Confronting the growing burden of kidney disease: the sub-Saharan landscape

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CONFRONTING THE GROWING BURDEN OF KIDNEY DISEASE: THE SUB–SAHARAN LANDSCAPE

by

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DEDICATION

I would like to dedicate this work to my mom who always expresses such genuine interest in others and to Tod Turner for his unwavering support.
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I would like to acknowledge Dr. Swee Lian Tan for introducing me to SAO’s project and always believing in me, Dr. Richard Solazzi for opening SAO’s doors to me, Dr. Bernadette Thomas for her continued mentorship and support in kidney disease research, and my readers, Dr. Gwynneth Offner and Dr. Karen Symes.
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ABSTRACT

This report seeks to describe the status of kidney disease and renal replacement therapy in lower-resource settings, particularly sub-Saharan Africa. Acute kidney injury and transplantation are included on a limited basis because it is impossible consider the renal replacement therapy landscape at the exclusion of either. As in the rest of the developing world, chronic kidney disease and end-stage renal disease place a sizable and rapidly growing burden on sub-Saharan Africa, and Africans face a double-burden of disease from communicable and non-communicable diseases. Meanwhile, renal replacement therapy and the subspecialty of nephrology are expanding in sub-Saharan Africa, from non-existence in many countries to a limited, tentative subsistence, largely with the support of international organizations and the dedication of local nephrologists. Hemodialysis is the most common form of renal replacement therapy in sub-Saharan Africa, but peritoneal dialysis services, particularly for acute kidney injury, are growing and renal transplants are performed in a few sub-Saharan countries. Nonetheless, in the majority of sub-Saharan Africa, maintenance dialysis is still only available to the wealthy urban few. Although peritoneal dialysis may seem more feasible in the developing world than hemodialysis for multiple reasons, it is still fraught with challenges that make widespread implementation presently unadvisable. As renal replacement therapy is costly
and currently unaffordable on a large scale for most of these countries, emphasis must be on identifying at-risk populations through screening and low-cost treatment or management of risk factors to mitigate chronic kidney disease.
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LIST OF ABBREVIATIONS

AFRAN ........................................................................................................ African Association of Nephrology
AIDS ............................................................................................................ Acquired Immune Deficiency Syndrome
AKI .............................................................................................................. Acute Kidney Injury
APD ............................................................................................................. Automated Peritoneal Dialysis
ARF .............................................................................................................. Acute Renal Failure
CAPD .......................................................................................................... Continuous Ambulatory Peritoneal Dialysis
CHF .............................................................................................................. Congestive Heart Failure
CKD .............................................................................................................. Chronic Kidney Disease
CME ............................................................................................................ Continuing Medical Education
COPD .......................................................................................................... Chronic Obstructive Pulmonary Disease
CRRT .......................................................................................................... Continuous Renal Replacement Therapy
CSO ............................................................................................................. Civil Society Organization
CVD .............................................................................................................. Cardiovascular Disease
EHR .............................................................................................................. Electronic Health Record
ESRD .......................................................................................................... End-Stage Renal Disease
GDP ............................................................................................................. Gross Domestic Product
GFR .............................................................................................................. Glomerular Filtration Rate
GNI .............................................................................................................. Gross National Income
GNP ............................................................................................................. Gross National Product
HBV .............................................................................................................. Hepatitis B Virus
HCV .............................................................................................................. Hepatitis C Virus
HD ................................................................. Hemodialysis
HIV ............................................................ Human Immunodeficiency Virus
HIVAN ...................................................... HIV-Associated Nephropathy
ICU ............................................................... Intensive Care Unit
IHME .......................................................... Institute for Health Metrics & Evaluation
IPD ............................................................. Intermittent Peritoneal Dialysis
IPNA .......................................................... International Pediatric Nephrology Association
ISN ............................................................... International Society of Nephrology
ISN-COMGAN .................. ISN’s Commission for the Global Advancement of Nephrology
ISPD .......................................................... International Society for Peritoneal Dialysis
KDIGO ..................................................... Kidney Disease: Improving Global Outcomes
KDOQI ....................................................... Kidney Disease Outcomes Quality Initiative
KEEP ......................................................... Kidney Early Evaluation Program
MDG .......................................................... Millennium Development Goal
MoH ............................................................ Ministry of Health
NCD ............................................................. Non-Communicable Disease
NHANES ............................................. National Health and Nutrition Examination Study
PD ............................................................... Peritoneal Dialysis
pmp .............................................................. per million population
RRT ............................................................. Renal Replacement Therapy
SAO .......................................................... Seattle Alliance Outreach
SKCF ........................................................ Sustainable Kidney Care Foundation
SSA .......................................................... Sub-Saharan African
SYL .......................................................... Saving Young Lives
TB .......................................................... Tuberculosis
UN .......................................................... United Nations
UTI .......................................................... Urinary Tract Infection
WHO ...................................................... World Health Organization
YLDs ........................................................ Years Lived with Disability
INTRODUCTION

“Contrary to popular mythology, these diseases are not the revenge of the human body on a wealthy and overindulgent lifestyle, nor are they diseases of old age” (Dirks et al, 2006)

Many developing countries have been challenged by the uncoordinated activities of many altruistic donors. On one hand, their activities typically fill a need that the government has failed to fill, either for lack of stewardship or for lack of resources, but at the same time, the myriad of uncoordinated donor activities coupled with a lack of country ownership make it challenging to build a functioning health system, the end-goal. The Seattle Alliance Outreach (SAO) is a non-governmental organization that has sought, since its inception in 2008, to improve medical care at the Black Lion Hospital (Tikur Anbessa) and Zewditu Hospital in Ethiopia’s capitol, largely through improving anesthesia services, hospital facilities and surgical training. This research project on dialysis in developing countries began because the SAO sought to make maintenance dialysis more accessible to the average Ethiopian at the behest of a wealthy Ethiopian family whose patriarch was donating his time on the dialysis machine to others, compromising his own health. Hemodialysis was only available to those who could afford the fees and functioning machines were in short supply.

Peritoneal dialysis (PD) was chosen as the dialysis modality that SAO would strive to implement. Despite lower rates of usage, PD is more cost-effective than HD in
the developed world, achieving comparable outcomes at significantly lower cost, and these trends are often assumed to hold true in developing countries as well (Neil et al., 2009). SAO was new to the scene and had limited awareness in the beginning of the international nephrology network that already existed in sub-Saharan Africa. In fact, many donors had already attempted to expand dialysis access in Ethiopia with minimal success. Dialysis and kidney disease in lower-resource countries must be viewed from a different lens than it is viewed in higher-resource countries. Even without considering the price tag, there are practical concerns around dialysis implementation in developing countries that do not normally exist in developed countries, such as the feasibility of maintaining sterility when performing CAPD at home where there is no running water or improved sanitation. In order to ask the right questions, a literature review on renal replacement therapy in developing countries was performed. Based on the volume of literature returned, this report was scaled down to ultimately answer, “What is the state of renal replacement therapy in sub-Saharan Africa?”

Sub-Saharan Africa is the only region in the world where non-communicable diseases have not surpassed all other causes of death, but they are still responsible for 66% of morbidity in the region and are growing enormously: By 2030, it is expected that there will be a 250% increase in the burden of diabetes and cardiovascular disease in sub-Saharan Africa (IHME, 2013; Sumaili et al, 2009). The “end result” of many chronic conditions is chronic kidney disease (CKD), an expensive disease that is linked to significant morbidity and mortality (Moosa et al, 2016; Halle et al, 2015; Mushi et al,
The prevalence of CKD is only predicted to increase, driven by aging and increasing prevalence of diabetes and hypertension, and developing countries, such as those in sub-Saharan Africa, will overwhelmingly see the greatest increase in both NCDs and CKD (Halle et al, 2015). Currently, the proportion of the population needing treatment for ESRD via dialysis is growing by 8% annually even though the global population is only growing at 1.3% (Fabian et al, 2014). Despite these ominous facts, CKD receives little attention from health organizations (Sumaili et al, 2009).

Paying for dialysis is a major issue worldwide with costs ranging from US$30,000 to $60,000 annually in developed countries and from $6,000 to $40,000 in developing countries, a prohibitive price tag for lower income countries (Dirks & Levin, 2006). However, renal replacement therapy is not an anomaly; commonly deployed therapies such as HIV antiretrovirals are expensive as well (Dirks & Levin, 2006). There is an urgent need to increase CKD awareness globally and to improve targeted screening and prevention, yet while CKD screening and prevention are the most cost effective option, they also demand human and capital resources, and there is the imminent issue of caring for existing ESRD patients (Dirks et al, 2006b; Pozo et al, 2012). In sub-Saharan Africa, in the face of scarce resources for healthcare, treatment for ESRD exemplifies the weighty dilemma facing public health planners and policy-makers of “who shall live?” (Mushi et al.,2015).
Both AKI and transplantation are inextricably interwoven into discussions of CKD and RRT. AKI shares both etiologies and therapies with CKD and despite differences in duration and initial presentation, both are part of a clinical syndrome of reduced glomerular filtration rate (Jha et al, 2013). It is also useful to consider AKI because there has been a recent push by international organizations to provide AKI treatment in developing countries, which has led to the training of nephrologists and growth of PD programs. Transplantation, widely considered to be the most clinically effective and economical outcome for patients with ESRD, cannot be ignored either. Several developing nations do not accept ESRD patients for dialysis unless they are candidates for transplantation. Like dialysis, however, transplantation is also challenged by inadequate infrastructure and financing, in addition to issues of organ trade and trafficking (Ajayi et al, 2016).

KIDNEY DISEASE

The Kidneys

Perfused with 20% of the cardiac output, the kidneys are vital organs that excrete metabolic waste products such as urea, regulate electrolyte concentration and blood pressure, maintain the acid-base balance of the blood, and secrete important hormones including erythropoietin, renin and prostaglandins (Harris, 2013; Eckardt et al, 2013). Renal function is determined by glomerular filtration rate (GFR), which is typically clinically determined by measuring an individual’s creatinine clearance over 24 hours, and albuminuria, oliguria, hypertension and edema are often indicative of kidney disease.
(Harris, 2013). The kidney is targeted by a multitude of systemic vascular, hemodynamic, metabolic and inflammatory disorders, and loss of renal function is rapidly fatal without renal replacement therapy (RRT) (Eckardt et al, 2013). Kidney disease is classified as acute or chronic, although the categorization belies the fact that chronic disease may initially present as an acute condition, only later to be determined to be chronic, and that acute disease may later contribute to the development of chronic disease. Although symptoms of renal injury and disease are often limited and non-specific, both CKD and AKI can be detected by non-nephrologists, and novel diagnostic techniques, such as a saliva urea dipstick test, may aid in timely diagnosis (Callegari et al, 2012). The relevance of kidney disease to public health is undeniable as all other acute and chronic diseases have a worse prognosis when kidney disease is present (Eckardt et al, 2013).

**Definitions & Etiologies of AKI, CKD and ESRD**

*Acute Kidney Injury (AKI):* AKI, a relatively common clinical condition, is the abrupt loss of kidney function (Li et al., 2013; Arogundade et al, 2007). Patients often present with oliguria and the condition is associated with high mortality in both developed and developing countries (Li et al., 2013; Arogundade et al, 2007). The KDIGO (Kidney Disease Improving Global Outcome) defines AKI as either: 1) an increase in serum creatinine by $\geq 0.3\text{mg/dL}$ within 48 hours, 2) an increase in serum creatinine to $\geq 1.5$ times the baseline value within the last 7 days, or 3) a urine volume $<0.5$ mL/kg/h for 6 hours (Li et al., 2013). AKI has many causes, including both infectious and non-communicable disease etiologies, and can lead to the development of
chronic kidney disease (CKD) (Li et al., 2013). Causes of AKI are commonly categorized as hospital-acquired or community-acquired (Lunyera et al, 2016). Hospital-acquired AKI is often medication-induced or caused by inadequate blood flow to the kidneys, precipitated by conditions such as heart failure, sepsis and diarrhea. Community-acquired AKI often affects a younger, healthier demographic and is frequently caused by infectious agents, obstructive uropathy, snakebites, nephrotoxic herbal medicines, intravascular hemolysis and maternal hemorrhage or septic abortion (Li et al., 2013). The infectious diseases that can lead to AKI are numerous and malaria, hepatitis B virus, leptospirosis, dengue, yellow fever, tetanus and HIV are all known to cause AKI (Li et al., 2013). AKI can also occur in neonates secondary to birth asphyxia after unattended births and in children due to diarrheal diseases, septicemia and hemolytic uremic syndrome (Jha & Chugh, 2003). During major disasters like earthquakes, AKI is also commonly seen in patients with crush injuries (Dirks et al, 2006). Patients may be asymptomatic but some common symptoms are oliguria, edema, fatigue, nausea and shortness of breath (Dirks et al, 2006b). The epidemiology, prevention and treatment of AKI are outlined below.

*Chronic Kidney Disease (CKD) & End-Stage Renal Disease (ESRD):* There are 5 stages of CKD and each subsequent stage represents decreased renal function (Neil et al, 2009). The final fifth stage is end-stage renal disease (ESRD), defined by a near total loss of kidney function, and in the absence of treatment, patients quickly die of uremia- often within a few weeks (Neil et al, 2009). Chronic kidney disease is a slow-progressing non-
communicable disease with non-specific symptoms although patients may present with fatigue, hypertension, loss of appetite, oliguria, and edema (Dirks et al, 2006). In 2002, the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) released historical clinical guidelines on the categorization of chronic kidney disease based on glomerular filtration rate (GFR) (Odubanjo et al, 2011). The new guidelines were a noteworthy conceptual change because, despite a lack of uniformity in definitions, kidney disease had previously been categorized mostly by cause (Dirks et al, 2006). Stage one is proteinuria with normal kidney function (GFR $> 90$ mL/min/1.73 m$^2$). Stage 2 is mildly reduced kidney function (GFR 60-89 mL/min/1.73 m$^2$), stage 3 is moderately reduced kidney function (30-59 mL/min/1.73 m$^2$) and stage 4 is severely reduced kidney function (GFR: 15-29 mL/min/1.73 m$^2$). Many people with stage 4 CKD will progress to stage 5, or end-stage renal disease (GFR $< 15$ mL/min/1.73 m$^2$), and require dialysis or transplantation (Dirks et al, 2006). However, more patients with kidney disease will actually die of other causes before they need renal replacement therapy because nascent kidney disease is a major marker for CVD, heart failure, and stroke (Dirks et al, 2006b). CKD is not only a marker but it is also a potent risk multiplier for many non-communicable diseases (NCDs) (Feehally et al, 2014).

Like AKI, the causes of CKD are varied, numerous and often reversible. Causes of kidney disease can be classified as pre-renal, intrinsic or post-renal. Genetic causes are rare, except for autosomal dominant polycystic disease (Dirks et al, 2006b). Pre-renal causes of CKD are significant and include the highly prevalent chronic diseases- diabetes
and hypertension. In the developed world, diabetes and hypertension join glomerulonephritis among the top three causes of CKD (Dirks et al, 2006b). Diabetes leads to diabetic nephropathy, and 30% of diabetics with proteinuria eventually experience a complete loss of kidney function (Dirks et al, 2006b). Because the kidney functions as an important blood pressure regulator, hypertension is intimately linked to kidney disease. The high rate of hypertension globally likely contributes to significant undiagnosed CKD (Dirks et al, 2006b). Most primary renal diseases eventually cause hypertension while hypertension hastens the progression to ESRD (Dirks et al, 2006b). Consequently, damage to the cardiovascular system is a major cause of morbidity and mortality among ESRD patients (Dirks et al, 2006b). Both diabetes and hypertension are enormous and growing global challenges, augmenting the incidence of CKD incidence (Dirks et al, 2006b).

Glomerulonephritides, a group of intrinsic disorders with many etiologies affecting the glomerulus of the kidney, can be further classified as glomerulonephritis or glomerulosclerosis (Dirks et al, 2006b). Glomerulonephritis is a major cause of ESRD and is reported to be one of the top three causes in Europe and the United States and is the primary cause in many developing countries (Barsoum, 2002). The incidence of glomerular disease is higher in tropical regions and low-income countries largely because of the increased prevalence of infectious diseases with glomerular-related sequelae like malaria, schistosomiasis, leprosy, filariasis, HBV, and acute post-streptococcal nephritis, and it is estimated that 2-3% of medical admissions in tropical countries stem from renal-
related complaints (Dirks et al, 2006b). Acute kidney injury, also known as acute renal failure, is also a significant risk factor for CKD of intrinsic-origins (Jha et al, 2013).

Post-renal causes of CKD include infections, such as complicated UTIs, urinary schistosomiasis and genitourinary TB, and obstructive uropathy, often caused by kidney or bladder stones or benign prostatic hypertrophy (Dirks et al, 2006b). While obstructive uropathy is the cause of ESRD in about 1% of patients in developed countries, it can be the leading cause of ESRD in some developing countries and children in developing countries are more susceptible to bladder stones because of their poor diet (Dirks et al, 2006b).

Some identified risk factors for CKD are non-modifiable, including old age, genetic predisposition and ethnicity, while others can be more readily addressed, like smoking, alcohol, illicit drug or analgesic abuse, hypertension, dyslipidemia and poor glycemic control in diabetics (Dirks et al, 2006b). Others risk factors necessitate significant systemic changes. Low birth weight and intrauterine growth retardation due to malnutrition multiply risk for future chronic diseases including chronic kidney disease, ischemic heart disease, diabetes mellitus, and hypertension (Dirks et al, 2006b). In general, poverty increases CKD-risk and contributes to worse outcomes in those with the disease (Jha et al, 2013).
**Non-Communicable Diseases, Kidney Disease & the New Global Agenda**

Confronting kidney disease in the developing world sounds daunting and, without further education, to be of limited importance. It seems impossible to tackle kidney disease in nations where citizens may still lack access to potable water and improved sewage and sanitation, maternal and under-5 mortality are relatively high, and communicable diseases such as HIV, malaria, and tuberculosis are widespread. Yet 2015, the final year for the United Nations’ Millennium Development Goals (MDGs), has passed and enormous progress has been made in the aforementioned areas. Goals to halt and reverse HIV, malaria and TB epidemics were met, child and maternal mortality were decreased by 53% and 40%, respectively, 91% of the global population now uses an improved drinking water source and Official Development Assistance for health increased from $11.6 to $35.9 billion between 2000 and 2014 (WHO, 2016).

Today, NCDs cause more deaths in developing countries than communicable, maternal, neonatal, and nutritional diseases and injuries combined (IHME, 2013). NCDs, particularly cardiovascular diseases (CVD), cancers, chronic respiratory diseases (COPD) and diabetes, are not intended to replace MDG priorities but there is growing recognition of the disproportionate burden that non-communicable diseases place on developing countries both in terms of morbidity and mortality (Beaglehole et al, 2011). In fact, age-standardization of the NCD death rate in Africa shows that it is nearly twice that in the developed world (“Population Ageing and the Non-Communicable Diseases”). Not only are NCDs more fatal in developing countries, they also affect people decades earlier. The
majority of premature deaths (deaths before 70) from NCDs occur in low and middle-income countries (WHO, 2014). The Global Burden of Disease 2010 Report revealed that although life expectancy has increased, largely because of a reduction in child mortality, the survivors are not necessarily living healthier lives: 79.5% of the years lived with disability (YLDs) for all ages in developing countries were attributable to non-communicable diseases and the economic consequences are immense (IHME, 2013). The WHO forecasts a loss of US$7 trillion due to NCDs in low and middle-income countries between 2011 and 2025 (WHO, 2014).

In light of this, the UN General Assembly convened in 2011 to discuss NCD prevention and control. It was only the second time in history the General Assembly had ever convened on a health topic – the first time the topic was HIV/AIDs (WHO, 2011). The General Assembly concluded that NCDs are “hidden, misunderstood and under-recorded,” negatively affecting developing countries’ economies, hindering international development efforts and leading to significant unmet healthcare needs in developing countries (WHO, 2011). Although some MDG targets were not fully met, the WHO’s post-2015 development agenda includes an emphasis on health systems strengthening and non-communicable diseases (NCDs) with recognition of the importance of including multiple sectors, such as transportation and education (United Nations: Department of Economic and Social Affairs, 2012). Specifically, the WHO aims to have a 25% reduction in premature mortality (deaths before 70) from NCDs by 2025 by addressing physical tobacco use, sodium intake, alcohol use, physical activity, hypertension, obesity,
increasing availability and accessibility of basic technologies and essential medicines to treat NCDs, and supporting country health systems (Davids et al., 2015; WHO, 2014). Most countries cannot afford the cost of treating NCDs, while addressing many of the risk factors is a high-yield, comparatively inexpensive approach (Meiro-Lorenzo et al., 2011; Beaglehole et al., 2011). For example, providing drug combinations to individuals at high-risk for NCDs in India is estimated to cost US$0.90 per person, while accelerated implementation of tobacco control (WHO Framework Convention on Tobacco Control (FCTC)) would cost $0.16 per person (Beaglehole et al., 2011).

Despite the demonstrated burden of NCDs in developing countries there is a little interest in NCDs from most donors, and in 2002, only 3.5% of the WHO budget was spent on chronic diseases (Dirks et al., 2006). Aging, alcohol, and kidney disease received the least funding (Nugent & Feigel, 2010). Meanwhile, between 1990 and 2013, chronic kidney disease moved from the 21st-highest cause of death to 11th in the most productive age group, 15-49 year olds, in the developing world (IHME, 2013). In all ages (age-standardized), CKD jumped from 21st to 13th cause of death in the developing world (IHME, 2013). The only that disease that jumped further up the list was HIV/AIDS (Jha, et al, 2013). Despite this, kidney failure is only mentioned twice in the World Health Organization’s three hundred page “Global Status Report on Non-communicable Diseases 2014” (WHO, 2014). At first, the total lack of emphasis on chronic kidney disease in this lengthy WHO document on NCDs seems to be an enormous oversight.
Kidney disease’s exclusion is intentional though. The WHO has prioritized CVD, cancer, diabetes and COPD because they are comprise the majority of global NCD burden and they share common, modifiable risk factors (Couser et al, 2011). While CKD deserves more explicit mention, the disease will benefit from prevention targeted at the aforementioned diseases. Not only does CKD share risk factors with all of the prioritized NCDs, but diabetes and CVD are also risk factors for CKD themselves. Nonetheless, CKD should not be minimized and early detection and treatment of CKD using common, inexpensive therapies could easily be integrated into NCD programs to minimize the need for renal replacement therapy (Stanifer et al, 2014; Couser et al, 2011). In this new global agenda, collaborative, integrated approaches to NCDs and CKD will be most effective (Dirks et al, 2006b).

THE EPIDEMIOLOGY OF AKI, CKI & ESRD

Definitions: Prevalence counts existing cases, while incidence counts new cases. The number of prevalent cases is influenced by the rate of entry into the disease pool, which is related to incidence, and the disease duration, which is affected by treatment or mortality rates. In other words, the only way one can cease to be a prevalent case is by cure or death. Unfortunately, in some of the reviewed studies, “prevalence” and “incidence” were used interchangeably.
The Epidemiology of Acute Kidney Injury

Globally: It has been suggested that AKI is responsible for nearly 1.4 million deaths annually (Lunyera et al, 2016). In the developed world, hospital-based studies report AKI in 3.2-9.6% of admissions, and up to 50% in ICU patients (Li et al, 2003). AKI patients are typically older with multiple co-morbidities and risk factors include advanced age, diabetes mellitus, cardiovascular disease, and undiagnosed CKD. When children in developed world do present with AKI, it typically occurs as a consequence of other medical procedures such as open-heart surgery and bone-marrow and solid-organ transplantation and thus AKI is accompanied by multi-organ dysfunction, hemodynamic instability and a need for vasopressors (Ademola et al, 2012).

Developing World & sub-Saharan Africa: There is limited data on the epidemiology of AKI in the developing world and where epidemiologic studies exist, they are typically from tertiary institutions, which are accessed by a small portion of the critically ill (Obiagwu & Abdu, 2015). The extent of AKI morbidity and mortality cannot be determined cannot be determined at the community level (Lunyera et al, 2016; Li et al., 2003; Burki, 2015). Yet, despite the lack of data, AKI is estimated to be more prevalent in developing countries than developed countries (Lunyera et al, 2016). Limited awareness of AKI amongst healthcare workers and a pervasive lack of laboratory facilities means AKI frequently goes undiagnosed but the Sustainable Kidney Care Foundation (SKCF) estimates the 130,000- 150,000 people die in sub-Saharan Africa
each year from AKI and its thought that 3% of admissions to general healthcare facilities in low-resource settings are for AKI-related problems (Lunyera et al, 2016; Burki, 2015)

In contrast to the developed world, AKI disproportionately affects otherwise-healthy children and young adults in the developing world (Lunyera et al, 2016; Smoyer et al, 2016) Children in rural areas are particularly vulnerable because of the prevalence of diarrheal diseases and the lack of basic infrastructure and health services (Jha et al, 2013; Obiagwu & Abdu, 2015). In Africa, AKI typically affects young adults younger than 40 – a situation resembling the UK in 1956-1959, where the median age was 42 years – whereas AKI typically affects adults older than 60 in more developed countries in the northern hemisphere (Lengani et al, 2010). The patterns and causes of AKI in developing countries are often different from those in developed countries as well, although the causes of AKI in large urban centers more closely resemble those in developed countries (Ademola et al, 2012; Lunyera et al, 2016). One study in Uganda found the prevalence of AKI among patients admitted with sepsis, a common cause of hospitalization in the region, to be 16%, with an in-hospital mortality rate of 21% (Lunyera et al, 2016). Another hospital-based study in Nigeria of 45 patients with AKI found that sepsis (35.5%), pregnancy-related events (22.2%) and toxic nephropathy (13.3%) were major causes (Adu, 2013). AKI was similarly fatal in this study with 22% dying after their first hemodialysis session, leading the authors to conclude that the patients likely presented late in the disease course (Adu, 2013). In another study in children with AKI, intravascular hemolysis, presumably secondary to malaria, and
septicemia were the main causes (Ademola et al, 2012). The principle causes of AKI in rural areas are variable and largely unknown (Lunyera et al, 2016). More accurate data about the prevalence of AKI is needed to put AKI on the political agenda and on the medical radar, yet efforts are stymied by under-reporting and limited diagnostic capacity (Li et al., 2003).

The Epidemiology of CKD & ESRD

The prevalence of CKD depends on the prevalence and management of risk factors while the prevalence of ESRD depends on the baseline incidence of CKD and the rate at which CKD progresses to ESRD, often dictated by the success of prevention and management efforts, as well as ESRD mortality rates (Odubanjo et al, 2011). A successful CKD management program will decrease the prevalence of ESRD, while a successful renal replacement therapy program will increase the prevalence of ESRD by keeping ESRD patients alive.

