2021

Grounds for a New Normal: Integration of Telenephrology in Rural Communities

Carolyn J. Mattson
Seattle University

Grounds for a New Normal; Integration of Telenephrology in Rural Communities

Carolyn J. Mattson

A DNP project submitted in partial fulfillment of the

requirements for the degree of

Doctor of Nursing Practice

Seattle University

2021

Approved by: Diane Fuller Switzer Date March 30, 2021
DNP Faculty Mentor: Dr. Diane Fuller Switzer, DNP, ARNP, FNP/ENP-BC, ENP-C, FAEN

Approved by: Benjamin J Miller Date March 30, 2021
DNP Faculty Reader: Dr. Benjamin Miller, Ph.D., ARNP, FNP-C, ACNPC, ENP-C, FAANP

Whatever you can do, or dream you can, begin it.

Boldness has genius, power, and magic in it.

- Johann Wolfgang von Goethe

Acknowledgements

The author would like to acknowledge and thank all the frontline and behind the scenes healthcare professionals for routinely putting the needs of others before their own during the COVID-19 pandemic.

This study would not have been possible without the unwavering support and encouragement from my DNP faculty, colleagues, family, and husband. You all have been a tremendous help and I cannot thank you enough.

Abstract

Patients with kidney disease represent a group of people who are known to have comorbidities, high costs of care, decreased quality of life, and invasive interventions. In rural communities of Western Washington State, many nephrology patients experience factors evidenced to impede access to quality and timely management of their disease, compounding the risk for poor outcomes. Telenephrology is a novel modality of service delivery with the potential to make care more efficient, cost-effective, flexible, and accessible. The author created this project to develop a telenephrology program plan and evaluation for rural settings in Western Washington, informed by relevant epidemiology, pathophysiology, standards of care, and evidence in the literature. As there are a paucity of program plans specific to this service delivery in rural Western Washington, development of this project aims to substantiate the need for evidence-based implementation in this setting. The appraisal of barriers to care for this patient population was used to guide aspects of telenephrology program planning and evaluation to ensure intervention outcomes are equitable. This project provides grounds to support the adoption a *new normal* for nephrology care and utilizes the existing evidence to inform the planning and evaluating of telenephrology services, implementation processes, budget, and outcomes to assist healthcare providers and their institutions in successful integration of telenephrology in rural communities of Western Washington State.

Table of Contents

Grounds for a New Normal; Integration of Telenephrology in Rural Communities

Nephrology patients constitute a group of people who often have comorbidities, decreased quality of life, and an acquired need for frequent, costly, and invasive interventions that equate to an annual Medicare cost of $84 billion for the syndrome of chronic kidney disease (CKD) alone (Agarwal, 2020; Centers for Disease Control and Prevention [CDC], 2019; Colbert, Venegas-Vera & Lerma, 2020; Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020). When patients progress to renal failure, also known as end-stage renal disease (ESRD), the burden on patients and healthcare cost multiplies. ESRD management requires frequent laborious interventions that cost around $56,300 more per patient per year than CKD (CDC, 2019). At the onset of the COVID-19 (coronavirus disease-2019) pandemic, the United States' healthcare systems became abruptly aware of populations that were especially vulnerable to the consequences of SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) infection. Due to the intensive nature of nephrology care and immunodeficiency resulting from renal damage, patients with kidney disease are posed to be disproportionately impacted by COVID-19 as well as the ensuing policy changes (Agarwal, 2020; Colbert, Venegas-Vera & Lerma, 2020; Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020).

In rural settings, this baseline risk can be compounded by factors evidenced to impede access to quality and timely management of disease (Agarwal, 2020; Colbert, Venegas-Vera & Lerma, 2020; Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020; Osman *et al*., 2017; Washington State Department of Health [WDOH], 2017). For rural communities in Western Washington State, data illustrate these areas characteristically have underdeveloped public transportation, substantial distance between patients and their specialty care facilities, and a relatively high prevalence of social and economic risk factors (Agarwal, 2020; clinician, personal communication, May 4, 2020; Colbert, Venegas-Vera & Lerma, 2020; Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020; Osman *et al*., 2017; WDOH, 2017; WDOH, 2019).

While the necessary social distancing precautions brought on by the COVID-19 pandemic created challenges to healthcare delivery, it simultaneously made widespread adoption of virtual care services possible in quick succession (Agarwal, 2020; Jain, Ahmad & Wallace, 2020; clinician, personal communication, May 4, 2020). *Telenephrology*, the application of telehealth modalities in the field of nephrology, was widely adopted at an unprecedented rate as a provisional solution to mitigate risk of patient and provider SARS-CoV-2 exposure (Agarwal, 2020; Jain, Ahmad & Wallace, 2020; White & Kribs, 2020). However, in making these services *the new normal* beyond the pandemic paradigm, there is potential to address critical healthcare access barriers - both geographical and socio-economic - that are characteristic of nephrology patients living in rural Western Washington (Agarwal, 2020; Ishani *et al*., 2016; Jain, Ahmad & Wallace, 2020; Osman *et al*., 2017; Rohatgi, Ross & Majoni, 2017; WDOH, 2017; WDOH, 2019; White & Kribs, 2020). This project seeks to substantiate the need for continued use of telenephrology services and provide a program plan as a resource for further development and implementation of telenephrology in rural communities of Western Washington.

