struggle to pay for the procedure, it is likely that if the patient overstays at the hospital, the excess charges will likely have to be covered by the hospital.

The hospitals also must continue to secure its employees. One of the problems that has plagued many developing countries for years is brain drain. [70, 92] This is especially true for highly trained healthcare workers who often leave for a developed country for a better income, improved working environment, and better career opportunities. [92, 93] This is a difficult issue because it is certainly not possible to forcefully stop someone from pursuing a better life, however, the exodus can be minimized by providing adequate salaries, clear responsibilities,

opportunities for upward mobility, and a better working environment. [2] Also in turn, some have suggested that wealthy countries should refrain from recruiting highly skilled workers from these developing countries. [2]

In the long run, this investment in cardiac surgery will actually be financially beneficial to the country. In the case of Zambia, its government spends over $17,000 to send a patient overseas for an open heart surgery [94]. In Nigeria, between $20,000 - $40,000 is spent on a patient who must travel overseas to receive cardiac surgery. [95] It is reported that this type of medical tourism drains estimated $500 million from the Nigerian government. [95] In a study by a new surgical center in Nigeria, open heart surgery costs range between $6,230 and $11,200 for an ASD repair and mitral valve repair, respectively. [96] In Sudan, the average cost for CHD repair was $4,000. [10] This value is significantly more affordable considering that coronoary artery bypass grafting (CABG) costs anywhere between $70,000 to $130,000 per procedure in the United States compared to $8,430. [96]

Table 4 : Total Cost of Open Heart Surgery Procedures in US Dollars [56]

Category	**ASD Repair**	**Mitral valve repair**	**Off pump CABG**
Drugs	600	1200	740
Intensive Care	410	500	625
Pre-op investigations	955	3040	3020
Perfusion	1080	1100	915
Operating room	1360	3535	1305
Honorarium	925	925	925
Hospital stay	900	900	900
Total (USD)	**$6230**	**$11,200**	**$8,430**

XV. Conclusion

The world's leading economists have recently shed light on surgery as one of the most important aspects worthy of investment to improve the general welfare of the poor. [97] Surgical conditions account for an estimated 11% of global burden of disease, however it is likely that the impact is larger because surgical conditions are often debilitating if not treated and can pose significantly larger impact on the family of the patient. [93, 98] Though in this thesis we had only focused on patients with CHD and RHD, along with the urbanization of Africa, patients suffering from cardiac conditions are on the rise. It is time that we increase awareness and shed further light on this particular matter, make contributions and efforts in alleviating this problem in addition to the current relief efforts. We must have better collaboration between the countries in need and developed countries, and we must develop a self-serving, sustainable solution. Through collaborative work, we can reach the ultimate goal of establishing an independent cardiac surgery program that will provide much needed care to the people who deserve it.

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