Globally: The prevalence of CKD and ESRD is growing globally (Okpechi et al, 2012). Furthermore, recent research suggests that data often underestimates the global prevalence of kidney disease as CKD patients often have comorbidities like cardiovascular and cerebrovascular disease that are ultimately listed as the cause of death (Dirks et al, 2006b). For example, the actual mortality rate from diabetic renal disease is thought to be 4-9 times the reported rate (Jha et al, 2013). Often-asymptomatic early stage CKD is thought to account for 80-90% but it is hard to determine the prevalence of
pre-ESRD CKD when symptoms may be “mild, ignored, or undiagnosed” (Jha et al., 2013; Dirks et al., 2006b). Recent widespread application of the KDOQI definition to CKD revealed that it is much more prevalent than previously thought (Eckardt et al., 2013). By the KDOQI definition, 10% of the population has CKD, a comparable prevalence to diabetes (Eckardt et al., 2013). In 2000, the NHANES study estimated CKD prevalence in US adults to be 11.7% ± 08% (Odubanjo et al., 2011). Diabetes, hypertension and glomerulonephritis are the leading causes of CKD in all developed and many developing countries, while hyperlipidemia, smoking and obesity are other important risk factors (Jha et al., 2013). In the US, diabetes accounts for 44% of CKD while hypertension accounts for 27% of CKD, and the most common risk factors are diabetes, hypertension, cardiovascular disease, a family history of CKD and age greater than 60 years (Harris, 2013; Odubanjo et al., 2011).

**Quality of Epidemiologic Data in sub-Saharan Africa:** Exact counts of prevalent and incident kidney disease are challenging to obtain in developing countries where screening is uncommon (Bamgboye, 2009). Estimates are typically derived from data from urban dialysis centers or hospitals, but estimating CKD epidemiology from registration and treatment records has been found to lead to gross underestimation of CKD prevalence in other countries (Odubanjo et al., 2011). Population-based studies, such as the NHANES and KEEP in the US and Italkid in Italy give much more accurate estimates of CKD burden (Odubanjo et al., 2011). The validity of the data from many studies from sub-Saharan Africa (SSA) is particularly compromised by the small sample
sizes and the practice of convenience sampling. The source population from which cases are drawn matters and if the sample is drawn from a population of patients at risk, such as a group of diabetic or hypertensive patients, the prevalence and etiology of renal disease will differ significantly from the general population (Odubanjo et al, 2011). A literature review indicated that 93% of the epidemiologic data on CKD in SSA was determined from urban settings and over half of the studies were from just three countries (South Africa, Nigeria and Ethiopia) (Stanifer et al, 2014). Furthermore, the research is typically from nephrologists in tertiary referral hospitals (Sumaili et al, 2009). Given the low dialysis acceptance rates amongst ESRD-patients, there are important differences in the number and profile of patients living with ESRD, patients diagnosed with ESRD and patients receiving renal replacement therapy (RRT) (Jha & Chugh, 2003). Exacerbating the issue is the matter of poor-record keeping and in several Nigerian articles, authors had to estimate CKD incidence from a wide variety of records (autopsy records, records of renal biopsies from surgical day books for histology in various departments of pathology in Nigeria, records of admissions into medical wards and information found in patients’ case notes) (Odubanjo et al, 2011).

Quantifying CKD in Lower-Resource Settings & sub-Saharan Africa: Increasing life expectancy, economic improvement, and a dramatically growing incidence of hypertension of diabetes combined with enduring infectious diseases, such as HBV, HCV, HIV, malaria and skin infections will converge over the next few years, resulting in an overwhelming burden of renal disease in sub-Saharan Africa (Awuah et al, 2013).
Because of the lack of functioning registries and inaccurate reporting the prevalence and incidence of AKI and CKD cannot be quantified, but it has been estimated that CKD is at least three to four times more prevalent than in more developed countries (Okpechi et al, 2012; Callegari et al, 2012; Elhassan et al, 2007). Based on a literature review the overall prevalence of CKD in sub-Saharan was found to be 13.9% based on medium and high quality studies, but reported estimates ranged from 2% (Cote d’Ivoire) to 30% (Zimbabwe) (Stanifer et al, 2014). By the year 2030, it is estimated that more than 70% of those with ESRD will be in developing countries, whose combined economies will make up less than 15% of the world total (Mushi et al., 2015). Studies from the United States and Africa suggest that ESRD may be more prevalent among black individuals than other races and that this increased prevalence may be attenuated by more aggressive disease (Odubanjo et al, 2011). In the African setting, premature ESRD may also result because of late presentation, inadequate diagnostic tools, and unavailability of treatment (Okpechi et al, 2012). At the same time, prevalence of ESRD in sub-Saharan Africa will be dampened by the unfortunately rapid exit of patients from the renal disease pool: In sub-Saharan Africa, CKD is imminently fatal for most patients because they cannot afford or access treatment (Kresinski et al, 2007). The prevalence of ESRD in sub-Saharan Africa was reported to be less than 100 per million population but most experts believe the prevalence is closer to 150 per million population is (Mushi et al., 2015). The economic burden of renal disease on Africa is magnified as it affects a younger population, afflicting Africans between ages 20 and 50, and patients on sustained on RRT
are often the main money earners (Kresinski et al, 2007; Jha et al, 2013; Mushi et al, 2015; Chugh et al, 1999).

*Understanding the Etiology of Kidney Disease in sub-Saharan Africa:* There are many potential assaults on the kidneys in lower-income and tropical countries that often go unaddressed, such as infectious parasites and viruses (Stanifer et al, 2014). This not only heightens the risk of chronic renal failure, but also means that chronic kidney disease etiologies differ somewhat from patterns seen in higher-income countries (Harris, 2013). Infectious diseases in low-income countries such as water-borne diseases (schistosomiasis, leptospirosis, scrub typhus, hantavirus, malaria) affect the kidneys, and sickle cell disease can have renal manifestations (Jha et al, 2013; Odubanjo et al, 2011). Glomerulonephritis, often infection-driven, hypertensive nephrosclerosis (“hypertension”) and chronic glomerulonephritis (“glomerulonephritis”) are reported to be the primary causes of CKD in sub-Saharan Africa (Bah et al, 2015; Jha et al, 2013; Odubanjo et al, 2011; Arogundade & Barsoum, 2008). Diabetic nephropathy is increasing and obstructive uropathy also contributes significantly to chronic kidney disease (Arogundade & Barsoum, 2008). HIV-associated nephropathy (HIVAN) contributes to the burden of kidney disease in Africa (Okpechi et al, 2012). Curiously, in the United States, HIVAN is more common in African-Americans, and it is hypothesized that this difference may be attributable to high-risk alleles for CKD, MYH9 and APOL1 (Jha et al, 2013). Population screening in sub-Saharan Africa shows that the kidneys are affected in 5-83% of HIV-infected individuals in sub-Saharan Africa, while 11% of the 210 screened
HIV-positive patients in a Democratic Republic of Congo study had HIVAN (Jha et al, 2013; Krzesinski et al, 2007). As people live longer with HIV, the management of chronic diseases in HIV-positive people becomes more important (Stanifer et al, 2014). Meanwhile, many HIV-infected patients are denied access to renal replacement therapy because of concerns about transmission of the virus to healthcare workers and other patients (Okpechi et al, 2012). In addition to HIV, several authors report that hypertension and diabetes are growing causes. For example, although glomerulonephritis is reported to be the primary cause of ESRD in the Democratic Republic of Congo, hypertension and diabetes are responsible for nearly 30% and 25% of renal diseases, respectively (Krzesinski et al, 2007). Similarly in Ethiopia, CKD incidence is increasing reflecting a growing prevalence of hypertension and diabetes (Tuso, 2009).

*Diabetes in sub-Saharan Africa:* The largest increase in diabetes prevalence globally is expected in developing countries with urbanization and dietary changes, and by 2030, sub-Saharan Africa is expected to experience a 161% increase in diabetes prevalence, with associated increases in the incidences of CKD and ESRD (Elhassan et al, 2007; Jha et al, 2013; Krzesinski et al, 2007). In 2012, Okpechi and others reported that diabetes affected 9.4 million in Africa with the prevalence of diabetic nephropathy to be estimated at 6-16% in sub-Saharan Africa (Okpechi et al, 2012).

*Hypertension in sub-Saharan Africa:* Reported rates of hypertension in sub-Saharan Africa are high and getting worse, but estimates vary. One author reported that
hypertension affects approximately 27.0% of men and 28.0% of women in sub-Saharan Africa and is more prevalent in urban than rural areas, while another author noted that hypertension in sub-Saharan African countries is reported to range between 25% and 48% (Jha et al, 2013; Okpechi et al, 2012). A third reported that the prevalence of hypertension in adults over 25 was 36.8% (Tshamba et al, 2014). The Nigerian Association of Nephrology conducted screening during a kidney awareness campaign and found that 13.6% and 19% of participants had hypertension and proteinuria, respectively (Arogundade & Barsoum, 2008). In the Democratic Republic of Congo, the prevalence of hypertension in adults over 25 in 2008 was found to be 38.5% in men and 33.3% in women (Tshamba et al, 2014). The same study indicated that hypertension was the direct cause of renal insufficiency in a third of dialysis patients and was present in 80% of patients (Tshamba et al, 2014). Hypertension is expected to increase by at least 70% between 2008 and 2025 (Moosa et al, 2016). Clearly, chronic diseases have already begun to figure prominently into patterns of chronic kidney disease in sub-Saharan Africa.

Recording Incidence & Outcomes: Renal Registries

Most developed countries have renal registries, an organizational structure for the collection of important patient data on renal disease and therapy (Odubanjo et al, 2011; Davids et al, 2015). Registries, which are relatively inexpensive, elucidate the burden of renal disease, guide policy formation, aid in the planning of treatment and prevention services and provide vital information for monitoring and evaluation (Odubanjo et al,
2011; Davids et al, 2015). Key elements are a defined purpose and scope, good documentation, clear guidelines on what data should be recorded, a data dictionary, regular data collection and cleaning, data quality-control, established data ownership and access and the dissemination of registry findings (Davids et al, 2015). As indicated in the epidemiology section, renal registries are lacking in sub-Saharan Africa and most African governments are oblivious that kidney disease is an important cause of death amongst their citizenry (Davids et al, 2015). Historically, African nephrologists have attempted to establish renal registries and publish data but efforts were not sustained (Davids et al, 2015). Several authors have called for the formation of renal registries in sub-Saharan Africa: “To communicate our needs to these bodies [MoH or donors], we cannot rely on guesstimates of the burden of renal disease in Nigeria” (Odubanjo et al, 2011).

Recognizing the value of renal registries and the need to drawn attention to the unrecognized problem of CKD, the African Association of Nephrology (AFRAN) decided in March of 2015 to establish a regional renal registry (Davids et al, 2015).

**Screening for CKD**

*General:* Screening has been a useful tool for many chronic diseases, although it is best to screen judiciously as demonstrated in the cases of breast and prostate cancer screening. Frontline workers in primary care can easily drive screening for kidney disease (Moosa et al, 2016). However, even most high-income countries, except Japan and the Netherlands, do not have screening programs for chronic kidney disease (Kirby, 2010). In the United States, no surveillance system tracks pre-dialysis patients with early stages of
CKD unless they are covered by Medicare (Schoolwerth et al, 2006). Consequently, epidemiologic comparisons between nations are typically based on ESRD prevalence versus CKD prevalence (Arogundade & Barsoum, 2008).

Initiatives to increase healthcare providers’ and the general population’s awareness of CKD are warranted but economic analysis suggests that screening and treatment for CKD should be restricted to high-risk populations (Schoolwerth et al, 2006; Dirks et al, 2006b). Screening programs demand both funding and manpower but determining the amount of funding and manpower requires knowing the size of the problem - an interesting quandary when attempting to quantify the incidence of an oft asymptomatic disease (Krzesinski et al, 2007). Given the relatively low incidence of ESRD in the general population (100 to 200 per million population) and limited accuracy of testing – the positive predictive value is only 0.3 – population-wide screening is not cost-effective (Dirks et al, 2006b). However, the most cost-effective method of screening in high-risk populations is disputed (Jha et al, 2013). Screening for CKD is known to be cost-effective in diabetics and screening is currently suggested at primary care encounters in individuals with diabetes, hypertension, cardiovascular disease, structural diseases of the renal tract, autoimmune diseases with potential for kidney involvement, and family history of kidney disease (Jha et al, 2013). Since the profile of risk factors for CKD, including smoking, obesity, alcohol abuse, and chronic gout, resemble the risk factors for CVD, it has been recommended to incorporate kidney disease screening into programs
for CVD or other NCDs, like diabetes, for opportunistic identification (Harris, 2013; Dirks et al, 2006b; Couser et al, 2011).

In high-risk patients, it is possible to obtain inexpensive measurements of proteinuria by dipstick urinalysis alone, but for more comprehensive identification of chronic kidney disease, a patient’s urine is tested for hemoglobin, glucose, leukocytes and proteins (albumin) (Couser et al, 2013; Dirks et al, 2006b). Albumin: creatinine ratios, which reveal the severity of glomerular disease, are then calculated from the urinalysis. Ratios indicative of albuminuria warrant further testing, specifically, serum creatinine and fasting glucose testing, as well as reassessment of the urine protein excretion rate (Dirks et al, 2006b). The patient’s cardiovascular risk can be determined as well from their BMI, blood pressure, fasting glucose level, albuminuria and serum creatinine (Dirks et al, 2006b).

*Screening in Lower-Resource Settings:* Most population-based screens for CKD have been undertaken in developed nations but using the same screening methods in other regions might miss important affected groups because the risk factors and patterns of CKD etiology are heterogeneous (Jha et al, 2013). One challenge to screening in the developing world is that programs should have a treatment arm for when disease is discovered but treatment for CKD or ESRD is often unavailable in developing countries (Arogundade & Barsoum, 2008). In a systematic review and meta-analysis, chronic
kidney disease was most commonly diagnosed in sub-Saharan Africa by urinalysis (Stanifer et al, 2014).

It has been asserted that screening for kidney disease in high-risk populations should be a pre-requisite of CKD prevention in developing countries (Naicker, 2009). Screening does exist on a limited basis in the developing world. In 2005, the International Society of Nephrology Commission for the Global Advancement of Nephrology (ISN-COMGAN) developed the “Detection and Management of Chronic Kidney Disease, Hypertension, Diabetes and Cardiovascular Disease in Developing Countries Strategy” and pilot programs have been proving that screening in low-resource countries can prevent CKD from progressing to ESRD (Kirby, 2010). The screening and prevention program includes a door-to-door survey asking lifestyle questions prior to a brief physician exam and dipstick urine test for proteinuria (Kirby, 2010). Patients with kidney disease are then enrolled in a lifestyle-modification and treatment program that aims to reduce alcohol and salt consumption, end tobacco use, and increase exercise, in addition to giving patients generic ACE inhibitors (Kirby, 2010). After one year, blood glucose and blood pressure control was reported in 60% and 72% of patients, respectively, with regression or stabilization of proteinuria reported in 52% of patients in the pilot programs (Kirby, 2010). Furthermore, the screening program helped to identify individuals at risk for CVD (Kirby, 2010). Similar programs in India and amongst disadvantaged Aborigine populations in Australia have shown similar success in identifying and managing CKD and its risk factors at a low cost (Krzesinski et al, 2007). In Africa, screening programs
“are in their infancy” with programs reported in South Africa, Nigeria, Ghana and Kenya” (Naicker, 2009; Arogundade & Barsoum, 2008).

PRIMARY & SECONDARY PREVENTION

Primary prevention aims to prevent disease or injury before it occurs, while secondary prevention aims to reduce the impact of disease or injury that has already occurred. Primary prevention would seek to prevent AKI or CKD from ever occurring, while secondary prevention would try to mitigate the severity of AKI when it occurs and prevent the progression of CKD to later stages.

Prevention of AKI

The heterogeneity of conditions precipitating AKI challenges the standardization AKI diagnosis, prevention and management (Li et al, 2013). In the developed world, electronic health records (EHRs) have contributed to earlier detection of AKI (Li et al, 2013). EHR features like alerts that guide drug dosing and an “AKI sniffer system” that alerts physicians to changing renal function help providers avoid severe AKI (Li et al, 2013). In many developing countries, strengthening primary care, increasing attended deliveries by trained healthcare workers, and improving access to clean drinking water, anti-malarial drugs and antibiotics would reduce AKI (Burki, 2015). Greater awareness of local infectious or venomous organisms and effective evaluation of the severity of fluid depletion during episodes of acute diarrhea would help healthcare workers recognize AKI before dialysis is required (Li et al, 2013). In many instances, efforts
towards the MDGs will help to prevent AKI, while reducing the severity of AKI will help to reduce CKD (Obiagwu & Abdu, 2015).

**Prevention of ESRD**

*General:* Prevention, the most cost-effective option, would seem to be the “obvious approach” to the growing burden of chronic diseases (Dirks et al, 2006b). Decelerating CKD’s progression to ESRD would save lives and reduce the cost of treatment (Neil et al, 2009). Prevention of CKD should be integrated into any NCD policy, irrespective of country income, as kidney disease figures prominently into poor health outcomes of diabetes and CVD (Couser et al, 2011). However, even in most developed countries, CKD is not detected early enough to reduce morbidity and mortality (Schoolwerth et al, 2006). Norway is singled out for its successful prevention of CKD progression to ESRD: While Norway has a similar CKD prevalence (10.2%) to the United States; the slower progression of CKD is responsible for the comparatively lower ESRD incidence in Norway (Odubanjo et al, 2011). Early detection of CKD through targeted screening is necessary though before the progression to ESRD is interminable (Dirks et al, 2006b).

Primary care workers must spearhead CKD prevention (Barsoum, 2011; Couser et al, 2011). Presently, though, CKD awareness is low among healthcare providers and incorrect diagnoses result in delayed referrals and missed opportunities to slow disease progression (Jha et al, 2013). Tools to control blood pressure and obtain good glycemic control are the single most important tools to prevent CKD progression (Jha et al, 2013).
Blood pressure control, often achieved through ACE inhibitors and angiotensin receptor blockers, slows the progression of CKD, buying patients years (Adu, 2013). ACE inhibitors are considered to be standard therapy in patients with diabetic nephropathy, irrespective of whether the patient has hypertension, and they are reported to have beneficial effects for patients with proteinuric renal disease in general (Couser et al, 2011; Harris, 2013). ACE inhibitors cost US$320 per year and will become cheaper as they come off patent (Dirks et al, 2006b). Treating diabetics has also been identified as a cost-saving strategy in developed countries. Salt control is cost-effective, simple and helpful in preventing the progression of CKD as well (Jha et al, 2013). The cost-effectiveness of a self-management intervention for people with stage 3 CKD is currently being investigated (Jha et al, 2013).

*Lower-Resource Settings & sub-Saharan Africa:* Since African governments will not be able to fund chronic dialysis in the near future, CKD prevention is vital (Adu, 2013). CKD prevention programs are rare in the developing world though (Mushi et al, 2015). CKD has received less attention than other chronic diseases and the lack of quantitative knowledge about its prevalence obfuscates prevention (Sumaili et al, 2009; Arogundade & Barsoum, 2008). Given that NCDs and infectious diseases alike contribute to CKD in many developing countries, prevention strategies must include timely treatment of parasitic, bacterial, and viral infections (Harris, 2013).
Successful prevention programs are reported in a few lower-resource settings (Aviles-Gomez et al, 2006). The Kidney Help Trust of Chennai screened 25,000 people and anyone with hypertension or diabetes (~15%) was treated with medication for hypertension or diabetes at a per capita cost of US$0.27 (Dirks et al, 2006b). A screening and prevention program for renal and cardiovascular disease in Australian Aborigines reduced the incidence of ESRD by 63%, saving an estimated US$500,000 to US$2.7 million in delayed or avoided dialysis costs (Dirks et al, 2006b). The most well coordinated prevention effort in sub-Saharan Africa is described to be the Chronic Disease Outreach Primary Prevention Program (CHOPPP), established in Dr. Katz and implemented in 16 primary care health clinics in Soweto (Arogundade & Barsoum, 2008). The program utilizes non-physician health workers to check blood pressure and glucose, to obtain a basic history and physical and to perform urinalysis (Arogundade & Barsoum, 2008). Findings are then reported to a program manager who then reports to a supervising physician (Arogundade & Barsoum, 2008)

**TERTIARY PREVENTIONS: TREATMENT OF AKI & ESRD**

Tertiary preventions are those that minimize the impact of an ongoing disease or injury that has enduring effects, often by forestalling death. Both dialysis modalities, hemodialysis and peritoneal dialysis, are used in treatment of AKI and ESRD, albeit for different durations, but transplantation is unique to ESRD treatment.
AKI TREATMENT

Untreated AKI is the “often fatal consequence” of common, preventable health events in the developing world (Smoyer et al, 2016). Nigerian literature, for example, documents AKI mortality rates to be between 28% and 46% (Obiagwu & Abdu, 2015). The benefits of early intervention in AKI are widely acknowledged and if possible, electrolyte and fluid imbalances should be corrected, infections treated, and nephrotoxic medications discontinued (Lunyera et al, 2016; Cruz et al, 2009). The necessary solutions and medications are often unavailable, though, and in one study, only 60% of respondents of study reported that rural health centers have IV fluids, while only 52% indicated that they have the right antibiotics for infection-related AKI (Lunyera et al, 2016). Oral rehydration solutions and antimalarial drugs are commonly available though (Lunyera et al, 2016). Complicating the lack of supplies is patients’ hesitancy to seek care because of long distances and transportation costs, concerns about payment, greater accessibility of alternative treatments and more (Obiagwu & Abdu, 2015). Perhaps the greatest challenge to AKI treatment in developing countries, however, is the lack of awareness of kidney injury and disease among staff at the primary level (Jha & Chugh, 2003). Early referral is critical to the success of an AKI treatment program but there are consistently low referral rates to established AKI programs in sub-Saharan countries because of insufficient healthcare worker knowledge and diagnostic capacity (Lunyera et al, 2016). Healthcare workers at the primary care level must be trained to document urine volume in acutely ill people and the importance of serial serum creatinine measurements in high-risk patients must be impressed upon physicians (Callegari et al, 2012; Li et al, 2003). Unfortunately,
the aforementioned factors - supply unavailability, patients’ delay in seeking care, and limited awareness of AKI and diagnostic capacity amongst frontline healthcare workers-limit opportunities to reverse AKI before more resource-intensive therapy is required (Jha & Chugh, 2003). By the time most AKI patients arrive at referral hospitals they have advanced uremia and additional complications, including infections and GI bleeding (Jha & Chugh, 2003). Untreated AKI negatively affects the functioning of many organs, including the brain, lungs and heart, and is often fatal. To regain kidney function, many patients require short-term renal replacement therapy in the form of PD, HD or CRRT.

KDOQI guidelines recommend initiating dialysis immediately in patients with severe hyperkalemia, severe acidosis, pulmonary edema and uremic complications and discontinuing dialysis when the patient has recovered sufficient intrinsic kidney function (“Section 5,” 2012). Two large RCTs demonstrated the mean duration of RRT required to be 12-13 days and many patients recover and do not require long-term RRT (“Section 5,” 2012). However, more than 50% of patients with severe AKI will not improve, even with appropriate therapy, and it may be appropriate to withdraw life-support treatments, including RRT (“Section 5,” 2012). In the case of AKI patients, un-cuffed, non-tunneled dialysis catheters are recommended, even though tunneled cuffed catheters are thought to reduce the risk of infection, because insertion of a tunneled cuffed catheter requires “expertise, time and effort, thus potentially delaying initiation of RRT” (“Section 5,” 2012).
PD and HD, which are discussed below, are common to both AKI and ESRD. In 2008, a RCT found clinical outcomes of PD and HD for AKI to be “comparable in terms of metabolic control, infectious and mechanical complications, renal function recovery, patient survival, and mortality” (Obiagwu & Abdu, 2015). CRRT, however, is unique to the treatment of AKI patients, and employs arteriovenous or venovenous hemofiltration to treat critically ill AKI patients (Jha & Chugh, 2003). The modality, which has become increasingly popular recently, offers advantages in hypotensive or hemodynamically unstable patients by using specialized machines to continuously regulate ultrafiltration and to replace fluid volumes (Jha & Chugh, 2003). CRRT’s use in developing countries is limited though, as it is much more expensive than HD (Jha & Chugh, 2003). Even the filters used for hemofiltration are approximately ten times more expensive than those used in HD (Jha & Chugh, 2003).

Many governments in developing countries do not want to become involved in renal replacement therapy because maintenance dialysis would place an insupportable burden on the health system but renal replacement therapy for AKI can actually be provided at low cost with excellent outcomes (Lunyera et al, 2016). While acute HD is often unrealistic in low-resource settings because of erratic water and electricity supplies, high overhead costs of machines and water purifiers and a lack of expertise, acute PD is technically simpler, does not require machines or electricity and can be more readily improvised with existing materials (Smoyer et al, 2016). Furthermore, a recent study in Tanzania found PD to be cheaper than HD for the management of AKI (Obiagwu &
Abdu, 2015). In contrast to chronic dialysis, which is fraught with financial and logistical challenges, a short course of PD can treat AKI and is relatively affordable (Callegari et al, 2012). Since >99% of AKI patients who will recover full renal function will do so within 30 days, it is possible to separate AKI treatment from ESRD treatment and employ a cut-off point when necessary (Lunyera et al, 2016).

TRANSPLANTATION

**General**

There is consensus that renal transplantation is the most cost-effective strategy for patients with ESRD (Dirks et al, 2006b). Transplantation offers the best possible quality of life, the lowest morbidity and mortality and considerable cost savings in the long run (Bamgboye, 2009). One-year graft and patient survival rates from kidney transplantation from living kidney donors are 95% and 98% and 80% and 95% from cadaver kidneys and with a skilled transplant surgeon, transplantation extends life of ESRD patients 10-15 years more than patients on HD (Rizvi et al, 2003; Harris, 2013). The cost of transplant has steadily declined in developed countries (Dirks et al, 2006b). Unfortunately, the difference between the number who need transplants and the number of donors is growing and donors, rather than economics, limit renal transplantation, leading some to believe that it is unlikely that renal transplantation will become more available in the near future (Dirks & Levin, 2006; Hooi et al, 2005; Just et al, 2008b). There are, however, several options to increase organ donation that predominantly require political will (Moosa et al, 2016). The best option is to increase deceased donor organ donation as
recent evidence indicates that living kidney donors’ health may be compromised in the long run (Moosa et al, 2016). Countries with op-out systems have 25-30% higher rates of donation than opt-in countries and both Spain and Croatia’s “integrated models” are noted to have particularly high rates of organ donation (Moosa et al, 2016). The integrated approach includes legislative changes and centralization of authority, employment of transplant coordinators specifically responsible for organ recovery, reimbursement of donor hospitals and public awareness campaigns (Moosa et al, 2016). In Israel, individuals who are registered as organ donors receive priority on the transplant list should they themselves ultimately need an organ, and this system has lead to a dramatic increase in donors and transplants in the country (Moosa et al, 2016). Although many authors are pessimistic about the future availability of organ donation, there are clearly strategies that can and should - particularly given the long-term economic and survival advantages of renal transplantation– be employed to improve donation rates.

**Lower-Resource Settings & sub-Saharan Africa**

In many developing countries, dialysis is only offered to kidney transplant candidates (Dirks & Levin, 2006). However, in the developing world, economic costs figure more prominently into the availability of transplantation and the initial costs of operation and hospital stay, maintenance immunosuppression, ambulatory care, treatment of opportunistic illness and re-hospitalization challenge transplantation in developing countries (Aviles-Gomez et al, 2006). Costs can be recovered though and an increase in the kidney transplantation rate is thought to reduce the national burden and long-term
costs of RRT in countries where RRT is provided. While the costs of transplant are reported to be higher than dialysis in the first two years in Sudan, kidney transplantation becomes cost-effective after the second year (Abdelwahab et al, 2013). A general lack of education and medical infrastructure, cultural opposition towards organ donation, an absent legal framework, concerns about transmission of HBV, HCV, HIV, malaria and TB through organ transplant and ethical issues also hinder renal transplantation in many developing countries (Rizvi et al, 2003; Dirks et al, 2006b). In addition, the lack of a renal registry for policy formation, the dearth of meaningful research, the shortage of trained and motivated staff, the paucity of cooperation between healthcare units in these countries, and the lack of a national health insurance scheme are all challenges to transplant programs in sub-Saharan Africa (Bamgboye, 2009).

Transplantation is often accompanied with complicated legal requirements and many developing countries lack legislation recognizing brain death (Jha & Chugh, 2003; Chugh et al, 1999). Although there are limited cadaveric donor programs in developing countries, there are better living donor programs (Dirks et al, 2006b). In countries where a large proportion of the population lives in absolute poverty, paid organ donation can be very attractive and issues range from “altruistic donation to criminal harvesting of organs from living people, and from selling of one’s organs to kidnapping, murder and harvesting of organs” (Rizvi et al, 2003; Ajayi et al, 2016). Some countries actually offer compensation for organ donation, such as Iran where the waiting list was completely eliminated in almost a decade by the practice paid donation (Ajayi et al, 2016). In other
countries, payment is informal but exploitation of impoverished individuals is widespread such as in Pakistan (Ajayi et al, 2016). Where high levels of corruption and poverty coexist, transplant activities need to be monitored extra carefully (Ajayi et al, 2016). In 2008, the Declaration of Istanbul was promulgated after an International Summit on Organ Transplantation Tourism and Trafficking, reasserting that organ trafficking and transplantation tourism are unethical (Ajayi et al, 2016).

Successful transplant programs in developing programs do exist though, such as the SIUT (Sindh Institute of Urology and Transplantation) in Karachi, Pakistan, a public sector organization that does over 130 renal transplants annually from living related donors (Harris, 2013; Rizvi et al, 2003). Although the institute initially was stymied by post-transplant infections, including activation of latent tuberculosis by immunosuppressive drugs, outcomes have since significantly improved (Rizvi et al, 2003; Harris 2013).

DIALYSIS

The Concept of Dialysis

Patients with ESRD require dialysis or renal transplantation to avoid life-threatening uremia (Odubanjo et al, 2011). If renal transplantation is unavailable, as is the case in many low-resource countries, patients with ESRD will depend on dialysis for the remainder of their lives (Mushi et al, 2015). The challenge of dialysis is to remove waste from the blood while ensuring the correct concentration of electrolytes and proteins
remain to maintain homeostasis. Dialysis, largely an act of diffusion, primarily functions by establishing a concentration across a selectively permeable membrane. In the case of peritoneal dialysis, the peritoneal membrane (peritoneum) is the selectively permeable membrane, while the dialyzer in the hemodialysis machine is the selectively permeable membrane in hemodialysis. Both modalities require dialysis fluid of an appropriate composition to create the desired concentration gradient for diffusion. The largest difference between hemodialysis and peritoneal dialysis is where the exchange occurs, with peritoneal dialysis being intracorporeal and hemodialysis being extracorporeal. Both modalities require access to internal bodily fluids: In PD, a catheter is used to access the peritoneal cavity, while a fistula, graft or temporary catheter can be used for vascular access for PD (Just et al, 2008 “Health Policy”). In PD, dialysis fluid is allowed to indwell in the peritoneal cavity for several hours and dialysis fluids exchange across the peritoneum and endothelium of blood vessels traversing the peritoneum. After a few hours, the waste-filled fluid is removed and is replaced with fresh dialysis fluid. PD is typically performed at home, rather than in a center, offering a comparatively greater freedom to patients (Abu-Aisha et al, 2009). HD, on the other hand, needs direct access to a blood vessel so that blood can flow into dialysis machine. HD can be performed at home but it is typically performed at a center and patients usually need dialysis 3-4 times per week for 3-5 hour sessions (Neil et al, 2009). Although absolute contraindications are few, PD is preferred over HD for patients with congestive heart failure, ischemic heart disease, extensive vascular disease or problematic vascular access, while HD is preferred over PD for patients with documented loss of peritoneal function, extensive abdominal
adhesions, or other uncorrectable mechanical defects that prevent effective PD or increase the risk of infection, such as a surgically irreparable hernia or bladder extrophy (Neil et al, 2009).

**PD Access**

There is significant debate in the literature regarding best practices in PD catheter placement, with researchers debating the advantages of laparoscopic-placement versus open-placement versus percutaneous placement of catheters, catheter type (swan-neck, straight, cuffed, et cetera), the merits of selective omentopexy and adhesiolysis, rectus sheath tunneling and more. In the face of high rates of peritonitis, the Cochrane review found no evidence that any particular [insertion] technique was superior (Strippoli et al, 2004). Instead, surgical skill and dedicated post-operative care are the some of the most important predictors of catheter survival and complications (Crabtree, 2006; Khanna & Krediet, 2009).

**HD Access**

For hemodialysis, a patient may either have an arteriovenous graft, an arteriovenous fistula or a venous catheter. The type of access create depends on the anticipated duration of dialysis, with arteriovenous grafts and fistulas preferred for long-term access (Smoyer et al, 2016). However, in much of the developing world vascular
surgery expertise is limited meaning that central venous catheters are commonly used, even for maintenance dialysis (Sinha et al, 2015).

**Versions of PD & HD**

Hemodialysis modalities involve home-based HD and center-based HD and center-based HD is far more common. PD modalities include IPD, APD, and CAPD. Although it was performed in the past, Intermittent PD (IPD) is not recommended as it associated with higher risks of peritonitis and worse outcomes (Sinha et al, 2015). Automated PD (APD) uses an automated cycler at night, freeing the patient from performing manual exchanges, and has been shown to reduce peritonitis rates in some cases (Correa-Rotter, 2001). APD is much less common in the developing world as the modality requires a consistent electricity supply and an APD cycler for each individual (Jain et al, 2010). Continuous Ambulatory PD (CAPD) occurs through out the day and involves manual exchanges by the patient or caregiver. “PD” most commonly refers to CAPD.

**PD VERSUS HD: QUALITY**

**Dialysis Outcomes**

*General:* The practice of renal replacement therapy (RRT) is not standardized and there are wide variations in the dialysis modality, choice of membrane and solutions for HD, catheters and fluids for PD, and frequency and duration of dialysis (Vale et al,
ESRD is still met with unacceptably high rates of mortality, even in developed countries, and much of the perennial debate over HD or PD stems from a desire to improve patients’ quality of life and long-term survival (Odubanjo et al, 2011; Mushi et al, 2015). Despite wide variations in PD usage globally, there are very few absolute medical contraindications for either modality and ESRD patients show similar survival rates at 6, 12, 24, 36 and 48 months (Neil et al, 2009; Karopadi et al, 2013). In fact, there may be some long-term survival advantages to using PD as the initial modality as it helps preserve residual renal function and saves vasculature for future HD use (Abu-Aisha et al, 2009; Neil et al, 2009). Although technique failure rates for PD are 7-11% higher than for HD, ‘the ‘integrated care’ approach to ESRD see this as a contraindication as all three modalities – PD, HD, and RRT- may be part of a patient’s treatment over their lifetime (Abu-Aisha et al, 2009). The quality of life of PD patients is at least as good as that of HD patients, if not better, according to the United States Renal Data System 2012 Annual Report and PD is reported to be associated with equal or better patient satisfaction (Karopadi et al, 2013; Neil et al, 2009). A Cochrane systematic review comparing CAPD and HD for ESRD in adults found no significant difference in survival or quality of life for PD and HD (Vale et al, 2004). Although improvements have been made, diabetic patients still have worse outcomes on both HD and CAPD, while dialysis outcomes also deteriorate with age (Hooi et al, 2005).

The quality of dialysis outcomes, particularly in terms of peritonitis and technique failure- seem to be particularly affected by the center size and by the frequency of home
visits by healthcare workers. PD outcomes are particularly challenged by rates of peritonitis and technique failure and studies suggest that outcomes are better in large PD programs, while, conversely, infections may be more common at smaller centers (Finkelstein et al., 2011; Sinha & Bagga, 2015; Woodrow, 2013). In Hong Kong, where PD is the predominant dialysis modality and programs often care for over 300 PD patients, outcomes are excellent (Finkelstein et al., 2011; Woodrow, 2013). Improvements in patient training techniques have also significantly reduced rates of peritonitis and home visits enhance both the quality of life and longevity of PD patients (Abu-Aisha et al., 2009; Okpechi et al., 2012)

Dialysis Outcomes in Low Resource Settings: Dialysis in the developing world is often characterized by higher rates of morbidity and mortality. The environment in which dialysis is performed strongly dictates the quality of the outcomes. In most low resource settings, short-term survival is prioritized rather than quality of life or longevity (Awuah et al., 2013; Mushi et al., 2015). Limited data suggests that care of ESRD patients is often “suboptimal by developed world standards” and patient care patterns are dictated by financial issues rather than dialysis adequacy in developing countries (Awuah et al., 2013). There are many challenges to quality dialysis outcomes in low-resource settings. Late patient presentation, unavailability of supplies, inadequate dialysis, infections and patient malnutrition all contribute significantly to patient mortality (Jha & Chugh, 2003). Late presentation is common in the developing world and many African predict that the proportion of survivors would have been higher if patients presented earlier with fewer
complications (Esezobor et al, 2014). Patients often receive inadequate dialysis, either because they receive an inadequate number of sessions per week or because dialysis was terminated for financial reasons or lack of functioning equipment or supplies. It is common for HD patients to receive only two sessions of dialysis per week, causing patients to suffer continually from uremia and “there are few long-term survivors” (Jha & Chugh, 2003). Frequency of dialysis is also reduced or dialysis is terminated when money runs out (Jha & Chugh, 2003). Furthermore, rehabilitation is unlikely when most patients are undernourished and nutritional management is inadequate due to the lack of trained dietitians (Chugh et al, 1999). Poor hygiene and living standards, limited laboratory facilities, and a lack of proper peritonitis treatment also contribute to high rates of peritonitis (Abu-Aisha et al, 2009; Li & Chow, 2001). All of these factors lead one author to hypothesize that careful patient selection would be the best way to improve outcomes in such settings (Suassuna, 1998). The dialysis outcomes in low-resource settings are most indicative of the environment rather than clinical quality.

PD VERSUS HD: COST

Overview of Costs

Cost Analysis & Terminology: One challenge of comparing cost analyses is that they often include different costs, terminology and methods of apportioning overhead expenses, impacting the total costs reported (Karopadi et al, 2013). The studies on dialysis costs are heterogeneous with regards to methodology, population-studied, costing perspective, and overall quality (Karopadi et al, 2014). For example, many studies on
dialysis omit relevant costs such as the costs of hospitalization for complications, nursing home or home-care, and transportation, yet these details are influential: One study noted that an HD patient travels to a clinic or a hospital 13 times a month on average while a PD patient does not need to travel nearly as often, while yet another reported that the annual travel costs per patient-year for an HD patient were nearly double that of an PD patient (US$817 vs. US$446) (Karopadi et al, 2013; Mendes de Abreu et al, 2013). In many instances, failing to consider all dimensions can result in conservative estimates of the cost advantage of PD over HD (Karopadi et al, 2013). In many developing countries, costs are often assessed as related only to the cost of supplies, especially if the hospital overhead and physician and nurse salaries are paid by the government (Just et al, 2008a). Unfortunately, the cost of supplies is only a fraction of the true costs and this costing methodology contributes to the perception that PD is more expensive than HD (Just et al, 2008a). Another challenge is that several published studies from sub-Saharan Africa confuses the terms “cost,” “price,” and “charge,” but there are significant differences in their meaning. For example, if the price of a hemodialysis session is $70, this does not mean that $70 was spent for that unit of care, but rather that the patient paid $70. Similarly, the hospital could charge $100 per dialysis session, but the government could subsidize $30, and the price would be $70 for the patient. Unfortunately, neither of these – “price” or “charge”- may equal cost, especially if the government is paying staff salaries and overhead costs, and appropriate analysis of all cost types, could reveal that $150 is spent to provide one unit of care (one dialysis session). Unfortunately, the price a patient pays for a dialysis session or the sum a hospital charges for a dialysis unit is
frequently reported as the cost. Further complicating a comprehensive understanding of the cost of the different dialysis modalities is the fact that cost analyses also do not include other aspects that may be of economic value, such as the greater feasibility of maintaining employment on PD. In short, the following cost analyses should be interpreted cautiously.

Costs Involved: There are an enormous variety of costs in providing dialysis. Laboratories, medications and equipment for dialysis access creation are necessary. For the patient there are transportation, loss of work, and social costs. Important variable costs in HD include dialyzers and tubing, while the variable costs of PD consumables – predominantly dialysis solutions and bags- can be a significant portion of the total cost of PD in many countries: In Sri Lanka, drugs and consumables accounted for 70.4%-84.9% of the total cost of PD (Karopadi et al, 2014; Mushi et al, 2015). Furthermore, in large countries with limited transportation infrastructure, transport of supplies to underserved or distant areas may be as much as 40% of supply costs (Suassuna, 1998). In addition to these variable costs, there are important fixed, direct costs, including the salaries of physicians, nurses, nutritionists, lab technicians and other personnel, HD machines and water treatment for dialysis machines. It has been noted that personnel expenses tend to be lower in developing countries but inadequate training may compromise quality of care (Suassuna, 1998). Finally, there are indirect costs including building costs, facility utilities, and other overhead, although many studies fail to state if indirect costs are even
included in their cost-evaluation (Just et al, 2008b). These costs tend to be higher in more
developed economies (Just et al, 2008a).

Cost Drivers: Generally, PD consumables are a significant portion of PD costs, while labor and capital expenses are a large portion of HD costs (Just et al, 2008b). Consequently, HD costs will be connected to the costs of skilled labor and capital, while the cost of PD will depend on the price at which necessary consumables can be acquired in the country (Karopadi et al, 2014). The costs can vary enormously and are very
country-specific, depending on local production or low tariffs (Figure 1) (Correa-Rotter, 2001). In countries where fluids are imported or other issues disproportionately affect costs, PD can be 2-3 times more expensive than HD (Correa-Rotter, 2001). In Japan, the
cost of a 2L bag of PD fluid was reported to be as high as US$22, and even the number of
PD exchanges done per day affects cost, as many South Asian patients only perform 3
exchanges, while Europe and the US recommend 4 or more (Li & Chow, 2001; Karopadi
et al, 2014).
Figure 1. Local Manufacturing or Low Import Duties


Time of referral to nephrologist, hospitalization, and center-size can all be cost-drivers. Late referrals almost always require urgent dialysis initiation and are typically sicker, requiring more resources for treatment (Just et al, 2008 NDT). Hospitalization of dialysis patients can drive up costs significantly. A comprehensive literature revealed hospitalization costs to be similar for PD and HD, although the cause for admissions differ between modalities, with HD patients being admitted for access issues, thrombosis and infections, while PD patients were most frequently admitted for peritonitis and CVD (Just et al, 2008 NDT). The center size and efficiency also matters, demonstrating
economy of scale as cost efficiency increases with greater volume (Hooi et al, 2005). A North American literature review reported the cost difference between PD and HD to be dramatic when the PD program is well run (Just et al, 2008 NDT). From a financial management standpoint this makes sense as it is typically easier for managers to reduce variable costs than fixed costs. A Malaysian study found that both PD and HD are “viable options…if both are done in an efficient manner,” concluding that to be cost-efficient, a PD center needs to serve at least 100 patients per year and an HD center needs to provide approximately 15,000 HD treatments per year (Just et al, 2008, Health Policy). The duration a unit has been in option and the presence of resident nephrologists are also reported to improve cost-efficiency in Malaysia (Hooi et al, 2005).

**Dialysis Costs Globally**

*Absolute Costs:* Treatment of ESRD is not only a medical problem – it is also an economic issue (Mushi et al, 2015). In absolute terms, dialysis is extremely expensive. In 2013, ESRD Medicare costs in the United States were $20.1 billion, or 6.7% of Medicare expenditure, and this does not even include the additional $12.4 billion non-Medicare dollars spent on ESRD in the United States that year (Harris, 2013). It has been suggested that “75% of the world’s dialysis resources are reserved for just 15% of its population” and the relationship between dialysis population per million population and per-capita income is typically linear (Li & Chow, 2001; Correa-Rotter, 2001). Not only is dialysis expensive, but it also benefits a small citizenry. In Europe, although dialysis treatment
consumes 0.7-1.8% of national healthcare budgets, the dialysis population is only 0.02 to 0.05% of total population (Dirks et al, 2006b).

**Relative Costs (HD to PD):** In light of these extraordinary costs, there has been significant interest in the comparative costs of HD and PD. Analysis reveals that PD is less costly than HD in developed countries with less conclusive results from developing countries (Just et al, 2008a). A literature review of review of 46 countries (20 developed and 26 developing) found the cost ratio of HD: PD to range between 1.25 - 2.35 in 22 countries (17 developed, 5 developing), 0.90-1.25 in 15 countries (2 developed and 13 developing) and 022-0.90 in 9 countries (1 developed and 8 developing), leading the authors to conclude that most developed countries can provide PD at a lower cost than HD, while in developing countries where economies of scale have been achieved, either by local production or low import duties on PD consumables, PD and HD are similar prices (Karopadi et al, 2013). Overall healthcare expenditure could be reduced in developed countries by increasing PD utilization rates (Karopadi et al, 2013).

The authors also reported a strong statistical effect of the country’s level of development, economies of scale and percentage of private health-care expenditure on HD: PD ratios (Karopadi et al, 2014). Cost ratios tend to follow utilization patterns. Japan is one of the only high-income countries where HD is reported to be cheaper than PD and it has one of the lowest rates of PD usage at 3.3% of dialysis patients (Karopadi et al, 2013). In contrast, in Mexico, where 65.8% of dialysis patients are on PD, the HD: PD
cost ratio is 1.53, and in Hong Kong, where 79.4% of patients are on PD, the HD: PD cost ratio is 2.35 (Karopadi et al, 2013). However, cost can vary immensely even within a single country (Just et al, 2008b).

**Developing Countries:** It would seem that PD is “particularly well suited for developing nations” compared to HD, but the cost-structure of the modalities makes this often untrue (Just et al, 2008a). HD, which is more labor-intensive for medical personnel, has higher fixed costs, such as the costs of purchasing machines and physician and nurse salaries, but in developing countries labor costs are typically much cheaper than in developed countries (Karopadi et al, 2014; Li & Chow, 2001). PD, on the other hand, has higher variable costs, but these supplies have to be imported, resulting in high costs, and the end result is that PD supplies are often a significant proportion of total treatment costs in developing countries (Li & Chow, 2001). However, many countries, including Nepal, Thailand and Malaysia, whose PD populations were too small to justify local production have made PD cheaper and reaped the benefits of economies by removing import fees (Karopadi et al, 2013; Karopadi et al, 2014).

**Dialysis Costs in sub-Saharan Africa**

**Absolute Costs:** The lack of quality economic evaluations obscure the true cost of dialysis care in developing countries (Just et al, 2008b). As previously noted, costs are often calculated as the cost of supplies rather than as the total cost of therapy (Just et al, 2008b). HD sessions are estimated to cost at least US$100 in sub-Saharan Africa.
Despite crude estimates, it is nonetheless clear that chronic dialysis is too expensive for most developing countries and “RRT tends to cost more in countries that can least afford it” (Aviles-Gomez et al, 2006). Even AKI PD programs are only sustainable when governments can fit them into the national healthcare budget (Callegari et al, 2012). Maintenance PD costs in developing countries can be much greater than the per-capita GNI (Li & Chow, 2001; Mushi et al, 2015). In Laos, the annual cost of maintenance dialysis for one patient is reported to be 46 times greater than the nation’s per capita GNI, while the cost of 1 HD session (US$100) in Nigeria is reported to be two times the minimum monthly wage of a federal government worker (Li & Chow, 2001; Jha et al, 2013). Maintenance dialysis leads to catastrophic expenditure, both personally and nationally, in developing countries (Jha et al, 2013; Krzesinski et al, 2007). AKI treatment for these countries may be sustainable as the cost for saving a life with AKI is much less at US$150-400 (Burki, 2015).

Exacerbating the unaffordability of dialysis in developing countries are referral patterns and the absence of economies of scale. Late presentations result in higher costs in several ways, including prolonged hospitalizations and the need for temporary vascular access and more intensive dialysis, and are associated with decreased patient survival, as patients often present with septicemia and multiple organ failure (Moosa et al, 2016; Jha & Chugh, 2003). If there are high peritonitis rates in a program, PD will also become more expensive and drop out rates will be high (Just et al, 2008 NDT). The absence of a “critical mass” of patients in sub-Saharan Africa means suppliers do not locally market or
produce their supplies, while tariffs and import duties can further increases costs (Aviles-Gomez et al, 2006). The failure to reduce import duties leads to unnecessarily high costs of imported consumables but fees collected along the roads in a country can also raise the cost of supplies by 25%, and government support of a program can be particularly vital to reduce these fees (Callegari et al, 2012).

**Table 1** Cost of Dialysis in Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Author(s) and year</th>
<th>Annually cost per patient [Int$ 2012]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan</td>
<td>Abu-Aisha and Elamin 2010 [8]</td>
<td>11,060</td>
</tr>
<tr>
<td>Sudan</td>
<td>Elsharif, Elsharif et al. 2010 [9]</td>
<td>15,280</td>
</tr>
<tr>
<td>Namibia</td>
<td>Abu-Aisha and Elamin 2010 [8]</td>
<td>25,800</td>
</tr>
</tbody>
</table>


**Figure 2.** Dialysis Cost Analyses from Select Sub-Saharan African Countries


**Relative Costs (HD to PD):** There are only a few countries in Africa where PD is reported to be cheaper than HD, but PD is also an underdeveloped modality in sub-Saharan Africa (Karopadi et al, 2013). Comparing costs of modalities is particularly
unreliable when a very small number of patients receive dialysis in these programs (Karopadi et al, 2014). It is also hard to determine costs in countries where general data collection is lack and there are often also many informal costs reported, such as those involved in the transportation of supplies. Evidence from more developed countries indicate that the relative cost advantage of PD to HD depends on the availability of PD supplies, specifically whether they are locally produced or whether there are tariffs or quotas restricting their import (Karopadi et al, 2014). Most African countries are brand new users of PD, solutions are typically imported and PD utilization is low (Karopadi et al, 2013). Karopadi and others report the HD: PD cost ratio to be 1.38 for Senegal (18.0% of patients on PD) to be 1.38, 1.33 for Kenya (12.0% patients on PD), 0.89 for Sudan (6.5% of patients on PD), 0.58 for South Africa (29.0% of patients on PD), and 0.70 for Nigeria (0.75% of patients on PD) (Karopadi et al, 2013). The cost ratio for South Africa is based on the use of imported solutions and Okpechi and others find PD to be significantly cheaper than HD if locally manufactured solutions are used (Karopadi et al, 2013).

**Conclusions on Cost-Effectiveness**

Determining cost-effectiveness relies on an understanding of both cost and the outcome since cost-effectiveness is broadly a measure of cost per quality-outcome. Since very little is known about patterns of ESRD care in developing world and there is a pervasive lack of renal registries tracking outcomes, it is impossible to determine the comparative cost-effectiveness of PD and HD in most countries in the developing world
(Jha & Chugh, 2003). Since HD and PD have similar outcomes in developed countries and PD typically costs less, it can be concluded that PD is more cost-effective than HD in most of the developed world. The significant variation in costs between regions and economies means that local context must be taken into account and there is no “one-size-fits-all” dialysis modality that should be recommended across contexts.

A Brief History of Dialysis Modalities

Offered to patients since the early 1960s, HD is perceived in medical practice to be the most conventional form of dialysis (Karopadi et al, 2014). In 1976, Moncrief, Popovich and colleagues submitted an abstract on PD to the American Society for Artificial Internal Organs in 1976, and even though the abstract was rejected, CAPD was born (Krediet, 2007). PD had very discouraging results at first compared to HD and in 1979, the 2-year patient (and technique) survival was only 32% (Krediet, 2007; Karopadi et al, 2014). However, PD steadily improved such that the modality now offers comparable outcomes to HD (Woodrow, 2013). Although dialysis is widely accessible to those who need it in most high-income countries today, this was not always the case in recent history. Until 1972, when the Social Security Act was amended to cover dialysis and renal transplantation for all ESRD patients irrespective of age, dialysis in the United States was marked by “death panels,” who, because of limited funding, determined who would receive dialysis and who would not (Odubanjo et al, 2011). Rationing in healthcare may seem like a foreign concept to Americans, but it is not – it is still
practiced in some form with transplants. When resources are highly limited, careful rationing may be the best option.

**Current Landscape of Dialysis**

*General:* Globally, there has been a significant increase in the absolute number of people on maintenance dialysis and dialysis is growing at annual global average rate of 7% (Karopadi et al, 2014; Mushi et al, 2015). In 2012, 2.3 million were reported to be on dialysis, compared to 1.75 million just four years earlier, and the increase is largely attributable to an increase in dialysis rates in India and China (Karopadi et al, 2014). Access to dialysis is unequally distributed and over 80% of the RRT patients live in North America, Japan and Europe, even those these regions only have 15% of the world’s population (Kresinski et al, 2007). In 2004, less than 5% of the global dialysis population was in sub-Saharan Africa, yet it is estimated that by 2030, over 70% of the patients with ESRD will be living in low-income countries (Stanifer et al, 2014; Shibiru et al, 2013). The prevalence of dialysis per million population (pmp) corresponds with per capita income, rather than ESRD prevalence, and even in Europe, lower GNI per capita is correlated with a lower prevalence of RRT (Kresinski et al, 2007). For example, in Belgium the prevalence of RRT is reported to be nearly 1000 dialysis patients pmp, while in central and Eastern Europe, the prevalence of RRT is 160 pmp (Kresinski et al, 2007). In sub-Saharan Africa, because of high costs, dialysis is either “completely unavailable or available only to a very few patients” (Okpechi et al, 2012).
Global Modality Mix: Studies in US, Canada and UK indicate that practicing nephrologists think that the best clinical outcomes could be achieved with a modality mix of HD: PD of about 60:40, the two modalities have comparable outcomes and PD is typically cheaper in the developed world, yet of the 2.3 million people on dialysis in 2012, just 250,000 of those were using PD (Neil et al, 2009; Karopadi et al, 2014). There is enormous variety between countries in modality mix: As previously noted, the highest prevalence of PD use is in Mexico (65.8%) and Hong Kong (79.4%), while 0% of dialysis patients are use PD in Luxembourg (Karopadi et al, 2013; Just et al, 2008 NDT). The PD prevalence in the United Kingdom, the Netherlands, France and Germany are reported to be 19.3%, 23%, 12% and 5.3% of dialysis patients, respectively (Okpechi et al, 2012). Of the nations with well-established dialysis programs, PD is only used in the majority of dialysis patients in Hong Kong, El Salvador, Mexico and Guatemala (Jain et al, 2010). Despite a growth in dialysis between 1997 and 2008, the rate of PD use declined by 5.3% in developed countries (van Luijtgaarden et al, 2013). The declining use in developed countries is unexpected given that PD is documented to be less expensive while offering comparable health outcomes and quality of life in most of these countries (Jain et al, 2010). Yet despite the cost-effectiveness of PD in developed countries, 59% of PD patients were in developing countries and 41% in developed countries (Jain et al, 2010). In contrast with declining rates of PD-usage in more developed countries, developing countries seem less immune to the potential cost-savings of PD and there was a 2.5-fold increase in the prevalence of PD patients in developing countries between 1997 and 2008, illuminating “a paradigm shift favoring the choice of
PD” (Jain et al, 2010; Odetunde et al, 2014). With regards to modality mix in sub-Saharan Africa, there is little published data on modality mix (Abu-Aisha et al, 2009).

Factors Influencing Modality Mix: Given that there are relatively few absolute contraindications for either modality, that HD and PD are documented to offer comparable longevity and quality of life, and that PD offers significant opportunities for cost-saving, particularly in developed countries who possess the vast majority of patients on RRT, why is HD so much more prevalent? In light of wide differences in modality usage patterns, the EVEREST (Explaining the Variation in Epidemiology of RRT through Expert opinion, Secondary data sources and Trends over time) Study examined factors influencing modality mix in countries with renal registries, but “outliers” like Mexico, Hong Kong and Japan were excluded (van Luijtgaarden et al, 2013). The study found that the determinants that were independently associated with lower percentages of patients on PD were patients with diabetic kidney disease, health expenditure as percentage of GDP, private for profit share of HD facilities, and cost of PD consumables relative to staffing (van Luijtgaarden et al, 2013). More socialized healthcare systems and systems with more public providers tend to show higher rates of PD utilization, perhaps reflecting more influence over and interest in controlling healthcare costs (Karopadi et al, 2013; Jain et al, 2010). For example, Canada’s proportion (18%) of dialysis patients on PD is over two times greater than the United States’ proportion (7%) (Karopadi et al, 2013).
Government policies, reimbursement patterns, market factors and resource availability, patient and physician education, and a variety of sociocultural factors all affect the modality mix in each country. Some countries have mandated “PD-first” policies, leading to relatively high PD utilization rates. In the eighties, Hong Kong’s Central Renal Committee recommended a PD-first policy and it is this policy today that gives Hong Kong a PD utilization rate of almost 80% (Yu et al, 2007; Li & Chow, 2001). Thailand, too, recently instated a “PD-first policy” (Karopadi et al, 2013).

Reimbursement structure has been called “the ultimate controlling force in the establishment and maintenance” of PD (Just et al, 2008a). Even though HD is consistently 30-60% more expensive than PD in Europe, PD utilization rates vary from 5% in Germany to >20% in Scandinavian countries and in the Netherlands because of reimbursement structure (Karopadi et al, 2013). Private dialysis providers often receive greater reimbursement for administering HD than PD, and such prescription incentives increase the overall cost of ESRD treatment in a country (Karopadi et al, 2014). This was formerly the case in Japan, where doctors received an extra fee for prescribing HD, but recently the Japanese government reduced HD reimbursement and began promoting PD (Karopadi et al, 2013; Just et al, 2008a). Under the Affordable Care Act, the United States also moved to remove this incentive by reimbursing PD and HD at the same rates under the bundled payment scheme (Karopadi et al, 2014). Money, resources, and markets subtly, but significantly, influence patterns of dialysis modality usage (Karopadi et al, 2014). In the literature, Mexico’s remarkably high rates of PD utilization are largely attributed to market factors and the industry. In the eighties, PD fluid manufacturing
companies aggressively promoted PD in the country (Treviño-Becerra & Maimone, 2002). Pisa Farmacéutica produces dialysis fluid locally and Mexico is one of the only places where a truly oligopolistic PD supplies market exists, with competition between Fresenius, Baxter and Pisa Farmacéutica further driving down costs (Karopadi et al, 2014). The markets for PD are monopolistic in most countries, tending to drive up market prices, and Karopadi and others called price-controlling strategies for dialysis consumables a “government prerogative” (Karopadi et al, 2013). In Japan, resource availability contributes to particularly high proportions of HD usage. There are an enormous number of HD centers in Japan and “when centre HD capacity is high, there is an incentive to use” (Karopadi et al, 2013; Just et al, 2008 NDT). Blake and Finkelstein also suggest that the decline in chronic PD usage in the United States and Canada may be partially attributable to increased number of HD facilities and difficulty of running small PD units (Abu-Aisha et al, 2009). Larger, successful, prominent PD programs may encourage PD uptake (Woodrow, 2013).

Other studies have suggested that inadequate physician training in PD, lack of patient education, and sociocultural factors decrease PD utilization, while low population density and nephrologist enthusiasm for PD may increase the appeal of PD (Karopadi et al, 2013; Neil et al, 2009; Suassuna, 1998). Nephrologists and nurses may not receive adequate PD training, leading them to encourage HD, potentially leading to a spiral of events where future nephrology residents and nursing students have even less experience with PD in the clinical setting as a result (Neil et al, 2009; Mehrotra, 2007). Sociocultural
factors that may affect patient preference for one modality or another include aversion to
needle puncture (Hong Kong) and preference for clinic-based medical care over home-
care (Japan) (Neil et al, 2009). Additionally, most studies find that PD patients are more
likely to be employed than HD patients but the studies are cross-sectional, making it
“difficult to conclude whether dialysis modality influenced employment status or whether
employment status had an influence on the choice of dialysis modality” (Just et al, 2008
NDT).

**Is PD the Answer in Low Resource Settings?**

*PD- A More Feasible Modality?* Without considering costs and outcomes, PD
may be more feasible in low resource settings, demanding less of certain types of
infrastructure than HD. Good outcomes have been documented when using PD to treat
AKI in low resource settings even when requisite supplies were unavailable (Esezobor et
al, 2014; Ademola et al, 2012). Unlike HD, PD is relatively simple and nearly every
aspect of PD can be improvised (Esezobor et al, 2014). There are no HD machines to
maintain or water to purify and PD does not require a consistent electricity or water
source (Callegari et al, 2012). The modality is well suited to dispersed, rural populations
(Elhassan et al, 2007). It offers patients more freedom and the ability to continue
working, benefitting the economy (Elhassan et al, 2007). There are fewer overhead costs
and PD programs are less expensive to set up than HD programs (Callegari et al, 2012).
Even preemptive PD bag warming is unnecessary in warm climates, leading many to
conclude, “regular PD could signify an important addition to our RRT armamentarium”
(Elhassan et al, 2007). However, despite consensus that PD should be integral to providing RRT to populations, there are major barriers to PD in low resource settings making PD a difficult option as well (Finkelstein et al, 2007; Okpechi et al, 2012). While PD may demand less infrastructure than HD, it still demands a certain amount. Some caution against widespread promotion of one modality type, citing the Mexican Model where rapid expansion of peritoneal dialysis into “inexpert hands” resulted in an annual mortality of greater than 60% due to peritonitis (Treviño-Becerra & Maimone, 2002). PD requires mindfulness of potential barriers and discriminate implementation.

**General SES Issues:** General socio-demographic issues, like poor housing and inconsistent electricity and water supplies, make the provision of RRT a challenge in low resource settings (Okpechi et al, 2012). In contrast to HD, maintenance PD is typically performed at home, making the home environment more important. Peritonitis is one of the greatest challenges in PD, leading to technique failure and increased morbidity, and “a high rate of infection is bad publicity for the modality with patients and practitioners” (Niang et al, 2014). Peritonitis can make nephrologists and nurses feel that PD is too much work (Okpechi et al, 2012). South Africa has the greatest number of PD patients in sub-Saharan Africa and, in its quest to select the most promising dialysis patients, has noted that overcrowding and inadequate water and sanitation result in high rates of infection, making CAPD inappropriate (Swanepoel et al, 2013). Peritonitis was specifically shown to be significantly associated with high occupant-to-bedroom ratio, lack of electricity, informal housing, and limited education in the study (Swanepoel et al,
2013). However, another South African study found that home conditions, employment and education levels were not correlated with PD outcomes but rather that and non-compliance and poor clinical status were associated with PD failure and peritonitis (Swanepoel et al, 2013). In Sudan, touch contamination was “incriminated in a considerable proportion of peritonitis episodes... examples encountered were failure to wash or dry hands appropriately before performing the procedure” (Abu-Aisha et al, 2009).

Prohibitive Cost of Consumables: While PD does not require HD machines, public utilities or purified water, it does require a consistent supply of consumables. Many sub-Saharan African countries are completely dependent on imported PD supplies and the costs of imported fluids are typically high (Okpechi et al, 2012). Even though PD has been found to be the cheaper modality in most developed countries, PD can be more expensive than HD in developing countries because of the high costs of obtaining PD supplies (Okpechi et al, 2012; Karopadi et al, 2013). While local manufacturing could reduce costs, there is not a critical mass of PD patients in most countries to make local production economical. The cost of PD supplies limits the size of PD populations (Okpechi et al, 2012; Jha & Chugh, 2003). In many programs, when donated dialysis supplies are used up, the programs end for HD and PD alike (Callegari et al, 2012). While patients themselves may not need to travel to travel as often, the PD disposables still need to travel and are dependent on transportation infrastructure and shipping costs. Distributing supplies to remote areas is challenging and has restricted PD growth...
(Finkelstein et al, 2007). While PD offers the advantage of adaptability in the absence of proper equipment and supplies improvisation of PD often leads to higher complication rates (Ademola et al, 2012). When PD disposable costs are high, PD exchanges the high fixed costs of HD for high variable costs.

**Manpower Still Low:** The low number of qualified health care workers is a significant barrier to RRT in many developing countries (Okpechi et al, 2012). Dialysis requires front-line workers, who are aware of kidney disease, whether it is AKI or CKD, to refer cases to specialists for treatment, yet there is a shortage of healthcare personnel in many developing countries, with recent estimates that three times as many African healthcare workers are needed to address current healthcare needs (Krzesinski et al, 2007). There are not enough training opportunities and “brain-drain” is a detriment to many countries (Okpechi et al, 2012). A 2012 study reported that two-thirds of sub-Saharan African countries have just one medical school and 11 have no medical school at all (Okpechi et al, 2012). There are few nephrologists in many low-income countries and even when training opportunities exist, such as with the ISN, hospitals do not want to send an invaluable provider away for several months of training (Bah et al, 2015; Callegari et al, 2012; Fredrick et al, 2015). In sub-Saharan Africa, it is estimated that there are only 120-130 nephrologists, seriously challenging the implementation of RRT (see Figure 2) (Callegari et al, 2012).
Figure 3. Global Distribution of Nephrologists


*Institutional Stewardship Lacking in the Face of Other Priorities: Renal replacement therapy is challenged by limited institutional investment at almost every level. In countries confronted by infectious diseases and malnutrition, despite a high mortality rate, renal diseases are not seen as a major public health problem (Aloni et al, 2012). Much of the limited funding is channeled to tackling communicable diseases (Okpechi et al, 2012). Some programs have even had problems getting permission from the government to allow supplies into the country (Callegari et al, 2012). At the hospital level, although hospitals may initially commit to supporting PD programs after they
receive several years of support from international organizations, in reality, there may be limited financial commitment to the program’s sustainability. If hospitals are not dedicated to tracking revenue generated from PD programs and putting it in a separate account, “any revenue generated from this program becomes part of the hospital general fund and is nearly impossible to retrieve when new supplies are needed” (Callegari et al, 2012). In the face of limited institutional stewardship, many authors call upon the medical community to support the PD development (Ademola et al, 2012; Tuso, 2009).

Financing Largely Unavailable: If they exist, dialysis and transplant programs in low-resource countries often depend on donors and external funding, creating a significant barrier to long-term treatment of ESRD patients (Shibiru et al, 2013). Programs are only sustainable when governments can make them part of the national budget but dialysis programs generate unaffordable costs for many countries (Bah et al, 2015; Callegari et al, 2012). Chronic dialysis is not financially feasible for most low-income countries, except for the few who can afford it, and for these people HD might make sense. However, in middle-income countries that could afford chronic dialysis, governments simply may not have made funding available (Okpechi et al, 2012’ Krzesinski et al, 2007). In such instances, “governments must start taking responsibility for their people” (Okpechi et al, 2012).
International CSO Involvement in Sub-Saharan Africa

Several international organizations have had a documented impact on the nephrology and dialysis landscape in sub-Saharan Africa. Much of the literature on kidney disease and dialysis in sub-Saharan Africa is by nephrologists educated under the auspices of these organizations or intimately involved in leadership of them. Awareness of these organizations is necessary to grasp the full picture. Specifically, the International Society of Nephrology (ISN), the International Pediatric Nephrology Association (IPNA), the International Society for Peritoneal Dialysis (ISPD) and the Sustainable Kidney Care Foundation (SKCF) and Saving Young Lives (SYL), an amalgamation of the ISN, IPNA, IPSD and SKCF, are highly involved in sub-Saharan Africa (Burki, 2015).

The International Society of Nephrology (ISN)- General: The ISN was created in 1960 to “advance the diagnosis, treatment, and prevention of kidney disease in both the developed and the developing worlds” (Barsoum, 2011; Harris et al, 2012). The organization is the main driver of capacity building for the diagnosis, prevention and treatment of kidney disease in low-resource countries (Barsoum, 2011). Previously focused on supporting nephrologists, the ISN has expanded its vision to include other healthcare providers and the community in kidney disease prevention (Barsoum, 2011). In 2006 the ISN launched World Kidney Day to raise awareness about CKD and the organization recently established the Oby25 Initiative, which aims to eliminate all preventable deaths from AKI by 2025 by focusing on training health workers for early
detection and management of AKI, such as fluid repletion (Smoyer et al, 2016). The ISN has programs that operate in 126 countries and membership has grown from 40 to nearly 9000 scientists/clinicians (Barsoum, 2011). In 2012, the ISN supported 48 fellows, 37 sister renal centers, 48 CME programs, 16 educational ambassadors and 6 research and prevention grants at a total cost of US$1.5 million (Feehally et al, 2014). In past 25 years (1985-2010), ISN has sponsored the nephrology training of 545 physicians from 83 developing countries (Harris et al, 2012). The ISN emphasizes capacity-building for “sustainable self-sufficiency in nephrology” and operates several international programs to these ends under the ISN-Commission for the Global Advancement of Nephrology (ISN-COMGAN), including the Fellowship program, the Sister Renal Center Program and the Continuing Medical Education (CME) Program (Feehally et al, 2014).

The ISN’s Fellowship Program: The Fellowship Program, which was established in 1982, seeks to improve renal care by training physicians to practice nephrology in developing countries where there may be no nephrologists (Barsoum, 2011; Harris et al, 2012). Fellows undergo short (2-6 months) or long-term (6-12) training in host institutions (Harris et al, 2012). Originally training centers were in North America, Europe and Australia but in the past decade training centers have been established in the fellows’ regions to increase the training’s “relevance and utility” and to decrease ‘brain drain’ (Harris et al, 2012). As of 2012, 114 fellows from Africa had received training supported by the ISN, with 33 receiving training in host institutions in Africa (Harris et al, 2012). Fellows are now required to sign an agreement that they will return to their
home country after training, and in the past decade, 91% of fellows have returned to their home units (Feehally et al, 2014; Harris et al, 2012). ISN’s Fellowship Program has had the unexpected benefit of training individuals who become leaders in nephrology in their own institutions and regions, resulting in an impact outside of clinical practice and within 10 years of the fellowship, 66% occupied leadership position in department or hospital, 28% within their country, 7% at an international level (Harris et al, 2012). Furthermore, ISN fellows have been pivotal in establishing national and local research programs (Harris et al, 2012).

*The ISN’s Sister Renal Center Program:* The ISN’s Sister Renal Center Program was conceived in 1997 to foster nephrology by establishing relationships between established centers in developed countries and nascent “sister” nephrology programs the developing world (Feehally et al, 2014). In 2003, the program was actually lifted off the ground with US$150,000 and 6 pilot partnerships (Barsoum, 2011). Sister centers are stratified into 3 tiers (A, B, C) with greater privileges and funding at each subsequent level (Barsoum, 2011). Sister centers start at level C with renewable two-year cycles and promotion to higher tiers (B and A) is “competitive, based on realized achievements in patient care and local community support” (Barsoum, 2011). Sister centers typically graduate after 6-8 years and then support another emerging center in its region (Feehally et al, 2014). Analysis of the dialysis landscape reveals the far-reaching impact these sister centers have had on helping the nephrology specialty establish roots in African institutions.
The ISN’s Continuing Medical Education (CME) Program: The ISN organizes CME courses with international and local speakers, often former or current ISN fellows, to educate both the medical community and the greater community (Feehally et al, 2014). Continuing medical education is prioritized to regions with an active Sister Renal Center (Lameire, 2007). Speakers often meet with local healthcare leaders and sometimes health ministers to determine local nephrology needs (Feehally et al, 2014). Each year there are about 50 CME programs with over 10,000 developing world physicians attending (Barsoum, 2011).

The International Pediatric Nephrology Association (IPNA): The IPNA supports the training of international fellows in pediatric nephrology and donates USD$5000 to program in developing country each World Kidney Day (Esezobor et al, 2014).

The International Society for Peritoneal Dialysis (ISPD): The ISPD, whose involvement in the developing world is more limited than the other organizations mentioned, was founded in 1984 and Peritoneal Dialysis International is the journal of the ISPD (Krediet, 2007; Blake 2010).

The Sustainable Kidney Care Foundation (SKCF): SCKF works closely with the ISN, the IPNA and the ISPD to establish AKI treatment programs in the developing
world, with an emphasis on preventing AKI mortality in children and mothers. SYL projects are commonly labeled SKCF projects.

Saving Young Lives (SYL) Consortium: SYL was founded in 2012, with 5 years of funding from the Recanati-Kaplan Foundation, as a partnership between three international nephrology societies whose primary roles are education and training (ISN, IPNA, IPSD) and a fourth organization (SKCF), an non-governmental organization that aims to make dialysis supplies in low-resource settings (Smoyer et al, 2016). The goal of SYL is to establish sustainable acute PD programs for the treatment of AKI in very low-resource settings, and its pilot project was at Kilimanjaro Christian Medical Center (KCMC) in Tanzania (Smoyer et al, 2016). Thus far SYL has supported the development of 10 acute PD programs in centers where dialysis was previous unavailable (Smoyer et al, 2016). A SYL site is selected based on local leadership and commitment and the chosen hospital then signs commits to supporting the PD program for AKI after two years (Smoyer et al, 2016). The SKCF provides PD supplies (catheters and fluids) for the first two years (Smoyer et al, 2016). The final element is staff training and SYL has supported the training of over 50 nurses and physicians (Smoyer et al, 2016). Physicians and nurses receive all aspects of acute PD, including PD catheter insertion, PD fluid prescription, and clinical problem solving at the Red Cross War Memorial Children’s Hospital in Cape Town, South Africa (Smoyer et al, 2016).
THE SUB-SAHARAN LANDSCAPE OF RENAL REPLACEMENT THERAPY

INTRODUCTION

Sub-Saharan Africa is a vast region characterized by enormous diversity with an estimated population of over 937 million (Pozo et al, 2012; The World Bank, 2013). While 65% of its population is rural, the region has experienced rapid urbanization and a growing burden of NCDs recently (Pozo et al, 2012; Stanifer et al, 2014). Although absolute poverty is widespread, there are also extremely wealthy individuals and “the fortunate few can turn to private care” (Dirks & Levin, 2006). Although enormous progress has been on many MDGs in sub-Saharan Africa, ESRD is typically a death sentence as treatment is unavailable to the majority (Tuso, 2009; Stanifer et al, 2014). Whereas GDP is typically positively correlated with dialysis prevalence, “the situation here is more complex” and higher income countries in sub-Sahara Africa generally have lower RRT prevalence than would be expected based on their income (Abu-Aisha & Elamin, 2010). Dialysis was first introduced to the continent in 1957 when a physician built a dialysis machine in South Africa to treat two patients with AKI (Barsoum et al, 2015). Dialysis was subsequently introduced to Nigeria (1965), Sudan (1968) and Zimbabwe (1972) and military hospitals were instrumental in establishing dialysis to treat war casualties (Barsoum et al, 2015). Although a 2007 review indicated that maintenance dialysis was available in 32 countries on the Africa continent in 2007, new dialysis programs are frequently established while others are abandoned (Barsoum et al, 2015). A 2015 review documented that 29 out of 54 countries on the continent had maintenance
dialysis, and these countries collectively had 83% of the total African population (Barsoum et al, 2015). There are additional countries with short-term dialysis for AKI (Barsoum et al, 2015). The main mode of RRT is hemodialysis and units are concentrated in the private sector in urban centers (Arogundade & Barsoum, 2008; Jha & Chugh, 2003). Machines are typically outdated, water treatment is often suboptimal, and consistent provision is challenged by the “erratic power supply, inefficient organization, and insufficient funds for maintenance” (Jha & Chugh, 2003). PD has become available in the public sector in recent years, particularly for the treatment of AKI, and offers certain advantages over HD (Karopadi et al, 2013; Raaijmakers et al, 2010). Much of sub-Sahara Africa’s population rural and PD is thought to be less “dependent on infrastructure and geography” (Karopadi et al, 2013; Raaijmakers et al, 2010).

Maintenance PD accounts for ~10% of dialysis patients in Kenya; 20% in Uganda; 34% in Zambia, South Africa, and Senegal; 41% in Sudan, 56% in the Democratic Republic of Congo; and 60% in Rwanda, although the sustainability of maintenance PD is precarious because of reported high rates of peritonitis and high costs of imported fluid (Barsoum et al, 2015). When peritonitis results, the lack of microbiology laboratories hinders identification the causative organism (Sinha & Bagga, 2015). Although transplantation might seem like the best option, it is also challenged by infrastructure, regulation and financing issues, and whereas 30% of ESRD patients in US, Europe and Middle East undergo renal transplant, less than 1% of ESRD patients in sub-Saharan Africa receive a transplant (Pozo et al, 2012). Six countries however have opted to concentrate on transplantation even though their rates of maintenance dialysis treatment were low
Sub-Saharan Africa has suffered from significant “brain-drain” and most sub-Saharan countries have less than 1 nephrologist per million population, with the majority of nephrologists concentrated in the capital cities (Callegari et al, 2012; Barsoum et al, 2015). There are inadequate resources and infrastructure at present to confront the burden of chronic illness including chronic kidney disease in these countries (Finkelstein et al, 2007).

Renal replacement therapy in the developing world is highly involved and it is nearly impossible to tackle kidney disease vertically. Renal replacement therapy requires all of the components of a functioning healthcare system. Dysfunction in one building block results in dysfunction in another component, since they are all interconnected. Kidney disease is the endpoint of many diseases, acute and chronic, and the landscape of dialysis provision is a microcosm of the nation’s health system. The World Health Organization has laid out six building blocks that are necessary for a functioning health system: 1) Service Delivery, 2) Health Workforce, 3) Information, 4) Medical Products/Vaccines/Technologies (Medical Supplies), 5) Financing and 6) Governance/Stewardship (World Health Organization, 2007). While this paper will not evaluate the entire health system in each country, it will evaluate the state of renal replacement therapy, a slice of the larger health system in which it operates, in light of these six integral building blocks. Each building block is loosely defined with some sample considerations.
Service Delivery specifically refers to the availability and organization of care. Are patients receiving safe, effective care when needed as efficiently as possible? What dialysis services are offered? How are patients referred? Are dialysis services concentrated in urban areas? Is there a main center of excellence for dialysis in the country?

Health Workforce refers to an appropriate mix and quantity of competent staff. Are there enough physicians, nurses, and lab technicians? Is there retention of these staff? Are they well trained and motivated?

Information on the health system is necessary to guide decision-making and allocation of resources. Are health records available? Is there data on burden of disease and risk factors? Is there a formal national renal registry? Are patients aware of which services are available? Are first-point-of-contact caregivers aware of services available so that they can refer patients as needed? Is there a way to measure impacts and make improvements?

Medical Supplies (Medical Products, Vaccines and Technologies) are essential to a functioning health system and must be of “assured quality,” safe, cost-effective, and available (World Health Organization, 2007). Are dialysis consumables available? Where
are the equipment and medications acquired? Is there local production? Are there shortages of equipment and if so, why? What happens when drugs are unavailable?

**Financing** the health system is necessary and ideally helps people access necessary services without catastrophic costs (World Health Organization, 2007). How do people pay for healthcare services, specifically dialysis? Are donors providing supplies, training nephrologists or funding the RRT system? Does the government subsidize dialysis costs? Are there user fees or health insurance to cover dialysis costs?

**Leadership & Governance** is “effective oversight” and includes policy- and regulation-creation, “attention to system design” and accountability (World Health Organization, 2007). Who are the stewards of kidney disease programs and renal replacement therapy in each country? Is the government committed to the healthcare system and renal replacement therapy? Are there government policies in place to guide RRT provision? Are there other organizations or prominent individuals that provide leadership?

**Search Strategy:** Country-specific data was obtained either by searching “developing country AND dialysis OR renal replacement therapy,” “developing world AND dialysis OR renal replacement therapy,” or “[country name] AND dialysis OR renal replacement therapy” in PubMed. There are several limitations to this search strategy. English is not the national language of many countries in Africa and a significant
proportion of publications may have been in French, Arabic, Portuguese, or Spanish. Many journal articles may not have been available on PubMed as there are many African journals that are not peer reviewed or indexed and the lack of literature on a country does not equate to the absence of RRT in that country (Barsoum et al, 2015). Much of the information on dialysis services exists outside of the literature and it is certain that dialysis centers were missed by this search strategy. Furthermore, dialysis product suppliers such as Baxter Healthcare Corporation and Fresenius Medical Care may have access to more complete, unpublished numbers, as several studies indicated. This literature review should be taken as illustrative of the landscape, rather than absolute.

The sub-Saharan African countries are divided by income according to the World Bank classification in 2016. However, countries constantly change in classification and many countries, such as Ghana and Kenya, may have been recently reclassified, often to a higher income group, as their economies grow. The bolded countries are noted in the literature to have some form of renal replacement therapy available. Peritoneal dialysis is far less common than hemodialysis. Furthermore, online newspapers and hospital websites reveal that most countries have recently established at least one hemodialysis unit in their capital city.

THE LOW INCOME LANDSCAPE

The 2016 low-income sub-Saharan economies are Chad, Mali, Niger (Sahel), Benin, Burkina Faso, the Gambia, Republic of Guinea, Guinea-Bissau, Liberia, Sierra
Leone, Togo (*West Africa*), Central African Republic, South Sudan (*Central Africa*), Burundi, Comoros, Democratic Republic of Congo, Eritrea, Ethiopia, Madagascar, Rwanda, Somalia, Tanzania, Uganda (*East Africa*), Malawi, Mozambique, and Zimbabwe (*South Africa*). The bolded countries are noted in the literature to have some form of renal replacement therapy, although it is quite possible dialysis exists on a small scale in the non-bolded countries outside of the literature.

**Chad, Mali, Niger, The Gambia, Guinea- Bissau, Liberia & Sierra Leone**

In the Sahel region, only Mali is mentioned in the literature to provide renal replacement therapy – Chad and Niger are not. Although Fresenius Medical Care’s “Africa Market Survey 2000” noted that a hemodialysis project was supposed to start in Niger in 2002, it is unclear whether this planned project came to fruition and was sustained (Fogazzi et al, 2003). In Bamako, Mali Dr. Mahamane Kalil Maiga founded the Nephrology and Hemodialysis Department at the National University Hospital of Point G (CHU) in 1981 (Ing et al, 2012). This is the only center in Mali where dialysis treatment is provided and the modality is hemodialysis. In regards to dialysis financing, the Mali government finances therapy for a limited number of patients (Naicker, 2009). In West Africa, Benin, Burkina Faso, the Republic of Guinea, and Togo are mentioned to have dialysis programs, while the Gambia, Guinea-Bissau, Liberia and Sierra Leone are not.
**Benin**

In 1997 in Cotonou, the capital of Benin, a hemodialysis unit was established at Centre Hospitalier Universitaire de Cotonou for patients with AKI and ESRD (Fogazzi et al, 2003). As of 2003 there were eight modern dialyzers “with occasional technical problems” (Fogazzi et al, 2003). A nephrology short-term program that included care of patients with renal disease, improvement of urinalysis, introduction of serum Na+ and K+ measurements, and screening of renal diseases was reported to be established in St. Jean de Dieu hospital de Tanguïéta in north Benin between December 1997 and May 2001. With the support of Saving Young Lives (SYL), Benin has also established a PD program for the treatment of AKI Centre Hospitalier Universitaire-HKM de Cotonou. The program, which began in December 2012, has treated 1-2 children per month under Dr. Francis Layla, a pediatric nephrologist (ISN, 2016). Typically in SYL partnerships, the ISN, IPNA, and ISPD are responsible for educating and training healthcare professionals – physicians, nurses and lab technicians- but do not pay for the direct costs of patient care (ISN, 2016). Meanwhile, the SKCF enters into a Memorandum of Understanding with the host hospital and agrees to donate two years of supplies, with the “contractual agreement that the host hospital will, in due course, take on the long term costs of the program” (ISN, 2016).

**Burkina Faso**

In 2010, Burkina Faso’s nephrology program was described as recent and country data on kidney disease is reported to be non-existent (Lengani et al, 2010). The
only renal replacement therapy is available at Chuyo (Centre Hospitalier Universitaire Yalgado de Ouagadougou), which has a department of Nephrology and Hemodialysis for adults, although it will take children (Lengani et al, 2010). Patients come from the city of Ouagadougou and the interior. A study on acute kidney injury at Chuyo revealed that the mean time between first symptoms and initial hospitalization in the Chuyo nephrology department was over three weeks (21.9 ± 18.3 days), with patients from rural areas arriving later (Lengani et al, 2010). The study also noted that while dialysis was indicated in 84 patients (69.4% of the study population), only 14 patients received renal replacement therapy (16.7% of dialysis indications) (Lengani et al, 2010). Preference was given to patients of higher socioeconomic status who could pay, while those of lower socioeconomic status were typically managed with conservative treatment (Lengani et al, 2010).

**Republic of Guinea**

In the Republic of Guinea, the sole department of nephrology is located in the capital, Conakry, at Donka National Hospital (Bah et al, 2015). The nephrology department, a recent addition to Donka, is comprised of 15 beds and an outpatient clinic that sees about 300 patients per month (Bah et al, 2015). There are ten dialysis machines and the facility is able to conduct three sessions per day per machine, six days a week. With each dialysis patient receiving two sessions per week, the facility can accommodate about 90 patients per week. According to a 2015 study on the epidemiology of CKD in the Republic of Guinea, unsurprisingly, nephrology services are not evenly distributed
throughout the country. Most nephrology patients seen at Donka come from Lower Guinea, the region where Conakry is located, and only 24.4% of CKD patients come from the other three regions of Guinea, despite that the fact that these three regions have 63% of the country’s population (Bah et al, 2015). Patients typically come to the hospital as a last resort after traditional medicine has failed and the study noted that 21.2% of the 1161 nephrology patients were admitted as emergency cases over the three-year study period (2009-2012) (Bah et al, 2015). Less than 40% of the 385 ESRD cases received hemodialysis (Bah et al, 2015). There are currently three senior nephrologists, who were all trained in France, as well as twelve nephrology residents and three senior internists (Bah et al, 2015). While hemodialysis at Donka is said to be “almost free of charge” (USD $3.20 per session), 55% of Guinea’s population lives on less than USD$1.25 a day (Bah et al, 2015). The cost of travel and relocation to Conakry for hemodialysis makes dialysis inaccessible for patients located outside of the city. Patients bear the cost of hospitalization (USD $23 for one month or less) and must pay for medications and dialysis disposables (Bah et al, 2015).

**Togo**

Togo’s lone hemodialysis unit is in Lomé, the capital, at University Hospital Sylvanus Olympio (Sabi & Kaza, 2014) and there is a lack of basic diagnostic and treatment facilities, including electrolyte measurement, urinalysis, and renal biopsy, throughout the country (Fogazzi et al, 2003). A nephrology program was developed in Afagnan Hospital in south Togo by the religious Order of Saint Jean de Dieu and is
capable of measuring serum creatinine and blood urea nitrogen, as well as performing urinalysis and intravenous pyelography (Fogazzi et al, 2003). The urinalysis improvement aspect of the nephrology program was noted to be the most successful component (Fogazzi et al, 2003). Renal transplantation is not available in Togo (Fogazzi et al, 2003). In a study of Sylvanus Olympio in September 2012, 78 patients were maintained on dialysis in twice weekly sessions over a 31-day period (Sabi & Kaza, 2014). Although a 2003 study noted that each dialysis session is only available to those who can afford it and costs USD$80 in a country with an average annual income of nearly USD$400, a more recent 2014 study reported that 74% of the 78 patients over the 31-day study period were considered to belong to the lower socioeconomic class (monthly income less than 35,000 CFA francs (USD$53.32)) and only 6% had social security yet they received dialysis (Fogazzi et al, 2003; Sabi & Kaza, 2014). The method of financing for these patients is unclear.

Neither of the two low-income countries in Central Africa, the Central African Republic nor South Sudan, are reported in the literature to have established any form of renal replacement therapy. In East Africa, dialysis is reported in the Democratic Republic of Congo, Ethiopia, Madagascar, Rwanda, Tanzania and Uganda. A website notes that peritoneal dialysis has recently been started at Kamenge Hospital University Center (Manishatse, 2014). Since several of these countries have recently established peritoneal dialysis programs, one author envisioned the East African communities, including Burundi, Kenya, Rwanda, Tanzania and Uganda, forming a “united front” to set up local
manufacturing and supply of peritoneal dialysis consumables, particularly fluid (Carter et al, 2012). However, industry is currently reluctant to build the infrastructure for production because there is a lack of commitment from these countries to “procure enough supplies to make the operation financially viable” (Carter et al, 2012).

Democratic Republic of Congo (DRC)

Renal replacement therapy exists in a few urban hubs in the Democratic Republic of Congo. Treatment for ESRD is prohibitively expensive, making ESRD a significant cause of mortality (Sumaili et al, 2009). As of 2009, dialysis was only available at the University of Kinshasa Hospital and peritoneal dialysis was the sole renal replacement therapy modality available (Krzesinski et al, 2007). In 2007, the country had seven nephrologists or 0.11 nephrologists per million population (Krzesinski et al, 2007). Of 400 kidney disease patients admitted to the University of Kinshasa Hospital, only 11% could afford peritoneal dialysis and “the others rapidly died” (Krzesinski et al, 2007). However, a recent study from 2014 notes that a hemodialysis unit was established in Lubumbashi in 2011 at “Clinic CMDC” (Centre Medical du Centre Ville) (Tshamba et al, 2014) and it is reported than in 2014 the HEAL Africa Medical Center in Goma began providing dialysis to children with AKI as well (HEAL Africa, 2015). Lubumbashi is the second largest city and the mining capital of the country and Clinic CMDC has five hemodialysis machines (Tshamba et al, 2014). 80% of the staff at the CMDC unit received specialized dialysis training in South Africa through partnership with Fresenius Medical Care (Tshamba et al, 2014). In 2012, hemodialysis at Clinic CMDC cost
USD$317.50 per session but 52.8% of the 53 hemodialysis patients in 2012 had a monthly income of less than USD$300, making maintenance dialysis unaffordable (Tshamba et al, 2014). Only 17% of the 53 patients had any form of insurance, either through public administration, a mining society or private enterprise (Tshamba et al, 2014). Patients at CMDC received an average of 4.2 dialysis sessions per month, compared to the recommended minimum of twelve sessions per month (three per week), likely contributing to high mortality rate over the year-long study period (33 out of 53 patients died), and investigators at Clinic CMDC concluded that death of dialysis patients is “associated statistically with an interrupting of the treatment and with the irregularity of treatment” (Tshamba et al, 2014). Located in Goma, the capital of the North Kivu province, the HEAL Africa Medical Center has 155 beds and is one of the three tertiary hospitals in the country. Notably, located near the DRC-Rwandan border, conflict from the Rwandan genocide was pushed into Goma where it still simmers and occasionally leads to violent outbreaks. Notwithstanding the violence and instability, HEAL Africa has started treating children with AKI, providing dialysis to three patients in 2014 (ISN, 2016; HEAL Africa, 2015). The HEAL Africa dialysis program benefits from the leadership of Luc Malemo, the center’s medical director, and the support of the ISN (ISN, 2016). In Kinshasa, the capital, the pediatric nephrology unit of University Hospital of Kinshasa provides PD for AKI for patients who can pay, providing that the dialysis consumables are available (Aloni et al, 2012). Unfortunately, dialysis supplies are often unavailable and although dialysis was indicated in fifteen of the 56 children over the study period (Jan. 2000- Dec. 2007), only four children received PD, while eleven
children only received conservative treatment due to financial constraints (Aloni et al, 2012). Pediatric hemodialysis is not available in the country (Aloni et al, 2012). Quality research on kidney diseases has come out of the DRC recently and a systematic review and meta-analysis of the epidemiology of CKD in sub-Saharan Africa in the Lancet (2014) concluded, that two out of three studies meeting criteria for the highest quality grade were from the Democratic Republic of Congo (Stanifer et al, 2014). Nonetheless, despite a CKD prevalence of 12.4-19% in Kinshasa’s population (prevalence varies depending on the method used to estimate GFR), awareness of kidney disease is low (Sumaili et al, 2009).

**Ethiopia**

Dialysis for ESRD has been available in Ethiopia for less than a decade (Shibiru et al, 2013). In 2008, visiting nephrologist Dr. Tuso observed there to be about 20 functioning dialysis machines and under 100 chronic dialysis patients in the country (Tuso, 2009). Hemodialysis is available in Ethiopia for the wealthy living in Addis Ababa and each dialysis session costs about US$100 (1700 Birr), a price that does not include any other costs of care (Shibiru et al, 2013; Tuso, 2009). Until the Black Lion (Tikur Anbessa) Hospital began providing AKI treatment in 2015, there was no dialysis in public hospitals in Ethiopia (Shibiru et al, 2013). Three private hospitals in the literature are reported to provide limited dialysis services in the capital: St. Paul’s Hospital, Millennium Medical College (PSHMMC), Bethel Hospital and St. Gabriel General Hospital. In addition to this, the UK embassy reported in June 2015 that
hemodialysis is also available at three additional private hospitals in Addis Ababa, Korean Hospital (Myungsung Christian Medical Center), Hayat Hospital and Sante Medical Centre (British Embassy Addis Ababa, n.d.) and the Seattle Alliance Outreach has partnered with Zewditu Hospital in Addis Ababa with the goal of making dialysis available for those who cannot afford it (“Seattle Alliance Outreach,” 2016). Organ transplantation recently became legal in Ethiopia and a kidney transplant program is currently being established at PSHMMC (Horspool, 2015b). Although there is growing awareness of the problem of chronic kidney disease, patients are unwilling to be screened because treatment is understood to be unavailable (Tuso, 2009). While Ethiopian physicians are enthusiastic about dialysis, dialysis does not enjoy the same support within the government and no national strategy exists for the prevention and treatment of CKD (Shibiru et al, 2013).

In 2013, St. Paul’s Hospital, Millennium Medical College (SPHMMC) opened an acute HD unit with 6 dialysis machines with the help of the National Institute of Urology and Nephrology in Cairo, Egypt (Horspool, 2015b). Dr. Momina Ahmed, an ISN fellow who trained in 2011 at the University of Witwatersrand Hospital in South Africa, also recently established a nephrology program at SPHMMC. In addition to inpatient care, the nephrology program has an outpatient follow-up clinic 2 days a week, with at least 30 patients per day (Horspool, 2015b). With the support of the University of Michigan, Dr. Ahmed has been busy developing a kidney transplant program. Before transplants could occur, in addition to gathering the requisite equipment and medication, organ donation
and transplantation had to be legalized and chronic dialysis services had to be in place (Horspool, 2015b). Now a University of Michigan team visits SPHMMC every 4-6 weeks to help with procedures and local surgeons are supposed to take over in two years (Horspool, 2015b).

Bethel Hospital has a hemodialysis unit as well. In 2008, Bethel Hospital was selected as the site for the dialysis program for the poor envisioned by the Dr. Yeneneh Betru Foundation. The Dr. Yeneneh Betru Foundation was founded by the family of Dr. Betru, a US-educated Ethiopian physician who was killed on 9/11 when his plane crashed into the Pentagon (Tuso, 2009). In 2001, donations enabled the foundation to purchase several machines and send them to Ethiopia but, although Ethiopian physicians had requested the dialysis machines, without an accepting physician, they were quarantined in the Ministry of Health for several years (Tuso, 2009). The healthcare staff at Bethel needs additional education and supplies as it was observed that dialysis order were written by an internist with no dialysis training and the patients’ permanent dialysis access sites were typically subpar – non-cuffed, unsecured catheters placed in the subclavian vein, increasing the risk of infection and stenosis – with fewer than 10% having AV fistulas (Tuso, 2009).

As of 2013, St. Gabriel General Hospital had three dialysis machines, two dialysis nurses, one general practitioner with some dialysis training and one nephrologist (Shibiru et al, 2013). Between February 2002 and August 2010, 190 patients were registered for
hemodialysis, although it is unclear what percentage of these patients actually received dialysis and for how long (Shibiru et al, 2013). A study evaluating survival patterns for dialysis patients at St. Gabriel included 91 of the 190 patients. Unlike Bethel Hospital, far more had a fistula (45.1%) or graft (13.2%), compared to a catheter (41.8%) for dialysis access (Shibiru et al, 2013). Sepsis was a common cause of death (34.1%) (Shibiru et al, 2013). No patients using catheters survived to two years and type of vascular access was the strongest predictor of patient outcomes (Shibiru et al, 2013). The majority (56.0%) dialyzed twice a week and only 42.1% of patients evaluated survived one year (Shibiru et al, 2013). Data collection is not a straightforward task in many of these countries and in addition to failing to mention the specific exclusion criteria, the authors note, “incomplete documentation, inappropriate chart labeling and lost records made it difficult to include all patients registered for dialysis” (Shibiru et al, 2013). Furthermore, their findings are not representative for the country because the participants were overwhelmingly from Addis Ababa where living conditions are better (Shibiru et al, 2013).

The Black Lion (Tikur Anbessa) Hospital is the University of Addis Ababa’s principal teaching hospital. With 800-beds, the Black Lion is also Ethiopia’s largest public hospital, treating approximately 370,000-400,000 patients a year (ISN, 2016). In 2010, an ISN Sister Renal Center Program partnership was established between the renal units of the Black Lion (Tikur Anbessa) Hospital and the Cardiff University School of Medicine in the UK. After failing to receive satisfactory progress reports from level “C” to level “B” after two years, the partnership was held at “Honorary C” until it dropped
out in 2014 (ISN, 2014). In November 2015, though, the ISN reported that the Black
Lion Hospital had started a hemodialysis program with three machines (Horspool,
2015b). In addition, a new partnership was formed in 2015 between the Black Lion
Hospital, the University of Toronto (Canada) and St. John’s Medical College (Bangalore,
India) under the Saving Young Lives (SYL) initiative (Horspool, 2015b). The
Sustainable Kidney Care Foundation, the SYL partner that provides dialysis consumables
to developing countries, has been working for two years to gain government approval to
import dialysis consumables and recently received final government approval (ISN,
2016). Under this initiative, Dr. Yewondwossen Tadesse, who trained with Dr. Saraladevi
Naicker, a leader of nephrology education in Africa, has started an acute PD program for
AKI at the Black Lion (Horspool, 2015b). In 2015, the nephrology fellowship program
was finalized and hopefully will begin taking trainees this year (Horspool, 2015b). The
Black Lion Hospital is the only hospital that is mentioned to have PD in Ethiopia.

**Madagascar**

Hemodialysis has been available in Antanarivo, the capital, since 1989
(Randriamanantsoa et al, 2011). Peritoneal dialysis is not mentioned to be available in the
literature. As of 2011, there were six hemodialysis units in Antanarivo, one of which is at
the public hospital, University Hospital of Joseph Raseta Befelatanana
(Randriamanantsoa et al, 2011; Ramilitiana et al, 2010). Although one study writes that
Madagascar finances chronic dialysis for its patients with 66% of ESRD patients being
placed on hemodialysis, the authors’ conclusions, which are based on a 2010 study by Ramilitiana and others, are erroneous (Bah et al, 2015). Although Ramilitiana and others write that 39 of 59 patients (66%) received dialysis at the public hospital over the study period (May 10, 2006 to December 31, 2008), the authors also note that the cost of care was prohibitive and many patients could not receive regular dialysis sessions because of the high cost (“certains patients ne pouvaient pas effectuer régulièrement leurs séances d’hémodialyse à cause du coût élevé de chaque séance”) (Ramilitiana et al, 2010). Another “exhaustive” retrospective study including all dialysis patients registered at the six dialysis centers in Madagascar described a study population of only 59 patients (Randriamanantsoa et al, 2011). In conclusion, it is unlikely that dialysis is available and accessible to the majority who need it in Madagascar.

**Rwanda**

After the Rwandan genocide decimated Rwanda’s health system, Rwanda has benefitted from robust international support and strong country ownership of the reconstruction process. Dialysis for ESRD in Rwanda is less than ten years old (Kolb et al, 2014). In 2014, it was estimated that there were 60 chronic dialysis patients in Rwanda (Kolb et al, 2014). In Kigali, the capital, there are hemodialysis units at the King Faisal Hospital and the University Hospital of Kigali (CHUK) (Kolb et al, 2014). King Faisal Hospital had 9 dialysis machines as of 2014, in addition to 2 dialysis machines for AKI in the intensive care unit of the hospital (Kolb et al, 2014). In the south, near the Rwanda-Burundi border, there is also a hemodialysis unit with six machines at Butare University.
Hospital as of 2014. (Kolb et al, 2014). Butare University Hospital also provided dialysis to Burundians, as Burundi did not have dialysis until recently. Anecdotally, it appears that a PD program has been started at Le Centre Hospitalo-Universitaire de Kamenge in Burundi’s capital, Bujumbura. The genocide resulted in a shortage of doctors in Rwanda and in 2014, the country only had 2 permanent nephrologists, both of whom practiced in Kigali (Kolb et al, 2014). Since there is not a vascular surgeon in the country to place AV fistulas, most chronic kidney disease patients have had to dialyze using catheters, although three nephrologists and a vascular surgeon from Strasbourg, France have visited Rwanda three times since 2010 to create AV fistulas (Kolb et al, 2014). France has been particularly supportive of Rwanda’s dialysis programs and helped to train Rwandan doctors in 2005 in intensive care and hemodialysis in Metz-Thionville and Nancy in 2005 and also helped to start the acute dialysis program in Butare. Unlike its neighbors, Rwanda has a national medical insurance program but unless the patient has FARG or RSSB insurance, dialysis is costly and is not covered (Kolb et al, 2014).

**Tanzania**

Tanzania is a country of 45 million with a GNP per capita of US$695 and health expenditure of US$41 per capita (Fredrick et al, 2015; Mushi et al, 2015). In comparison to the other low-income countries in sub-Saharan Africa, there is a relative wealth of literature on the status and development of renal replacement therapy programs in the nation, particularly in the last ten years. In the 1980s, efforts to start a peritoneal dialysis program in Tanzania were terminated when importing the fluids from Europe was too
expensive, while another more recent effort was stymied by high rates of peritonitis (Burki, 2015). Tanzania has been host to several strong North-South partnerships in nephrology that have been quick to document the experience. In particular, SYL’s pilot project implementing PD for AKI treatment at Kilimanjaro Christian Medical Centre and a trilateral partnership between Tanzania, India and Norway focusing on building Tanzania’s nephrologist training capacity have been instrumental in changing the dialysis landscape in Tanzania since 2007 (Fredrick et al, 2015). Even before these high-powered partnerships though, Tanzania was no stranger to efforts to launch dialysis programs.

**Service Delivery- General:** Before 2007, there was one dialysis unit in Tanzania, located in Dar es Salaam, providing maintenance hemodialysis to 32 patients, and there were no hospitals with acute PD programs (Fredrick et al, 2015). Between 2007 and 2015, when SYL and Norway and India entered Tanzania’s dialysis scene, the number of dialysis units (both public and private) increased to twelve units providing maintenance hemodialysis to 267 patients, and four hospitals developed acute PD programs (Muhimbili National Hospital, Kilimanjaro Christian Medical Center, Bugando, and St. Francis Designated District Hospital) (Fredrick et al, 2015). The majority of hemodialysis units are located in Dar es Salaam though, meaning most Tanzanian’s do not have access to dialysis (Fredrick et al, 2015). Specifically, nine units are in Dar es Salaam and there is one unit in Mbeya, Mwanza and Dodoma each (Fredrick et al, 2015). Renal transplantation is not available in Tanzania and few patients can afford to go abroad, but even the number of Tanzanian’s acquiring renal transplantation abroad increased from 26
to 135 between 2007 and 2015 (Fredrick et al, 2015). Both Muhimbili National Hospital and Kilimanjaro Christian Medical Center’s dialysis program are discussed in depth in the literature. In addition to these two programs, SYL has started a project at Bugando Medical Centre, a 900-bed tertiary referral hospital with a catchment zone of 13 million, in Mwanza, Tanzania under the leadership of Dr. Mubarak and Dr. Fatma Bakshi, but patients have not been treated yet (ISN, 2016).

Service Delivery- Muhimbili National Hospital: Muhimbili National Hospital (MNH) in Dar es Salaam is a teaching hospital and the highest public referral hospital (Fredrick et al, 2015) with 1500 beds and 1000-1200 outpatients per week (Mushi et al, 2015). The dialysis unit at MNH with 10 beds providing 3 shifts per day 6 days a week is government-owned and operated (Mushi et al, 2015). Since the MUHAS/MNH collaboration began with the India and Norway, nephrology services in Tanzania have improved drastically and pediatric nephrology, acute PD and nephropathology have been introduced as new services (Fredrick et al, 2015). The unit provides dialysis to NHIF members and acute dialysis to patients, who are exempted from payment (Mushi et al, 2015). As the hemodialysis service has grown at MNH to 60 patients, the average cost per patient has declined, but it is unlikely that the number of patients will increase much more as the unit has reached capacity and financing institutions are probably unable to sponsor any additional patients (Mushi et al, 2015).
Service Delivery- Kilimanjaro Christian Medical Centre: Opened in 1991 by the Good Samaritan Foundation, KCMC is a referral hospital of over 450 beds that serves more than 11 million Tanzanians (Callegari et al, 2012; Carter et al, 2012). KCMC is also the teaching hospital for Kilimanjaro Christian Medical College (Carter et al, 2012). In 2009, SYL selected Tanzania as the first place to start an acute PD program for AKI (Swanepoel et al, 2013) and much has since been written about Saving Young Lives’ pilot project at Kilimanjaro Christian Medical Centre (KCMC) in northern Tanzania. Prior to SYL’s involvement, there was no acute PD available in the country (Carter et al, 2012). The focus of the program is AKI treatment for women of childbearing age and children, although men with AKI have been treated (Callegari et al, 2012). Since 2012, KCMC has treated about 1-2 patients per month using peritoneal dialysis from the Moshi area, but it has been noted that the catchment area must include rural patients in order for the program to truly be successful (Carter et al, 2012). Peritoneal dialysis was chosen because of the modality’s greater simplicity (Callegari et al, 2012). Only AKI is treated, not ESRD (Callegari et al, 2012). Although the center is close to being freestanding, this belies the fact that the program has failed to assume responsibility for financing after two years as promised and has struggled to find patients (ISN, 2016). Nonetheless, KCMC’s success in service provision and construction of a healthcare workforce has led KCMC’s program to be considered “a shining example” and KCMC has been used as a model project for subsequent SYL programs in Africa (Swanepoel et al, 2013). The project is particularly hailed as a success because “infection rates are low and patients rarely
require catheter reinsertion…it drew a young internist into nephrology, and he plans to remain in Tanzania” (Burki, 2015).

*Health Workforce:* Before 2007, there was one nephrologist in Tanzania (Fredrick et al, 2015). He had been trained through an ISN fellowship program and practiced at Muhimbili National Hospital in Dar es Salaam (Fredrick et al, 2015). Nephrology training programs supported by the ISN through SYL and a trilateral collaboration between MUHAS and MNH in Tanzania, Christian Medical College (CMC) in Vellore, India and the University of Bergen/Haukeland University Hospital (UoB/HUH) in Norway have been instrumental in the growth of nephrology services in Tanzania (Fredrick et al, 2015). Between 2007 and 2015, the number of nephrologists in Tanzania increased to ten, although one is not in clinic practice, with five located at MNH and one each at KCMC, Bugando Medical Center (in Mwanza), Mbeya Referral Hospital (Mbeya) and Regency Medical Centre (Dar es Salaam) (Fredrick et al, 2015). The trilateral collaboration, established for the purpose of nephrologist training, was supported by the Norwegian government through NORAD’s (Norwegian Agency for Development) Cooperation Programme for Master’s Studies and funding was provided for 7 years (2007-2014), after which the program was to be supported by the Ministry of Health and Social Welfare as a postgraduate medical training program (Fredrick et al, 2015). A Memorandum of Understanding was signed between MUHAS/MNH, CMC and UoB/HUH in 2006, initiating a “fruitful” global collaboration (Fredrick et al, 2015). At the onset, two semesters were spent at CMC and UoB/HUH, while the remaining two
semesters were spent at MNH, allowing candidates to experience both limited-resource and highly developed settings, and candidates became proficient at various skills including renal biopsies, nephropathology interpretation, temporary hemodialysis access establishment and percutaneous insertion of catheters for both acute and chronic PD and gained exposure to kidney transplantation practices (Fredrick et al, 2015). Seven candidates, five from Tanzania, one from Uganda and one from Ethiopia, were recruited from general medicine or pediatrics backgrounds and trained in nephrology, (Fredrick et al, 2015). Each candidate returned to their home institutions and all of the Tanzanian candidates are now involved in teaching, with two working at MUHAS and three at MNH (Fredrick et al, 2015). The nephrology program is now fully established and candidates can train locally for all four semesters under the guidance of the original Tanzanian-trained candidates (Fredrick et al, 2015). The program notes that retention of graduates and their cohesive efforts have particularly contributed to the enduring impact of this program (Fredrick et al, 2015). As of 2014, MNH had 20 specialized nurses, 4 nephrologists, 8 registrars, one nutritionist, 2 biomedical engineers, 4 health attendants and nine dialysis machines in their dialysis unit (Mushi et al, 2015).

In 2009, under the SYL partnership, the ISN paid for two doctors, Dr. Kajiru Kilonzo, a resident in Internal Medicine, and Dr. Nicholas Chota, a pediatrician, to travel to Brazil to study nephrology for five weeks (Burki, 2015). They learned to identify AKI and insert a peritoneal catheter at various hospitals throughout Curitiba and Sao Paolo (Burki, 2015). The ISN’s Dr. Finkelstein of Yale University has noted that general
internists can successfully be trained to perform PD for AKI (Burki, 2015). The two physicians were accompanied by two nurses, one from the ICU and another from the pediatric ward, and a biochemist, as a hospital clinical laboratory pivotal in the success of any nephrology or dialysis program (Burki, 2015, Carter et al, 2012). Upon returning to Tanzania, the four then served as trainers for others, training the entire ICU nursing staff and two additional physicians (Callegari et al, 2012). Meanwhile, quality control measures were implemented in the laboratory (Carter et al, 2012). Duplicate testing was performed in the KCMC laboratory and the United States with the University of Massachusetts-Lowell providing pretested samples to run at the KCMC laboratory (Callegari et al, 2012). Although Dr. Chota ultimately left for another position in central Tanzania, Dr. Kilonzo ultimately obtained ISN funding for fellowship in nephrology in Cape Town, South Africa and has been a strong leader in the KCMC program (Burki, 2015). Continued clinical support is provided from doctors in US and Canada via phone and the internet (Carter et al, 2012). Since 2012, an ISN Sister Renal Center Program partnership has also been established between Queens University in Canada and KCMC, which has helped KCMC to further establish training links in nephrology (ISN, 2014). This partnership, however, has remained at the lowest grade (C) in the program and as of 2014, had only one additional chance to graduate to the next level (B) (ISN, 2014). It has been noted that KCMC needs to train healthcare workers in the hospital’s catchment zone to detect AKI to improve referral to the hospital (Callegari et al, 2012) and new techniques, such as the saliva urea dipstick test for semi-quantitative diagnosis for AKI, would help improve timely diagnosis (Callegari et al, 2012). Although the hospital
receives 1-2 patients per month, there are undoubtedly far more AKI sufferers in the catchment region and lack of awareness of AKI amongst healthcare workers seriously hinders referral.

*Information:* Tanzania does not have a national registry for kidney disease and knowledge of kidney disease is low (Mushi et al, 2015; Burki, 2015). Low awareness in the health centers and district hospitals is problematic and patients typically arrive late, undiagnosed (Burki, 2015). Even within the hospital, it is not guaranteed that they will be referred to the appropriate department and many cases still go undiagnosed (Burki, 2015). Finding patients for dialysis programs has turned out to be an unexpected challenge (Burki, 2015). At KCMC, for example, only 32 patients in a catchment area of 10 million were treated over the first six years and it became clear that knowledge in the community about kidney disease was non-existent (Burki, 2015; Carter et al, 2012). Prompt diagnosis of AKI is key, particularly as many patients need to travel from remote villages (Callegari et al, 2012). In light of this, there is currently a strong emphasis on education and healthcare workers in the acute PD program will venture to clinics and secondary hospitals in KCMC’s catchment zone to inform and raise awareness about kidney disease in the local community (Carter et al, 2012). Ideally increased awareness among frontline healthcare workers will improve the referral pattern, increasing treatment of AKI.

*Medical Supplies:* One author noted that it is easy to envision the East African Community, including Tanzania, banding together to set up a local manufacturing of
dialysis supplies (Carter et al, 2012). Instead, supplies are imported adding nearly 25% to the cost of treatment (Carter et al, 2012). In the case of KCMC, the consumables were obtained from Fresenius Medical Care in Germany, shipped to Dar es Salaam and then taken by truck to Moshi (Carter et al, 2012).

**Financing:** In Tanzania, dialysis is covered for those in public service - a small portion of the population - by the National Health Insurance Fund (NHIF) while a few other patients have private insurance, but the majority of dialysis patients have high out-of-pocket expenditure (Mushi et al, 2015; Callegari et al, 2012). At Muhimbili National Hospital, AKI patients are exempted from payment (Mushi et al, 2015). The NHIF pays US$187 for a single HD session and based on this price, the MNH dialysis unit needs 288 dialyses per month to cover costs, meaning the minimum number of patients receiving three sessions per week needs to be at least 23 (Mushi et al, 2015).

At KCMC in Moshi, only AKI is treated, meaning healthcare workers must be trained to recognize ESRD (Burki, 2015). Treating ESRD would result in the rapid depletion of supplies and funds to the benefit of only a few patients (Burki, 2015). At KCMC, patients receive dialysis for a maximum of 30 days, and the cost to save a life under these circumstances is US$150 to $400, with the single-cuffed silicon catheter typically used being one of the larger costs (US$100) (Burki, 2015). SKCF, one of the SYL partners, provided the consumables (catheters, fluids, etc.) for the first two years in addition to providing funding for the centrifuge, microscope and urinalysis lab set up.
(Burki, 2015). Supplies were transported from Europe rather than South Africa, where PD fluids are locally manufactured, because fewer duties had to be paid on supplies coming from Europe, and SKCF discovered that sometimes the price of transporting the supplies was four to five times more than their actual cost because of corruption (Carter et al, 2012). Although KCMC agreed upfront to fully finance the procurement of supplies after two years the institution has not yet managed to assume fiscal responsibility, calling the sustainability of the venture into question (Carter et al, 2012). Articles describing Tanzania are predominantly from 2012 and it is unclear if the financing issue has been resolved.

*Leadership & Governance:* Tanzania has benefitted from both strong local and international involvement and stewardship. The nephrologists trained through the MNH/MUHAS collaboration are continually mentored by trainers in both India and Norway, and the three nations work together not only in managing difficult cases but also through joint publications and workshops (Fredrick et al, 2015). Prior to implementation of acute PD at KCMC, the Tanzanian Ministry of Health was fully informed of the plan in advance (Carter et al, 2012). It is unclear the extent to which the hospital administration or the government support nephrology and dialysis services in Tanzania, although it has been noted that a culture of corruption tends to make the programs more expensive and that hospital support can wane and individuals may return from training to discover the promised position has evaporated (Burki, 2015). At KCMC, despite pledging to assume responsibility for program financing, the hospital has not done so (Burki,
At the same time, there is strong individual leadership. Dr. Kilonzo, mentored by Dr. Karen Yeates at Queen’s University, at KCMC is mentioned as an example (Burki, 2015). In August 2012, the Nephrology Society of Tanzania (NESOT) was established, becoming an ISN-affiliated member in May 2013 (Fredrick et al, 2015). During World Kidney Day 2013, NESOT conducted an awareness campaign and screened 4000 people for CKD risk factors (Fredrick et al, 2015). Both Tanzanian physicians and international physicians continue to provide leadership through mentoring as well (Burki, 2015). The strong international partnerships in Tanzania could work on improving “financing” and “information” as next steps.

**Uganda**

Uganda has only one national dialysis center, Mulago National Referral Hospital, located in the capital city of Kampala, although it is possible that there are a few small private dialysis centers in Kampala as well (Carter et al, 2012). In addition to being the national referral hospital for Uganda, Mulago is also the primary teaching hospital for Makerere University College of Health Sciences (Carter et al, 2012). In 2012, it was noted that Mulago National Referral Hospital, in the capital of Kampala, had six HD machines, three of which were in “good operational status,” supporting 25 ESRD patients who could afford to pay (Carter et al, 2012). However, in 2013, Mulago National Referral Hospital was described to have 32 dialysis machines for a population of 34 million Ugandans (0.1 machines/100,000 population) (Bagasha et al, 2015). It is unclear if the program at Mulago has grown from six to 32 machines, if this larger number includes
machines at other dialysis centers, or if this number includes non-functioning equipment. Mulago National Referral Hospital offers dialysis at subsidized prices that are still unaffordable to the majority of patients (Bagasha et al, 2015). In a four-month study on AKI-epidemiology at the hospital in 2013, none of the patients who needed dialysis received dialysis because of the expense (Bagasha et al, 2015). Mulago is reportedly poorly resourced and laboratory tests, including tests of renal function, are typically unavailable (Bagasha et al, 2015). There has been little infrastructure developed to keep up with the growing challenges of AKI prevention or treatment (Carter et al, 2012). Uganda’s health system lacks sufficient healthcare personnel, particularly specialists, and the country currently has 5 adult nephrologists and no pediatric nephrologists for a population of 34.6 million (Horspool, 2015a; Carter et al, 2012). In 2015, however, SYL began working with the Mulago National Referral Hospital and Kisenyi Health Center, a smaller, city-owned hospital, to establish AKI treatment (ISN, 2016). Mulago’s “importance,” “excellent reputation” and strong staff and administrative staff make Mulago an ideal place to start an acute PD program (Carter et al, 2012). SYL in Uganda benefits from the organization’s past experience with PD implementation in Tanzania at Kilimanjaro Christian Medical Center and the strong support of Uganda’s Sudanese neighbors. One of the pioneers of the Sudanese PD program, Professor Hassan Abu Aisha, is highly supportive and encourages collaboration and joint research between the Ugandan and Sudanese teams (Horspool, 2015a). Four Ugandan healthcare professionals (Judith Aujo, Peter Ntege, Margaret Idumira and Milly Nakazzi) from the Kisenyi Health Center and Mulago National Referral Hospital recently spent two months at a Sudanese
center learning from local experts’ experience in setting up a PD program and covering PD principles, such as AKI and catheter insertion (Horspool, 2015a). Although PD treatments for AKI have not started yet, the first shipment of supplies recently arrived (ISN, 2016).

**Malawi**

There have been recurrent efforts to establish dialysis services on a small-scale in Malawi. In the 1980s, dialysis machines were donated to Lilongwe Central Hospital by the NGO Chitukuko Cha Amayi m’Malawi for the creation of the Lilongwe Dialysis Unit, but the lack of a water-purifying system to convert tap water to medical-grade dialysis water was a major barrier (Mtika et al, 2002). By 1994, after several years of poor maintenance, the equipment was broken and patients had to go abroad for renal replacement therapy, usually to South Africa (Mtika et al, 2002). Four years later, in 1998, the Lilongwe Dialysis Unit was revitalized when the government purchased four new machines and a water-purifying unit (Mtika et al, 2002). Twelve staff (three physicians, including V.G. Mtika and J Chipolombwe, five senior nurses, two laboratory technologists and two electromedical technicians) traveled to South Africa for a one-week intensive course in dialysis (Mtika et al, 2002). Between June 1998 and November 2000, 29 patients received dialysis at Lilongwe Dialysis Unit (Mtika et al, 2002). In 2002, Mtika and others reported that the Lilongwe Central Hospital offered HD, CAPD and preparation and follow-up of live-donor renal transplants for patients who received a kidney transplant abroad. Dialysis is offered to both AKI and ESRD patients, with
transplantation being the ultimate goal for ESRD patients, and of the four dialysis machines, one is reserved for patients with HIV or HCV (Mtika et al, 2002). Dialysis consumables must be purchased outside the country as there is no local production and each hemodialysis session costs approximately US$100 (Mtika et al, 2002). In total, treating AKI costs about $500-700 (Mtika et al, 2002) but the unit is fully funded by the Ministry of Health and Population (Mtika et al, 2002). The cost-intensive unit is being threatened by cost-cuts and Dr. Mtika and others call for creative cost-sharing methods (Mtika et al, 2002). Attempts to shift financial responsibility for the unit to Lilongwe Central Hospital have failed (Mtika et al, 2002). Malawi benefits from the leadership of the Malawi Kidney Foundation Trust, which was formed to increase awareness of kidney injury and disease and to provide support to the dialysis unit (Mtika et al, 2002). The Trust also helps to counsel long-term dialysis patients at Lilongwe (Mtika et al, 2002).

In the second largest city, Blantyre, an ISN Sister Renal Centre was established between the renal department of the Royal London Hospital and the Queen Elizabeth Central Hospital (QECH) in 2012 (ISN, 2014). In 2014, the QECH- Royal London Hospital partnership graduated from level “C” to level “B,” evidencing progress by QECH (ISN, 2014). QECH is reported to have PD and HD available for AKI, although there limited awareness of this service compounded by a general lack of renal education (Evans et al, 2015). A symposium on AKI held in Blantyre March 2015 revealed the lack of education on AKI and renal disease among healthcare workers: 22% of healthcare workers had never received any education on any aspect of renal disease, 50% had never
received any education on AKI, 34% were unaware hemodialysis was available at QECH and 53% were unaware peritoneal dialysis was available for treating children with AKI (Evans et al, 2015). Rates were even higher amongst district healthcare workers (Evans et al, 2015). High staff turnover and a lack of laboratory testing for renal function throughout Malawi challenges the creation of a sufficiently educated workforce and contributes to healthcare workers lack of confidence in diagnosing and managing renal disease (Evans et al, 2015). In light of this, QECH is in the process of opening an AKI center of excellence that can serve as a training center for healthcare workers on AKI diagnosis and management (Evans et al, 2015).

**Zimbabwe**

In the literature, hemodialysis is noted to exist in Zimbabwe. A 2013 study conducted by the University of Zimbabwe College of Health Sciences on hypoalbuminaemia indicated that hemodialysis is available at the Parirenyatwa Group of Hospital renal clinic and Chitungwiza Central Hospital renal clinic (Machingura et al, 2015). Between January and February 2013, 60 patients were enrolled in the study and no exclusion criteria are noted (Machingura et al, 2015). Since the majority (70%) of dialysis patients were male, it is probable that there are significant costs to the patient associated with dialysis and these patients were important breadwinners in the family (Machingura et al, 2015). It is unclear from the literature if peritoneal dialysis is available in Zimbabwe or if there is any government support or subsidization of renal replacement therapy.
THE LOWER-MIDDLE INCOME LANDSCAPE

Fifteen countries in sub-Saharan Africa are classified as “Low-Middle Income” by the World Bank: Mauritania, Sudan (Sahel), Cabo Verde, Cameroon, Cote d’Ivoire, Ghana, Nigeria, Senegal (West Africa), Republic of the Congo, Sao Tome and Principe (Central Africa), Djibouti, Kenya (East Africa), Lesotho, Swaziland, Zambia (South Africa). The bolded countries are noted in the literature to have some form of renal replacement therapy available, although it is quite likely that a few dialysis units exist in the capital cities of the three remaining countries. ISN Sister Renal Centers exist in Cameroon, Ghana, Nigeria, Kenya, and Zambia (ISN, 2014).

Mauritania

In the Sahel, only Sudan is noted in the literature to have dialysis. There is no literature dedicated to dialysis in Mauritania but the Fresenius Medical Care “Africa Market Survey 2000” estimated in 2000 that there were 50 patients on hemodialysis, 10 machines and one nephrologist in the country (Fogazzi et al, 2003).

Sudan

Sudan is a large country with a predominantly rural population (Elhassan et al, 2007). Recent developments in Sudan are promising: Large oil reserves were recently discovered, contributing to Sudan’s economic base, a peace agreement was signed between the North and the South, and international sanctions imposed on Sudan were
Sudan’s first renal unit was established in 1967 at Khartoum Civil Hospital, with acute intermittent PD and HD via a single HD machine being offered (Elhassan et al, 2007). Sudan has relatively strong PD and HD programs compared to the rest of sub-Saharan Africa, as well as a transplantation program, and its PD program particularly benefitted from strong governance and leadership. Nonetheless, HD is still the main RRT modality, with 69% of treated ESRD undergoing HD (Abdelwahab et al, 2013).

_Service Delivery:_ HD is available at public and private centers, while PD is delivered entirely at public hospitals (Abu-Aisha et al, 2009). There were 27 registered HD centers in Sudan as of 2007, 21 of which were public while 6 were private (Elhassan et al, 2007; Abu-Aisha et al, 2009). HD is limited to a few major towns and most patients undergo twice weekly HD (Abu-Aisha et al, 2009). In December 2006, there were 2129 patients on maintenance dialysis in Sudan (19 HD patients: 1 PD patient) and by December 2007, the number of maintenance HD patients had grown to 2750 (Elhassan et al, 2007; Abu-Aisha et al, 2009). One-third of these patients lived outside of Khartoum, where they were looked after by non-nephrologists, and trained staff and dialysis machines are reported to be “scarce” (Abu-Aisha et al, 2009).

Acute PD with a hard-catheter, a risky procedure fraught with complications, is common in Sudanese hospitals as a life-saving intervention (Abu-Aisha et al, 2009; Elhassan et al, 2007). In 2005, CAPD was introduced as a national service because
the modality “is mostly self-administered; secures the ability to work, study, or travel; requires fewer dietary restrictions, and should potentially decrease hospital and medical costs” (Elhassan et al, 2007). Over 20 months (June 2005 to January 2007), the program - a national experiment- was launched sequentially in 5 adult centers and 2 pediatric centers in Greater Khartoum (Ribat University Hospital, Military Hospital, Soba University Hospital (Pediatric Unit), Khartoum Teaching Hospital, Ibn-Sina Specialized Hospital, Ibn-Auf Pediatric Hospital, Khartoum North Renal Center) (Abu-Aisha et al, 2009; Elhassan et al, 2007). In 2008, the first regional center outside of Khartoum was launched at Medani (Abu-Aisha et al, 2009). In January 2007, 111 patients had been enrolled nationally in the chronic PD program and by July 2008, this number had grown to 232 (Elhassan et al, 2007; Abu-Aisha et al, 2009). Over half of these patients lived outside of Khartoum, coming from as far away as Port Sudan and Nyala, over one thousand kilometers away (Abu-Aisha et al, 2009). For many of them, CAPD was the only option because of the distance and lack of dialysis units in those regions (Abu-Aisha et al, 2009). PD patients are chosen from a multitude of ESRD patients in light of their “social and home environment. Motivation and willingness to adopt the procedure and comply with the instructions are the major criteria used,” although many are enrolled simply because HD is inaccessible for them (Elhassan et al, 2007). The centers have carefully documented complications and rates of peritonitis, finding peritonitis to be 1 episode per 21.5 patient months, which was well within the ISPD recommended guidelines of 1 episode per 18 patient months, but incidence of peritonitis increased notably after the first year and with some centers being outside of the targeted range
(Abu-Aisha et al, 2009). In light of this, centers have carried out home visits and worked to regularly provide continuing staff education (Abu-Aisha et al, 2009).

In Sudan, kidney transplantation is reported to account for 28% of the renal replacement therapies (Abdelwahab et al, 2013). Kidney transplantation, recently rejuvenated, is offered in a few major hospitals and is growing (Abu-Aisha et al, 2009). Kidney transplantation is only available from living donors because there is a lack of appropriate legislation to provide the framework for a deceased-donor program (Abu-Aisha et al, 2009; Swanepoel et al, 2013; Abdelwahab et al, 2013). Many patients still seek transplants abroad, particularly from Egypt, Saudi Arabia, Jordan and Pakistan (Abdelwahab et al, 2013). Sudan budgets to provide full financial support for 120 kidney transplants each year but only 588 transplant operations were funded by the government between 2000-2009 according to official reports because there are only two transplant surgeons available in Khartoum State, leading to long waiting lists (Abdelwahab et al, 2013). Without financial support, the cost of the pre-transplant work-up and immunosuppressive medications are prohibitively expensive for most patients (Abu-Aisha et al, 2009).

**Health Workforce:** In 2009, Sudan was reported to have 20 nephrologists and 1 or 2 nephrologists or experienced general physicians and nurses work at each PD center (Abu-Aisha et al, 2009). Catheters are typically placed by physicians using the blind Seldinger technique, but trained surgeons can place catheters by the open method more
complicated cases (Elhassan et al, 2007). Most of the senior nephrologists were trained in the UK (Elhassan et al, 2007). Sanctions imposed on Sudan limited international training opportunities for many years (Elhassan et al, 2007). Because of the embargo, several Sudanese ISN fellowships had to be denied, since the ISN is registered in the United States, and in 2006, Sudan was in the process of developing a course curriculum for nephrology (Harris et al, 2012; Elhassan et al, 2007). Staff at the PD centers are reported to be enthusiastic, cooperative, and participatory: “Credit must also be given to all the team members of the seven centers, who fully cooperated and enthusiastically accepted the unified protocols and regularly attended the monthly meetings” (Abu-Aisha et al, 2009). Furthermore, in spite of international sanctions, Sudanese physicians still regularly attended regional and global conferences and maintained external connections (Elhassan et al, 2007). One challenge for the units though has been retaining nurses, as nurses are not dedicated to one unit and would be transferred to another unit as needed, and it is thought that this staffing inconsistency contributed to the higher peritonitis rates experienced after the first year (Abu-Aisha et al, 2009). This issue has largely been resolved and peritonitis rates are improving (Abu-Aisha et al, 2009).

Information: Sudan does not have a national renal registry, although the prevalence of CKD has been estimated to be 5.1% in the adult population based on a pilot study in Khartoum (Abu-Aisha et al, 2009). For healthcare staff, access to medical literature is limited because of financial difficulties resulting from the embargo, while political issues have limited both educational opportunities and international support.
Both patient and staff education is vital and the increase in peritonitis highlighted the need for constant training of patients and staff (Abu-Aisha et al, 2009). Also, earlier recognition and preparation of PD candidates in the system is a priority as 17% of PD patients required urgent dialysis initiation (Abu-Aisha et al, 2009). Of note, the program staff has taken commendable initiative in monitoring and evaluating the PD program (Abu-Aisha et al, 2009).

Medical Supplies: The Central Medical Supplies (CMS) Corporation, a federal state organization, coordinates the acquisition of PD supplies from Baxter International through their local agent in Sudan (Shaweesh Company) (Abu-Aisha et al, 2009; Elhassan et al, 2007). Because of the crisis in Darfur, Baxter first had to obtain an exemption to the economic embargo imposed by the US (Elhassan et al, 2007). PD supplies, including fluids and double-cuffed soft Tenkhoff catheters, are shipped from Europe or from the Middle East to the Port of Sudan and are then “transported for over 1000 km across inhospitable desert to Khartoum for distribution,” resulting in a much higher cost of supplies than in developed countries (Finkelstein et al, 2007). Once the PD supplies are in their respective centers, it is unclear how they are distributed to patients. While Sudan’s PD supply chain seems to function, there is a lack of laboratory supplies for proper culturing technique that contributes to high culture-negative peritonitis rates, which have been reported to be as high as 40%-53% compared to the maximum of 20% recommended by the ISPD (Finkelstein et al, 2007; Abu-Aisha et al, 2009; Abu-Aisha & Elamin, 2010). Specifically, large volume centrifuging devices and blood culture bottles
are expensive and inconsistently available (Abu-Aisha et al, 2009). Instead, a few mL of
dialysate are injected directly into culture media and then checked daily for growth (Abu-
Aisha et al, 2009). Another concern is that, in children, parents may be finding it difficult
to throw the unused portions of the adult 2L bags away and are instead reusing the bags,
contributing to particularly high peritonitis rates in younger patients (Elhassan et al,
2007).

**Financing**: In Sudan, PD costs more than HD (Abu-Aisha & Elamin, 2010; Abu-
Aisha et al, 2009; Swanepoel et al, 2013). HD is reported to cost US$100 per session
with physicians and facilities being reimbursed US$70 per session (Abu-Aisha et al,
2009). No reimbursement had been set for PD as of 2008 (Abu-Aisha et al, 2009). The
annual cost of PD was reported to be US$11,680 per patient on maintenance dialysis,
while the annual cost of HD was US$10,400 per patient (Abu-Aisha et al, 2009). The cost
of HD, however, does not include working days lost and hospital admissions charges, as
both of these are lessened with PD, making the financial picture incomplete (Abu-Aisha
et al, 2009). The federal government reportedly supports all forms for renal replacement
therapy although it is unclear how the government can afford these expensive therapies
(Abdelwahab et al, 2015; Obiagwu & Abdu, 2015). However, the funding provided for
HD in Sudan is inadequate to cover growing number of ESRD patients and HD patients
often undergo twice-weekly HD sessions instead of the prescribed thrice-weekly because
of costs (Abdelwahab et al, 2015; Abu-Aisha et al, 2009). Not all ESRD patients are
treated though: Dialysis- eligible ESRD patients are chosen by program organizers (Abu-

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Aisha et al, 2009; Elhassan et al, 2007). It is also possible that extra costs, such as the cost of labs and medications, may be borne by the patients (Abu-Aisha et al, 2009). Finding a way to help patients afford these costs may help system performance (Abu-Aisha et al, 2009).

**Leadership & Governance:** Sudan’s “well-run” program is considered to be a success story because of strong government support and individual leadership (Swanepoel et al, 2013). Professor Hasan Abu-Aisha, who established the Saudi PD program in the early 1980s, played an instrumental role in the development of Sudan’s PD program, and the country has a passionate workforce of physicians and nurses committed to the success of the PD program (Elhassan et al, 2007; Finkelstein et al, 2007). The PD program was initially accepted by National Ribat University with the university agreeing to be the “Leading Center” and an integrated multi-center approach is used, with a central headquarters and a unified database for all patients, protocols and fluid transfer arrangements (Abu-Aisha et al, 2009). Monthly meetings held in alternately participating centers allow staff to discuss individual patient issues, update center reports, and design protocols (Abu-Aisha et al, 2009). An “appreciation-incentive system” (such as “Best Center in Patient Care and “Least Peritonitis”) has proven to be particularly effective in correcting mistakes and has lead to a “positive competitive environment”(Abu-Aisha et al, 2009).
Perhaps most impressive though, is how carefully nephrologists have monitored the program by documenting outcomes, peritonitis rates and complications, and coordinated dialogue between all of the PD centers (Finkelstein et al, 2007). This careful research and documentation has led to a relative wealth of literature on the state of dialysis in Sudan and has enabled the Sudanese centers to continually improve. In 2007, the African Congress of Nephrology was held in Khartoum and was attended by over 250 healthcare personnel from Sudan and other African countries (Elhassan et al, 2007; Finkelstein et al, 2007). Public support is being sought for the expansion of PD in Sudan by ‘The Board of Trustees for the Sudan National PD Program,’ a group of activists, journalists, and businessmen, and as the program grows, potential centers will be reviewed for the presence of an enthusiastic nephrologist, a team-oriented approach and a willing hospital administration (Abu-Aisha et al, 2009).

**Cameroon**

*Service Delivery:* Renal replacement therapy, in the form of both HD and PD, was launched in the early 1980s in Cameroon in the capital city of Yaoundé and services were then extended to Douala, the economic capital, but the PD services did not last (Halle et al, 2015, Kaze et al, 2008). Thirteen patients were described to have undergone CAPD in the 1980s with moderate success (Youmbissi et al, 1989). Five patients died, two from peritonitis and three from causes unrelated to dialysis treatment, while two additional patients had to be transferred to HD because of peritonitis, leading the author to predict that peritonitis will PD expansion in the developing world and for many years PD was
not an option in Cameroon (Youmbissi et al, 1989). PD recently became an option for the treatment of AKI at Mbingo Baptist Hospital in Bamenda, Cameroon. Mbingo Baptist Hospital entered into a Memorandum of Understanding with SKCF in May 2013 and successfully treated five AKI patients in its first month of operation (ISN, 2016). Until 2006, when WORTH (World Organization of Renal Therapies) started their pilot project in Yaoundé, adding a second private unit, there was 1 private HD unit and 2 public dialysis units in Cameroon (Kaze et al, 2008). In 2008, HD services were also extended to a few other cities and at the end of 2012, there was a total of eight hemodialysis centers in the country (Halle et al, 2015). These centers typically offer twice-weekly four-hour sessions to patients (Kaze et al, 2008). At the end of 2012, the Douala unit was providing dialysis to 140 patients, while the total count of ESRD patients receiving dialysis in Cameroon was about 500 (Halle et al, 2015). Dialysis and nephrology services in Cameroon are often unavailable and if available, they are understaffed (Halle et al, 2015).

**Health Workforce:** Between 2006 and 2007, Cameroon was reported to have 6 nephrologists, three of which were located in Yaoundé (Kaze et al, 2008). The renal unit at Douala has always had at least one nephrologist and general practitioner and at the end of 2012, the unit had one nephrologist, two general practitioners and 12 nurses (Halle et al, 2015). There were five nephrologists in the country at the end of 2012, practicing in the two largest cities, Yaoundé and Douala (Halle et al, 2015).
**Medical Supplies:** The Douala General Hospital (DGH), a tertiary referral hospital with 320 beds serving a population of approximately 3 million, has the largest HD unit in the country with 17 dialysis machines and the most recent count of dialysis machines at the public center in Yaoundé was 12 (Halle et al, 2015, Kaze et al, 2008).

**Financing:** Dialysis at the public HD units have been heavily subsidized by the government since 2002, with patients being responsible for US$12 per session, which equates to an annual cost of US$1248 for HD (Kaze et al, 2008; Kaze et al, 2015). Unfortunately, the GNI per capita of Cameroon in 2011 was US$1210, meaning dialysis was still prohibitively expensive for many (Kaze et al, 2015). Furthermore, US$1248 does not include the costs associated with any comorbidities or complications, such as anemia, which are not covered by the government (Kaze et al, 2015). Nonetheless, government subsidies of HD have still improved the care ESRD patients requiring dialysis (Kaze et al, 2015).

**Leadership & Governance:** The PD program established for AKI at Mbingo Baptist Hospital benefits from the guidance of the SYL project and the leadership of Dennis Palmer, in addition to being supported by the North American Baptist Conference (NABC) (ISN, 2016). The leadership for HD in Cameroon is unclear although Dr. Francois F. Kaze has written multiple research articles on the subject of ESRD and dialysis in Cameroon and the government has continued to subsidize the cost of dialysis for over a decade (Kaze et al 2008; Kaze et al 2015; Halle et al, 2015).
Cote d’Ivoire

PD was introduced to the Cote d’Ivoire in December 2008 when the Yopougon University Hospital in Abidjan, the capital, opened a pediatric nephrology unit offering PD services (Diarrassouba et al, 2015). Until that time, all dialysis was in the form of HD, although the literature does not mention the number or location of HD units in the country (Diarrassouba et al, 2015). The pediatric unit found the cost of dialysis to be prohibitive for many parents of children requiring dialysis and even for the two parents with health insurance, the scheme required them to pay upfront and then collect the reimbursement (Diarrassouba et al, 2015). In 2013, under the leadership of Laurence Adonis Koffy, the hospital also began an acute PD program specifically for AKI with the SYL project (ISN, 2016). Kidney transplantation is not available in the Cote d’Ivoire and patient who can afford it travel abroad (Ackoundou et al, 2010). These “transplant tourism” patients experience a greater incidence of acute rejection and severe infectious complications, leading the author to call for the creation of a local transplantation unit (Ackoundou et al, 2010). Non-published hospital-based data reported the prevalence of CKD in the nephrology department of the hospital to be 69% of 610 patients in the nephrology department with a high fatality rate - 74% of CKD patients died (Ackoundou et al, 2010).
Ghana

Service Delivery: As of 2015, HD was available in urban areas for adults in three public and three private facilities, while PD for children with AKI was available in two public facilities (Antwi, 2015). Over half of the land space in Ghana is not covered by dialysis services (Antwi, 2015). PD is not available for adults and maintenance dialysis for children with ESRD is not available (Antwi, 2015). Although there is no national transplant program, renal transplantation is available on a limited basis (Antwi, 2015). The three public facilities with transplantation are Korle-Bu Teaching Hospital in Accra, Komfo Anokye Teaching Hospital (KATCH) in Kumasi and Cape Coast Teaching Hospital in Cape Coast (Antwi, 2015). Both Korle-Bu Teaching Hospital and Komfo-Anokye Teaching Hospital were part of ISN Sister Renal Center partnerships with British hospitals, Queen Elizabeth’s Hospital and St. George’s Hospital, respectively, and both graduated from the program in 2014 after several years of partnership (ISN, 2014). Korle-Bu is the largest facility, with up to 200 patients receiving maintenance dialysis, and the cardiothoracic unit also has HD capabilities for select cases of AKI related to cardiac surgery (Antwi, 2015). Komfo Anokye and Cape Coast typically serve about 20 maintenance dialysis patients (Antwi, 2015). Dialysis services are also available on a limited basis in the three private health institutions (Antwi, 2015). One major challenge to dialysis services is power rationing, resulting in an inconsistent electricity supply, and some centers have chosen to purchase back-up generators, adding to the cost of operations but affording greater consistency (Antwi, 2015). The lack of a consistent electricity supply makes a case for PD integration into the dialysis service (Antwi, 2015).
Until 2011, no dialysis was regularly available for children, not even children with AKI (Antwi, 2015). After pediatric nephrologists returned from training in 2008-2009, PD for AKI was periodically, but thanks to an SYL partnership established in 2011, PD for children with AKI became regularly available (Antwi, 2015). In 2012, the PD service for AKI became available at Komfo Anokye, the second largest hospital in the country, treating 2-3 patients per month on average and dialyzing 50 patients by 2015 (Antwi, 2015; “About SKCF,” 2011). In 2015, Korle-Bu began dialyzing patients and had dialyzed 5 patients at last report (Antwi, 2015). Nothing is available for children with ESRD (Antwi, 2015). It is reported that there are plans to expand the PD program to adults in the future (“About SKCF,” 2011). Starting in 2008, transplantation became available on a limited basis at Korle-Bu in the capital (Antwi, 2015). The sole transplant surgeon is Dr. Charlotte Osafo and she had completed 17 transplants as of 2015 (Antwi, 2015). An ethics committee regulates transplantation but there is not a national transplant program, although setting one up would ideally decrease the need for maintenance dialysis (Antwi, 2015).

Health Workforce: The renal replacement services offered have been particularly dependent on personnel available, as seen in the case of PD in children and transplantation. As of 2015, there were five adult nephrologists and 2 pediatric nephrologists, up from 5 providers reported in 2000 by the Fresenius Medical Care “Africa Market Survey 2000” (Antwi, 2015; Fogazzi et al, 2003).
Medical Supplies: SKCF’s supply of PD catheters, solutions, and other consumables enabled dialysis services to become consistently available for children with AKI (Antwi, 2015). SKCF reports that these supplies were ordered from Germany (Antwi, 2015). It is unclear from where the dialysis machines and respective consumables for HD are acquired.

Information: Ghana does not have a national renal registry and the exact burden of kidney disease is unknown. It was found in one survey of hypertensive adults in Accra that the CKD prevalence was 46.9% (Antwi, 2015). Dr. Saraladevi Naicker, a South African nephrologist highly involved in renal disease in Africa, noted that there are a few screening programs “in their infancy” in a few sub-Saharan countries, one of which is Ghana (Naicker, 2009). It is unclear if she is referring to the aforementioned study.

Financing: For acute dialysis, the National Health Insurance pays up to GHC 850 (US$265), but above this price, patients have to pay (Antwi, 2015). There is no national insurance for any aspect of chronic dialysis, meaning dialysis patients have to pay out of pocket, a situation that can lead to catastrophic costs for families (Antwi, 2015). Each HD session costs GHC200 (US$65), or US$9360 annually, but some families are motivated to pay for dialysis because “most clients on chronic dialysis are the bread winners in their families and as such there is the need to keep them alive” (Antwi, 2015). In Ghana, as in much of sub-Saharan Africa, many dialysis patients only undergo dialysis twice weekly, negatively affecting their health, because of the lack of funds (Antwi, 2015). Children, on
the other hand, are considered to be unproductive, making maintenance dialysis uneconomical and unrealistic (Antwi, 2015). Transplant costs too are paid for privately (Antwi, 2015).

Leadership & Governance: Dialysis in Ghana has particularly benefitted from the leadership of Dr. Sampson Antwi, who led the implementation of the acute PD program for children at KATH (Antwi, 2015; ISN, 2016). International organizations, such as SKCF and the ISN, have consistently been involved in Ghanaian dialysis programs, while Dr. Antwi has called upon the Ghana Kidney Association and the Ghana Kidney Foundation to take the lead in renal replacement therapy discussions (Antwi, 2015).

Nigeria

Service Delivery: Renal replacement therapy is largely unavailable and inaccessible for the average Nigerian, making “the diagnosis of ESRD a death sentence” (Swanepoel et al, 2013; Odubanjo et al, 2011). In two different teaching hospitals in Nigeria, CKD accounted for 11.4% and 5.3% of the deaths on the wards largely because of inaccessibility of RRT (Odubanjo et al, 2011). Hemodialysis, which is concentrated in urban areas, is the most common modality of renal replacement therapy and few units offer PD (Odubanjo et al, 2011). For ESRD patients requiring RRT, the dialysis access rates in two studies were 22.2% and 10.9% in a third study with most ESRD patients receiving a fewer than 10 dialysis sessions total (Odubanjo et al, 2011). Dialysis access rates have increased slightly though, as a 2014 study of PD in Nigerian children found
marginally higher access rates than noted in previous studies (Odetunde et al, 2014). The authors postulated that the small, relative increase in the dialysis access rate could be due to the donated dialysis consumables and support of international organizations such as the IPNA and the ISN (Odetunde et al, 2014). PD for children has been expanded recently in Nigeria. The Pediatric Nephrology Unit of the University of Nigeria Teaching Hospital (UNTH) in Enugu, the Lagos University Teaching Hospital and University College Hospital Ibadan in Ibadan all report on their experiences with PD in children, with the latter two focusing specifically on PD for AKI (Odetunde et al, 2014, Esezobor et al, 2014, Ademola et al, 2012). Critically ill children at these hospitals are typically cared for in the “general wards rather than the intensive care unit (ICU) of the hospital; mostly due to lack of money and unavailability of ventilator support for young children” (Esezobor et al, 2014).

As of 2011, four centers offered renal transplantation: Obafemi Awolowo University Teaching Hospital (Osun State), University College Hospital (Oyo State), Aminu Kano Teaching Hospital (Kano State), and in a private hospital, the St. Nicholas Hospital (Lagos State) (Odubanjo et al, 2011; Ajayi et al, 2016). These centers are overwhelming concentrated in the southwest of Nigeria, and only the Aminu Kano Teaching Hospital (AKTH) serves the north (Odubanjo et al, 2011). Renal transplantation was first performed in 2000 in Nigeria at the St. Nicholas Hospital (Ajayi et al, 2016). Transplant centers only accept living related donors and negative cultural attitudes surrounding organ donation and cost (approximately US$35,000) blocks the expansion of
transplantation (Ajayi et al, 2016; Odubanjo et al, 2011; Swanepoel et al, 2013). Indeed, many Nigerian patients travel to India with their donor where renal transplantation is less expensive (Swanepoel et al, 2013).

Health Workforce: Nigeria, like several other sub-Saharan African nations, has benefitted from the training of nephrologists with the support of international organizations (Esezobor et al, 2014). Since there are limited specialists at hospitals, the resignation of a single nephrologist can significantly affect service provision, as it did at the Lagos University Teaching Hospital in the early 2000s (Esezobor et al, 2014). However, training support to two physicians by the IPNA and ISPD allowed PD to become “a regular service” where it had previously been “virtually non-existent” (Esezobor et al, 2014). Nigeria’s enormous population undoubtedly requires more nephrologists, pediatric and adult, and trained nurses, but it is not void of nephrologists.

Information: Nigeria does not have a renal registry, which makes it challenging to formulate preventive health policies for kidney disease and limits the availability RRT (Odubanjo et al, 2011). Although a national policy on Integrated Disease Surveillance and Response (IDSR) was implemented in 2006, it only focuses on 22 priority diseases and despite ESRD’s public health importance, it is not counted amongst these 22 diseases. There is no system for reporting renal disease at any of the three levels of government in Nigeria (Odubanjo et al, 2011). There are several independent reports on CKD in Nigeria, though, reporting a range in incidence between 1.6% and 12.4% of the
population (Odubanjo et al, 2011). The significant variation in incidence is a result of the enormous variety of data sources used to estimate incidence and differing definitions of CKD and cut-off values for GFR used (Odubanjo et al, 2011). A study by Okunola and others reported the major causes of CKD at Ladoke Akintola University Teaching Hospital (LAUTECH) in Osogbo, Nigeria (Adu, 2013) to be hypertension (38.3%), glomerulonephritis (28.8%), and diabetic nephropathy (22.2%) (Adu, 2013). These values are similar to other reports on CKD epidemiology in Africa except diabetic nephropathy is more prevalent than in previous studies (Adu, 2013). Screening programs for CKD are reportedly “in their infancy” in Nigeria (Naicker, 2009).

**Medical Supplies:** The literature consistently reports a lack of consumables in Nigeria. PD fluid was previously manufactured in Nigeria but PD was not widely utilized enough to make local production economically viable (Swanepoel et al, 2013). A Nigerian trial comparing the cost and outcomes of HD with PD using Nigerian PD fluids found outcomes were comparable but PD was cheaper (Carter et al, 2012). The cessation of local production coupled with the “non-involvement of the national government in any form of renal replacement therapy” has exacerbated the non-availability of RRT for most Nigerians (Swanepoel et al, 2013). In 2014, UNTH reported that it was looking into collaborating with a local pharmaceutical company in southeast Nigeria on local production of PD consumables (Odetunde et al, 2014). Nigerian physicians report on their experience using modified catheters in pediatric AKI patients, including intercostal drains and nasogastric tube with additional fenestrations on the distal end, finding that the
method is successful but leads to higher rates of catheter blockage and peritonitis than would be found in patients with traditional PD catheters (Esezobor et al, 2014; Ademola et al, 2012). While modified catheters were used overwhelmingly in these studies, conventional PD catheters were used when physicians returned from visiting other centers outside of the country or when provided by a benefactor (Esezobor et al, 2014; Ademola et al, 2012). In addition to non-availability, the high price of conventional catheters, cuffed or percutaneous, precluded their use, whereas modified intercostal drains reportedly cost a fraction of the price (Esezobor et al, 2014). Cuffed catheters can also be inconvenient when patients present late, as most do because of referral patterns (Esezobor et al, 2014). Commercially available PD fluid was typically used, although prices were reported to be as high as US$40 for a 2-litre bag at one point in one study (Esezobor et al, 2014). One center reported that fluids were supplied free of charge by a benefactor, although supply exhaustion was an important reason for discontinuation of dialysis (Ademola et al, 2012). Stock-out and high costs of fluid were reported to be significant barriers to PD provision at another center with PD fluids occasionally being prepared by the physicians (Esezobor et al, 2014). The breakdown of hemodialysis machines was also reported to be a major barrier to RRT access. With regards to renal transplantation, as a legal framework is being created, a well-equipped immunology laboratory is needed to ensure proper matching as presently no Nigerian laboratory can do this “confidently,” requiring most samples to be sent abroad (Ajayi et al, 2016).
Financing: the Nigerian government does not subsidize renal replacement therapy nor is it covered by the underutilized National Health Insurance Scheme or any other quality health insurance program (Odetunde et al, 2014; Odubanjo et al, 2011; Obiagwu & Abdu, 2015). The result is that AKI or ESRD treatment leads to catastrophic costs as patients must pay entirely out of pocket (Ademola et al, 2012). Even dialysis, for AKI or ESRD, at government-funded hospitals is fee-for-service, and unaffordable for the average Nigerian (Esezobor et al, 2014). Presently, since consumables must be imported, PD costs more than HD (Swanepoel et al, 2013). HD is reported to cost $155 per session in Nigeria (Adu, 2013). Insufficient funds are a major factor contributing to patients’ inability to access RRT, and when they can afford to access therapy, they can rarely afford to continue it. In one study in a Nigerian hospital, 39.1% of the 64 patients needing RRT managed to access it and the remainder were discharged or passed away without treatment (Odetunde et al, 2014). However, only one patient, who was awaiting a transplant, was able to continue therapy, while the remainder could not afford to continue it (Odetunde et al, 2014). Other studies also report tragic access rates: In another study, only 3 out of 158 patients (mean age of 49 years) could afford maintenance dialysis for over 12 months with 116 patients being discharged home after less than 10 sessions because of financial issues (Swanepoel et al, 2013; Adu, 2013). Where renal transplant is available it is unaffordable (Odubanjo et al, 2011). It is unlikely that the Nigerian government will be able to afford funding maintenance dialysis for ESRD in the near future so authors call on the government to expand the national health insurance scheme to cover PD in children with AKI (Adu, 2013; Ademola et al, 2012).
Leadership & Governance: Currently there is little government ownership of strategies to prevent or improve accessibility to treatment for kidney injury or disease but Nigerian physicians are hopeful that there will be government or donor funding one day (Odubanjo et al, 2011). Authors consistently acknowledge international organizations such as the IPNA and ISN, particularly for sponsoring the fellowship training of physicians in nephrology and dialysis (Odetunde et al, 2014). Generally there seems to be more faith in medical professionals and associations’ ability to improve the situation than in the government. Presently the Nigerian legislature is considering a National Health Bill regarding the control of blood and human tissue that would create a legal framework for organ donation and transplantation (Ajayi et al, 2016). Before this bill, there was no legal framework, leaving doctors and patients unprotected (Ajayi et al, 2016). Consequently, Nigerian hospitals used their “own internal checks,” only accepted living related donors, and typically required an affidavit prior to transplantation – the result of which was significant transplant tourism despite the high costs involved (Ajayi et al, 2016). However, with the current levels of poverty and corruption in Nigeria, authors believe that greater enforcement will be necessary to discourage illegal organ sales or harvesting (Ajayi et al, 2016). With limited government stewardship, leadership and governance of renal replacement therapy falls on civil society, medical professionals and international organizations in Nigeria.
**Senegal**

*Service Delivery:* Both PD and HD are available in Senegal, while kidney transplantation is not (Niang et al, 2014). In 2003, there were an estimated 25-30 patients on HD, 14 machines, and three providers, but renal replacement therapy is growing and in December 2010 there were reported to be 230 dialysis patients (13% on PD) (Fogazzi et al, 2003; Niang et al, 2014). As of 2014, there were six HD centers, five in Dakar, the capital, and one in Saint Louis, and 130 patients were reportedly being treated at Centre Hospitalier Universitaire (CHU) Aristide Le DANTEC in 2014 (Niang et al, 2014). Dakar and Saint Louis are both large cities located on the coast and the interior of Senegal is not serviced by HD (Niang et al, 2014). PD was started in 2004 at CHU Aristide Le DANTEC, a public hospital in Dakar (Niang et al, 2014; Cisse et al, 2012). The choice of PD or HD is driven by “financial concerns and the lack of HD centers outside of Dakar” (Niang et al, 2014). Patients are selected for PD must have running water, electricity, and their own room to carry out PD treatment (Niang et al, 2014). Between March 2004 and December 2010, 62 patients were treated with PD at Le DANTEC (Niang et al, 2014). Although over 50% of the Senegalese population lives in rural areas, the majority (61.29%) came from Dakar and its suburbs, but one patient was noted to have come from 600 km away in Tambacounda (Niang et al, 2014). Since patients are often referred late, there is no time for to properly plan for dialysis (Niang et al, 2014).
Health Workforce: The number of nephrologists in Senegal is unreported in the literature but there were reported to be six surgeons trained to place double cuff Tenckhoff catheters for PD in 2010 (Niang et al, 2014). All 62 PD patients between 2004 and 2010 were trained by the same nurse, typically as outpatients, and ultimately 87% of the patients did their exchanges alone without requiring assistance (Niang et al, 2014). In particular, training of primary care doctors are needed for timely diagnosis and referral in Senegal (Niang et al, 2014). Lack of awareness of kidney disease among frontline healthcare workers contributes significantly to late referral patterns and one of the greatest challenges to the development of a PD program is healthcare provider training (Niang et al, 2014). Notably, of the six fellowship training centers established by the ISN in sub-Saharan Africa, one is located at CHU Aristide Le DANTEC, while the remaining five are in South Africa (“Africa: Training Centres,” 2016).

Information: The studies on dialysis from Senegal focus on peritonitis in PD patients, finding high rates of culture-negative peritonitis (Niang et al, 2014; Cisse et al, 2012). No renal registry is reported but it is estimated that the incidence of CKD in Senegal is between 300 and 500 new cases per million inhabitants per year (Niang et al, 2014). Greater information on kidney injury and disease to frontline workers could serve to improve late referral patterns.

Medical Supplies: For the first three years, Baxter Healthcare’s Y-set connection system was used for PD, but Fresenius Medical Care’s system has been used since 2007.
at Le DANTEC (Niang et al, 2014). Notably, the switch resulted in greater ease of patient education, decreasing the duration of education from seven days to two (Niang et al, 2014). Main challenges in equipment and supply provision were a lack of laboratory equipment and issues with getting PD consumables to patients (Niang et al, 2014). As in other sub-Saharan African countries, a lack of laboratory facilities and supplies for proper culture technique resulted in a high culture-negative peritonitis rate (51% versus the 20% recommended by the ISPD) (Niang et al, 2014). In addition to the lack of laboratory equipment, most PD patients at Le DANTEC have problems with the transport of their PD supplies (Niang et al, 2014). This is particularly notable because the majority of the patients come from the Dakar area and one can imagine it would only be more difficult to get PD supplies to a more diffuse patient population. As other articles on PD have suggested, the authors also indicate that domestic manufacture of PD consumables might be especially beneficial if the number of PD-treated patients increased based on economies of scale (Niang et al, 2014).

**Financing:** PD is reported to cost less than HD in Senegal (Abu-Aisha & Elamin, 2010). At the start of the program, PD cost about US$1300 per month, which was comparable to the cost of HD in the public sector (Niang et al, 2014). Prior to March 2010, patients bore the entire cost of treatment unless they were state employees or had private insurance (Niang et al, 2014). Between 2004 and 2010, 37% of patients were state employees and 3% had private insurance, while the remaining patients were supported their families and paid the entire fee out of pocket (Niang et al, 2014). However, in
March 2010, the government began to cover 95% of the PD cost and 80% of the HD cost for patients, meaning PD patients now have to pay about US$70 per month (Niang et al, 2014).

**Leadership & Governance:** Government support has been instrumental in establishing Senegal well-run PD program (Niang et al, 2014). International faith in Senegal’s program is also indicated by the establishment of the ISN fellowship center at CHU Aristide Le DANTEC, while Senegalese physicians such as Dr. Mouhamadou Cisse and Dr. Abdou Niang have been consistently involved in research and publications coming out of the region (Niang et al, 2014; Cisse et al, 2012).

**Republic of the Congo (Congo - Brazzaville)**

The state of renal replacement therapy in Congo-Brazzaville is unclear as dialysis services are not reported in the literature, but a Department of Nephrology and Hemodialysis exists at the Princess Marina Hospital (Assounga et al, 2000). A study on acute renal failure in children at Brazzaville’s University Hospital between 1989 and 1994 indicated that PD was used in eight cases (7.62% of ARF) (Assounga et al, 2000). Epidemiologic data for health policy decisions are lacking and the study establishes infections as the leading cause of ARF in children at the hospital over the study period (Assounga et al, 2000). When possible, conservative management was used and PD was performed using a pediatric Tenckhoff catheter or a rigid catheter in older patients (Assounga et al, 2000). Based on this information, at the time, some dialysis was
available in Congo-Brazzaville. Extrapolating from the dialysis patterns in other sub-Saharan African countries, it is likely that in urban centers, particularly the capital, hemodialysis exists for the select few who can afford it.

**Sao Tome and Principe & Djibouti**

Dialysis is not reported in the literature for Sao Tome and Principe or Djibouti but private or public hemodialysis units may still exist in the capitols of these countries.

**Kenya**

*Service Delivery:* In 2014, the ISN reported that there were two sister renal center programs in Kenya: One at the Moi University Department of Medicine (partnership with Rhode Island Hospital – Brown Medical School) and Moi Teaching and Referral Hospital- Eldoret (Department of Nephrology Vumc-Amsterdam) (ISN, 2014). The former was started in 2010 and the latter was started in 2013 and neither had graduated as of 2014 (ISN, 2014). The literature on renal replacement therapy in Kenya is outdated. Unlike many sub-Saharan African countries, as early as 1995, HD, PD and living-related renal transplantation were all noted to be available in Kenya (Were & McLigeyo, 1995). While many Kenyans have large families from which to obtain a living-related donor, those who cannot find such a donor can make arrangements with surgeons in India (Were & McLigeyo, 1995). The Kenyatta National Hospital renal unit has been operational since 1981 and in 1984 HD became consistently available with renal transplantation.
being initiated shortly after (Were & McLigeyo, 1995). PD, which was started in 1989, was popularized when Fresenius established a local branch (Hoechst East Africa company) and sponsored a series of countrywide lectures (Lengani et al, 2010; Were & McLigeyo, 1995). In the nineties, dialysis was available for those without HIV under 55 who had transplantation as an end-goal unless they were “financially endowed,” in which case dialysis-access was less limited (Were & McLigeyo, 1995).

**Health Workforce:** Kenya undoubtedly has nephrologists and specialized nurses based on the existence of the Kenya Renal Association, a professional body for nephrologists, and the Kenya Nephrology Nurses Association, but existing literature is inadequate for the evaluation of the state of nephrology and renal replacement manpower in Kenya.

**Information:** Kenya is noted to be one of the few countries in sub-Saharan Africa to have a screening program for kidney disease, although it is in its “infancy” (Naicker, 2009).

**Medical Supplies:** It is not clear if Fresenius’ East Africa branch still exists in Kenya. Nephrologists have reportedly made concerted efforts to reduce the cost of therapy by acquiring dialysis consumables and immunosuppressive medication at reduced costs from the source and bypassing middlemen (Were & McLigeyo, 1995).
Financing: In the nineties, the Kenyan government paid for the fixed costs of dialysis such as staff salaries, purchasing and maintenance of HD machines, and water treatment (Were & McLigeyo, 1995). Consequently, at public HD centers, patients are only charged about one-third of the cost. In contrast, PD has many more variable costs than HD, which would have made PD more expensive to patients, but the government elected to charge the same amount for PD as HD (Were & McLigeyo, 1995). At the time patients were evaluated on their ability to afford the recurrent expenditures of dialysis and selected based on their socioeconomic status (Were & McLigeyo, 1995).

Nonetheless, the price of maintenance dialysis was significantly out of the price range of the average Kenyan (Were & McLigeyo, 1995). Many patients supported their dialysis through Harambee efforts, a means of “pulling together” funds from the community by holding a social event to raise funds, but the success of the Harambee depends largely on the “perceived value of the patient to society” and the patient’s connections (Were & McLigeyo, 1995). Harambee were popularized by the President Kenyatta, the first president of Kenya, and Drs. Were and McLigeyo write that Harambee system is “probably the single most important reason for the measured success renal replacement therapy enjoys in Kenya, compared to the neighboring countries which are at the same socioeconomic level” (Were & McLigeyo, 1995).

Leadership & Governance: The outdated literature makes it challenging to evaluate government ownership and investment in kidney disease and renal replacement therapy but there are at least two international partnerships established through the ISN
(ISN, 2014). As noted above, both the Kenya Renal Association and the Kenya Nephrology Nurses Association are involved in leading renal replacement efforts in Kenya. Additional information on governance and leadership could be better elucidated through government health policy documents and additional gray literature.

**Lesotho, Swaziland, & Zambia**

No articles were found on renal replacement therapy in Southern Africa for Lesotho, Swaziland or Zambia. However, it is noted that the prevalence of dialysis in relatively wealthy African countries including Swaziland “is much lower than expected from the GDP” (Abu-Aisha & Elamin, 2010). In 2012, an ISN Sister Renal Center Program was established at the University Teaching Hospital of Zambia (partnership with University of Alabama at Birmingham) and there have been studies on the epidemiology of CKD in Zambia (Stanifer, 2014).

**THE UPPER-MIDDLE INCOME LANDSCAPE**

The upper-middle income countries in sub-Saharan Africa according to the World Bank are Angola, Gabon (Central Africa), Mauritius (East Africa), Botswana, Namibia, and South Africa (Southern Africa). The literature does not describe the dialysis programs in Angola or Gabon but in 2015, Barsoum and others noted that Angola had a dialysis capacity of 23.8 pmp and 7 nephrologists, while Gabon was reported to have a
national maintenance dialysis program and a dialysis capacity of 100 pmp with 4 nephrologists (Barsoum et al, 2015).

**Mauritius**

Mauritius is reported to be one of the few countries in sub-Saharan Africa where the government provides dialysis for free or at low cost (Abu-Aisha & Elamin, 2010; Naicker, 2009). Gaya and others reported on the history of renal transplantation in Mauritius between 1980 and 1997. The presence of transplantation in Mauritius confirms that dialysis must have been available at least for patients anticipating renal transplantation. Between 1984 and 1997, transplants have consistently been performed abroad, predominantly in India (Gaya et al, 2001). Foreign transplant teams came from Bombay six times and twice from South Africa, performing a total of 48 transplantations between 1992 and 1995 (Gaya et al, 2001). Mauritian physicians between 1993 and 1997 performed transplantation locally, with 37 renal transplantations performed between 1995 and 1997 (Gaya et al, 2001). In 2000, renal transplantation was reported to be available in Mauritius although there was a shortage of organs in the absence of legislation regarding brain death (Gaya et al, 2001).
Botswana

PD programs are noted to exist in Botswana and the country is currently training nurses in acute PD (Swanepoel et al, 2013). Nonetheless, the prevalence of dialysis is lower than expected based on GDP (Abu-Aisha & Elamin, 2010).

Namibia

Similar to Botswana, the prevalence of dialysis in Namibia is lower than would be expected based on their GDP (Abu-Aisha & Elamin, 2010). It is unclear the extent to which this is a direct result of the HIV/AIDS in these countries as resources and personnel have undoubtedly been shifted to confront the epidemic in these countries.

South Africa

Service Delivery - General: South Africa has the largest, most established dialysis program in sub-Saharan Africa but while the situation is slightly less dismal, each week “two planeloads” of South Africans die because of lack of access to RRT (Abu-Aisha & Elamin, 2010; Moosa et al, 2016). The majority of South Africans with ESRD die because limited resources, both human and capital, preclude universal access (Moosa et al, 2016). Although in many other countries, there is a linear relationship between GDP and prevalent dialysis population, the prevalence of dialysis (HD and PD) is South Africa is significantly lower than would be expected based on its GDP (Abu-Aisha & Elamin, 2010). Compared to its economic peers, South Africa has lagged severely in dialysis
provision and one South African nephrologist lamented that the “declining treatment rate in our unit contrasts sharply with the steadily rising incidence of renal replacement in developed countries” (Moosa et al, 2006). It is hypothesized that this is situation is partially attributable to the burden the HIV/AIDS epidemic has placed on the health system (Moosa et al, 2016). Treatment for ESRD in South Africa is characterized by marked inequality, and the growth of the private sector contrasts starkly with the stagnancy in the public sector, where dialysis is heavily rationed.

Service Delivery- Modality Mix: PD was first reported in South Africa in the 1980s but multiple early problems stunted its growth (Raaijmakers et al, 2010). South Africa contains the vast majority (85%) of African PD patients (Swanepoel et al, 2013; Abu-Aisha & Elamin, 2010). In 2009 it was reported that about 32% of the 1170 dialysis patients were on PD in South Africa (Abu-Aisha & Elamin, 2010). Patients in the public sector do not choose their modality – it is chosen for them by healthcare providers- but despite the enormous costs of HD, fewer patients are put on PD (Okpechi et al, 2012). The growth of PD in the public sector is blocked by the rationing system, which favors HD, while the growth of PD in the private sector is discouraged by methods of funding and remuneration of physicians (Okpechi et al, 2012). There are fewer PD spaces than HD spaces available in the public sector (Okpechi et al, 2012). Peritonitis rates are perceived to be high and many nephrologists and nurses feel that reoccurring peritonitis makes PD too labor intensive (Okpechi et al, 2012). Patients in the public sector will often not be offered PD because of concerns that low socioeconomic status will lead to
peritonitis, and there is a prevalent belief that in spite of education programs, patients have a low understanding of their disease and the therapy, resulting in poor outcomes (Okpechi et al, 2012). PD availability varies from province to province and is predominantly concentrated in big cities like Cape Town, Johannesburg, Durban, Pretoria, and Port Elizabeth (Okpechi et al, 2012). Most PD patients are trained on CAPD and only patients who cannot do PD exchanges in their work environment are trained on APD (Okpechi et al, 2012). However, after publication of renal registry results in 2012, a recent National Department of Health summit of stakeholders advocated a ‘peritoneal dialysis first’ strategy with the requisite infrastructure to support this approach (Moosa et al, 2016).

Service Delivery- Private Sector Growth, Public Sector Stagnation: The public sector serves the healthcare needs of 80% of South Africa’s population, yet the number of private sector dialysis facilities has grown by 3,000% (from 5 facilities to 163) over two decades (Moosa et al, 2016). PD has not experienced the same growth in the private sector because the profit margin is smaller (Okpechi et al, 2012). In contrast to HD in the private sector there has been no meaningful HD growth in the public sector (26 facilities to 28 facilities) (Moosa et al, 2016). There are still two provinces with no public dialysis facilities and poorer patients and rural patients are underserved (Fabian et al, 2014; Moosa et al, 2016). Similar trends exist in renal transplantation as well. In 2012, 110 adult cadaveric kidney transplants were performed but only 39.1% of these transplants
(43) were in the public sector (Fabian et al, 2014). Space in the private sector is unlimited: “anyone who can pay is accommodated” (Okpechi et al, 2012).

*Service Delivery- Rationing in the Public System: ESRD treatment in the public system is defined by rationing, treatment caps, and inequity (Moosa et al, 2006). Each center has a specified number of HD and PD spots (Okpechi et al, 2012). Dialysis spots are quickly filled and only open up when a current dialysis patient undergoes transplantation (Okpechi et al, 2012). However, if the program is full, patients with ESRD needing dialysis cannot be accepted and Moosa and others showed that 52% of all ESRD patients seen between 1988 and 2003 were denied RRT at their center (Tygerberg Academic Hospital in Cape Town) (Fabian et al, 2014; Moosa et al, 2006). Nephrologists report frustration that the caps are not updated to reflect increasing CKD incidence and population growth (Fabian et al, 2014). In past years, the number of kidney transplants has progressively declined because of declining donation, meaning fewer patients are accepted for dialysis, and the low national transplant rate (4.7 pmp) illustrates the need to increase organ donation (Moosa et al, 2016; Moosa et al, 2006; Fabian et al, 2014). To increase the accessibility of RRT for South African ESRD patients under this capped system, transplantation rates need to be increased (Moosa et al, 2006).*

*Not all patients are eligible for dialysis in the public system, and if they are eligible, there are unequal rates of access. Before Medicare was extended to all patients with ESRD a similar issue of unequal access was faced in the US and social factors*
figured prominently (Moosa et al, 2006). Only patients eligible for kidney transplant are offered dialysis at low or no cost by the state (Abu-Aisha & Elamin, 2010). Although rationing has been practiced since its inception in South Africa, the National Department of Health in South Africa formalized the selection process in 1997 (Moosa et al, 2006). There is very little public awareness of the rationing process in South Africa and because no independent body reviews the medical ethics of rationing, the ethics are often somewhat center-specific (Fabian et al, 2014). Patients are assessed for treatment acceptance by assessment committees, who are comprised of the referring physician and at least one nephrologist, social worker, renal nurse and renal technologist, who report to hospital authorities, at weekly meetings (Moosa et al, 2006). It is unclear the extent to which racial discrimination still occurs in dialysis treatment acceptance today but it was clearly a pervasive practice in the recent past. At one center, white patients were almost four times more likely to be accepted for treatment than non-whites (Moosa et al, 2006). According to published renal registry reports, between 1994 and 2012, there was a “population-appropriate” change in relative representation of different ethnic groups (64% increase in black patients and 50% in decrease in white patients) (Fabian et al, 2014). Socioeconomic and medical factors are both considered, but it has been found that socioeconomic factors are more influential and nearly 60% of patients were denied RRT because of factors related to poverty (Moosa et al, 2006). The dominant medical criterion is transplantability, although there is a documented reluctance to accept diabetic patients because of observations that these patients have worse dialysis and transplantation outcomes (Figure 4) (Moosa et al, 2006). Until criteria were revised in 2009, all HIV-
positive patients were also refused dialysis (Okpechi et al, 2012). HIV-positive patients continue to not be normally offered PD though out of fear that they will not dispose of PD effluent properly, even though the use of PD is associated with reduced transmission of viruses (Okpechi et al, 2012). Social factors barring access to treatment are often associated with poverty and include” living circumstances that were unsuitable for continuous ambulatory dialysis, unemployment, lack of insight into illness, lack of education/illiteracy, criminal record, poor compliance, substance abuse, traveling difficulties” (Moosa et al, 2006). Acceptance rate of unemployed patients is low (16%) as they are seen as already burdening a struggling social security system (Moosa et al, 2006). Other factors influencing acceptance are marital status, parenthood and proximity to a dialysis center (Moosa et al, 2006). Patients most likely to be accepted for renal replacement therapy between 1988 and 2003 were 20-40 years of aged, white, employed, married, non-diabetic and close to a dialysis center, while the poor and elderly have the worst odds of being offer therapy in the selection process (Moosa et al, 2006).
Figure 4. Rationing Criteria in A South African Center


*Health Workforce:* Although South Africa still faces a healthcare worker shortage, it is less severe than in other sub-Saharan African nations, and South Africa has a comparatively higher number of nephrologists (Okpechi et al, 2012). However, looking across the Sahara, South Africa’s 1.1 nephrologists pmp is dismal in comparison to Egypt’s 6.5 pmp and Morocco’s 4.5 pmp, while the United States has 28 nephrologists...
South Africa capably trains quality medical and paramedical staff, but poor salaries, frustration with the health system and lack of opportunities often drive South African health professionals into the private sector or abroad to North America, the Middle-East, and the UK (Dirks & Levin, 2006; Moosa et al, 2006). Greater numbers need to be trained with quality retention strategies (Moosa et al, 2016). In recent years, some training programs have successfully imposed conditions that the professional must stay in South Africa (Dirks & Levin, 2006). The lack of trained staff hampers expansion of RRT and a recent summit of stakeholders suggested creating more nephrology-training posts, as well as reorganizing the staffing model at dialysis units to include more mid-level workers to address this issue (Moosa et al, 2006; Moosa et al, 2016). More surgeons and nurses also need to be trained (Moosa et al, 2016).

Nurses are central to dialysis provision, providing invaluable patient education and often performing home visits, and South Africa one center specifically attributed high rates of peritonitis to the lack of permanent nursing staff (Raaijmakers et al, 2010; Okpechi et al, 2012). Notably, South Africa has been established as the hub for ISN Fellowship training in sub-Saharan Africa, which may help the situation, and there are ISN training centers at Stellenbosch University and Tygerberg Hospital, Charlotte Maxeke Johannesburg Academic Hospital, the University of the Witwatersrand, Groote Schuur Hospital and University of Cape Town, the Red Cross War Memorial Children's Hospital, and the University of Pretoria (“Africa: Training Centres,” 2016).
Information: Unlike many other sub-Saharan African countries, South Africa has a renal registry and a summary of findings was recently published in the South African Renal Registry Annual Report 2012 with the financial support of the private sector (Fabian et al, 2014). The last time a report was published from the registry was almost 20 years earlier in 1994 (Fabian et al, 2014). Because of the rationing system, there is also a relative wealth of literature from South Africa on factors that may negatively affect dialysis outcomes, with a particular emphasis on peritonitis (Raaijmakers et al, 2010). However, it has been concluded that reliable ESRD statistics are unavailable because the registry only includes those both eligible for transplantation and accepted for dialysis, making the registry unrepresentative of ESRD in the general populace (Raaijmakers et al, 2010). As in most countries, authors report a need for further dissemination of information on kidney disease and a need to improve referral patterns, which would improve RRT preparation and minimize acute dialysis, which is how the majority of South African CKD patients present (Moosa et al, 2016).

Medical Supplies: South Africa is one of the only sub-Saharan countries that manufactures dialysis solutions locally (Abu-Aisha & Elamin, 2010). There are contradictory reports on the price of fluid from local versus foreign manufacturers and researchers do not agree on the cost-effectiveness of local production of PD fluids. Some believe there is no advantage and that the high costs of locally produced fluids needs to be examined (Swanepoel et al, 2013; Moosa et al, 2016). Others report cost savings in PD as much as US$1200 per annum per patient with locally produced fluids (Okpechi et al,
Two unmentioned advantages of local production that are unrepresented by the price tag are a more reliable supply of consumables and investment in the local economy. Local production or not, cost of disposables is noted to be one of the largest limitations to increasing dialysis in public facilities (Moosa et al, 2016). In addition to local production, South Africa is set apart from many of its African counterparts by apparently better laboratory facilities as it reports comparatively lower rates of culture-negative peritonitis (Okpechi et al, 2012).

**Financing:** In 2004, South Africa’s GDP per capita was US$3480, less than half of the annual cost of HD (US$9130) or PD (US$8319) (Moosa et al, 2006). Most, even the relatively wealthy, would find financing dialysis out-of-pocket to be unaffordable (Moosa et al, 2006). While the economy has grown, the AIDS epidemic has cost South Africa a significant proportion of their GDP (Moosa et al, 2006). South Africa has a tiered healthcare system and those who cannot pay receive treatment in public hospitals, which are government-funded, while those who can afford medical insurance, either privately or through their employment, receive treatment in private hospitals (Okpechi et al, 2012). 82% of dialysis patients in South Africa rely on the public-health system and are state-funded while 18% rely on private insurance; South Africa is one of the only countries in sub-Saharan Africa that pays for dialysis for its citizens (Moosa et al, 2006; Okpechi et al, 2012). Government funding of dialysis, albeit limited, is cited as one of the primary reasons more patients are on dialysis in South Africa than any other sub-Saharan nation (Okpechi et al, 2012). Rationing of dialysis in the public sector has been practiced
since the modality’s introduction in the seventies, with draconian budget reductions for chronic dialysis in the mid-nineties, only resulting in more stringent rationing (Moosa et al, 2006). With finite resources, the need to ration and select the most suitable patients is a reality (Moosa et al, 2006).

**Leadership & Governance:** Many nephrologists seem to be frustrated by the government’s apparent lack of interest in kidney disease in South Africa. In many regards, physicians feel helpless and call on the government to expand RRT access and reduce inequities (Moosa et al, 2016). The recent release of the renal registry reported results that were so alarming that the National Department of Health (NDoH) convened a summit to discuss CKD and South Africa (Moosa et al, 2016). The government has produced a National Development Plan-2030 that emphasizes disease prevention but clinicians “appeals…for greater access to treatment have been met with the usual refrain that resources are insufficient” (Moosa et al, 2016). In a place where access to basic healthcare and facilities like infectious diseases like HIV cause high rates of mortality and areas still lack running water, kidney disease and dialysis is not a priority in the government (Moosa et al, 2006).

**THE HIGH INCOME LANDSCAPE**

*Equatorial Guinea & the Seychelles*

The high-income countries in sub-Saharan Africa are Equatorial Guinea (Central Africa) and the Seychelles (East Africa), according to the World Bank. Neither
country had literature dedicated to the subject of renal replacement therapy or dialysis but one author, describing chronic PD in South Asia, noted that chronic PD is noted utilized in the Seychelles (Abraham et al, 2008). At a minimum, hemodialysis is likely available in private centers.

**CONCLUSION**

Dialysis and kidney disease are very costly, whether in a low-income country or a high-income one. However, a nation’s approach must reflect both the disease burden and the economic environment. Since there are challenges to determining the true kidney disease burden without registries, screening or population-wide studies in many of these countries, it may be more judicious to confront kidney disease according to the country’s income and then adjust down for the burden of infectious diseases.

In low-income and lower-middle income countries – the vast majority of sub-Saharan Africa - prevention of kidney disease’s risk factors should be a priority, in addition to improving primary care and basic infrastructure. Kidney disease itself should not be the focus. National maintenance dialysis programs should not be an immediate goal either as neither HD nor PD is affordable or cost-effective in these countries. However, the government and international donors alike must acknowledge the burden of NCDs including CKD in these countries. Chronic risk factors such as hypertension and diabetes should be prevented and treated with known, cost-effective methods. In general, the government also needs to take ownership and ensure that the costs of consumables are
no higher than necessary for all essential medical supplies by relieving import restrictions and fees (Mushi et al, 2015). Improving water and sanitation and treating infectious diseases will also lessen the burden of CKD. Treating AKI is a noble effort that can lay the groundwork for future maintenance dialysis programs, but its success relies on greater numbers of frontline health workers and improved awareness of kidney injury and disease amongst these workers. To aid these workers and improve referral patterns, simple diagnostic checklists and tests for AKI and CKD need to be devised. In short, creating a knowledgeable primary care workforce should be a priority in low and lower-middle income countries. In addition to these efforts, centers of excellence in nephrology should be established with support from international organizations like the ISN as kidney disease will always be relegated to the shadows if there is no treatment available anywhere in the country (Barsoum et al, 2015). The emphasis should be on quality of treatment, as high rates of morbidity and mortality will deter patients and discourage health providers (Niang et al, 2014). Since transplantation is ultimately the most cost-effective approach to treating ESRD, the legal framework for organ donation and transplantation should be established and the notion of organ donation popularized for the future.

In upper-middle income and high income countries, the aforementioned measures should be pursued in addition to maintenance dialysis for citizens with ESRD with a concurrent renal registry. Dialysis is cost-effective for upper-middle income countries and “should definitely be included in the basic health care package” (Mushi et al, 2015).
As the most cost-effective solution, transplantation should be pursued as the first choice of treatment, followed by a “PD-first” policy (Barsoum et al, 2015). Countries should note though that PD is only more cost-effective than HD when it is utilized on a large scale and when variable costs are reduced. Strong, continual patient and health worker education and home-visits should help produce quality results (Nayak et al, 2012). In order to provide maintenance dialysis, functioning laboratories, a national funding source and sufficient manpower, including nurses, nutritionists, and physicians, must be in place.

CKD is not a burden exclusive to high-income countries but despite the burden kidney disease places on the economy, maintenance dialysis is not affordable in most sub-Saharan countries (Stanifer et al, 2014; Barsoum et al, 2015). Improving primary care and basic infrastructure should be paramount. CKD and dialysis should be subordinated within health systems strengthening and integrated into prevention and treatment programs of the WHO priority NCDs (CVD, cancer, diabetes and COPD).
REFERENCES


CURRICULUM VITAE

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EDUCATION

Boston University, Boston, MA
- Masters of Science in Medical Science, Masters of Public Health in Global Health

University of Pennsylvania, Philadelphia, PA
- Bachelor of Arts in Health & Societies with a Concentration in Global Health

HONORS, AWARDS & PUBLICATIONS

Robert F. Troxler Award in Biochemistry, Boston University
- Awarded to graduate student with highest grade in biochemistry

Presenter at WA-OR Chapter of the American College of Surgeons Meeting, ACS
- Selected for Extreme AV Grafts with surgeries performed by Dr. Swee Lian Tan, MD PhD FACS

Presenter at 98th Annual American College of Surgeons Clinical Congress, ACS
- Selected for Two Totally Laparoscopic Lumbar Sympathectomies with surgeries performed by Dr. Swee Lian Tan, MD PhD FACS


PROFESSIONAL EXPERIENCE

Boston University: Boston, MA, Graduate Biochemistry Tutor
- Tutored graduate students weekly in biochemistry concepts

SightLife: Seattle, WA, Distribution Technician
- Coordinated distribution of human eye tissue for transplant locally and internationally
- Communicated daily with domestic and international surgeons to ensure corneal tissue met their criteria
- Maximized tissue placement efficiency so that fluctuating donor volume matched recipient volume
- Evaluated quality of donor tissue by specular microscopy and other lab techniques
- Developed training program and materials for incoming SightLife employees in surgical services department

Vascular & Surgical Care Northwest: Seattle, WA, Medical Assistant
- Prepared patients’ charts for clinic, identified and gathered all relevant tests, and input patient data into EHR
- Communicated with PCPs, dialysis centers, skilled nursing facilities, et cetera to ensure coordination of care
- Checked patients in, scheduled appointments, took vitals, and updated patients’ medications and insurance
- Performed dressing changes and assisted with office procedures (angioplasties and endovenous ablation)
- Write and edit abstracts and videos for submission at various surgical conferences (October 2012 to present)

Nurturing Orphans of AIDS for Humanity: New York, NY, Intern
- Updated social media and edited monitoring and evaluation research paper for submission
- Performed various administrative duties and assisted with fundraisers and conferences
- Created poster presentation for the Children Hospital of Pennsylvania’s 5th Annual Global Health Symposium

UPenn Biology Labs: Philadelphia, PA, Research Assistant
- Extracted, replicated, and sequenced DNA and conducted ELISAs for antibody identification
- Conducted experiments on mice related to Lyme disease vaccine effectiveness and Borrelia burgdorferi strain competition and synthesized and interpreted experimental data using R
- Reviewed manuscript Borrelia burgdorferi sensu lato infecting ticks of the Ixodes ricinus complex in Uruguay: first report for the southern hemisphere for publication in Vector-Borne and Zoonotic Diseases

VOLUNTEER EXPERIENCE

Rosie’s Place: Boston, MA, ESL Teacher
- Prepare engaging and clear lesson plans for level 1 ESL classes
- Teach English twice a week to women of all language-backgrounds in the community
- Provided basic care and entertainment for inpatients disabled by chronic diseases such as ALS and AIDS
- Organized outpatient activities and assisted with outpatient meal service

Student Run Emergency Housing Unit: Philadelphia, PA, Shelter Volunteer November 2011 - May 2012
- Coordinated meals and shelter responsibilities for 30 men
- Supervised the 30 shelter inhabitants overnight with other university students

Global Medical Brigades: Honduras, Interpreter January 2009 - April 2009
- Worked as an interpreter for the doctors and a mediator between the community and our brigade
- Organized and distributed medicine in the makeshift pharmacy and took vitals in 5 rural communities

PERSONAL EXPERIENCE
Language Skills: Professional Spanish, Basic French
Computer Skills: Adept with Microsoft Office, Adobe Suite, Final Cut Pro, R
Activities: Penn Varsity Track & Field (Fall 2009-Winter 2010), Penn Club Soccer (Fall 2008-Spring 2012)