Background and Significance

Kidney Disease

Globally, nationally, and regionally, kidney disease poses a significant burden on both patients and healthcare systems. Kidney disease is the ninth leading cause of death in the United States, with an estimate of 37 million Americans living with chronic kidney disease (CKD) (CDC, 2017; CDC, 2019; United States Renal Data System [USRDS], 2020). CKD is defined as a reduction in function or kidney damage that has been present for at least three months (CDC, 2019; Kochanek et al., 2019; Villarroel, Blackwell & Jen, 2018). Unfortunately, due to the insidious nature of kidney diseases, nine out of ten adults with CKD do not know they have it (CDC, 2019). Whether a formal diagnosis has been given or not, CKD leads to $84 billion in annual Medicare Costs, while progression to end stage renal disease (ESRD) costs $36 billion (CDC, 2019).

Nearly 786,000 people in the U.S. are living with ESRD, with 71 percent relying on dialysis and 29 percent having received a kidney transplant (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020; USRDS, 2020). For adults, ESRD is largely caused by diabetes and high blood pressure while ESRD in those 18 years and younger is mainly caused by polycystic kidney disease and glomerulonephritis (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020; CDC, 2019; USRDS, 2020). Ultimately, the financial burden of advancing to renal failure equates to more costly management of disease with an annual Medicare spending of $80,000 per patient while CKD costs $23,700 per person (CDC, 2019).

Nationally, kidney diseases (nephritis, nephrotic syndrome, and nephrosis) are responsible for 15.7 per 100,000 deaths (CDC, 2019; USRDS, 2020). Due to the consequences of CKD, diseases affecting other organ systems are often accelerated, resulting in untimely death (CDC, 2020; Norman, 2020; USRDS, 2020). Patients with CKD are at increased risk for heart disease, heart failure, stroke, and early all-cause death, all of which make tracking the mortality burden of kidney disease difficult (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020; CDC, 2020; USRDS, 2020). For instance, people with an estimated glomerular filtration rate (eGFR) of 15 to 59 and macroalbuminuria experience cardiovascular mortality at a rate of 41 per 1,000 patient-years, while people with a normal eGFR and no albuminuria are at a rate of 5 per 1,000 patient-years (CDC, 2017; USRDS, 2020).

In Washington State, kidney disease mortality accounts for 4.8 per 100,000 of all cause deaths (CDC, 2020). Approximately, 15 to 20 per 100 people in the Western regions of the state are living with CKD while around 1,600 per million state residents are known to have ESRD (CDC, 2019). In conjunction, Washington's diabetes mellitus prevalence is about one in eight adults with 20-40% of them not receiving recommended preventive medical services (WDOH, 2019). This is important to note as people with diabetes are 4.6 times as likely than the general population to develop kidney disease (CDC, 2019; WDOH, 2019). Rural areas in the Western region of the state have some of the highest rates of diabetes mellitus with 10.6% to 12.5% of adults having been diagnosed (WDOH, 2019).

Kidney disease imposes significant morbidity and its effect on health and quality of life becomes more severe as renal dysfunction advances (Alhamad, Cheng, & Vijayan, 2021; CDC, 2019; Mandal, 2014; Norman, 2020; USRDS, 2020). As kidney disease worsens, incidence of health problems like anemia, fluid overload, weakened immune system, loss of appetite, sexual dysfunction, sleep disturbance, confusion, depression, and electrolyte imbalances increase (CDC, 2020; USRDS, 2020). In turn, these health problems can lead to serious consequences for patients, communities, and health systems (CDC, 2017; Mandal, 2014; Norman, 2020; USRDS, 2020). Across the lifespan, U.S. statistics show that worsening of kidney disease is associated with worsening physical disability that progressively impairs the ability to maintain activities of daily living, leisure and social activities, and the ability to work (CDC, 2017; USRDS, 2020). In addition to physical impairments, advancement of renal dysfunction is associated with lower levels of performance in tasks that require cognitive function, even when adjusted for age (CDC, 2017). For older adults in the U.S., self-reported disabilities in concentrating, doing errands alone, dressing and bathing, hearing, and seeing increase as kidney function decreases (CDC, 2017).

Consequently, patients with kidney disease frequently interact with healthcare systems, encounter substantial financial requirements for interventions and challenging care-plan decisions that require considerable medical literacy about their disease (Kiousi & Grapsa, 2015; Molzahn, Bruce & Sheilds, 2008; Perlman *et al*., 2004). Patients with CKD have been measured to have lower quality of life (QOL) compared to the general population as a result, while patients who have progressed to ESRD and require renal replacement therapy have even lower QOL measures and increased healthcare costs (Molzahn, Bruce & Shields, 2008; Perlman *et al*., 2004).

End-Stage Renal Disease

While not everyone with CKD progresses to kidney failure, reaching an end-stage of renal function is inevitably fatal without intervention (Alhamad, Cheng, & Vijayan, 2021; National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 2017; Norman, 2020). When patients reach 15 percent or less of normal kidney function, buildup of bodily waste products and fluid poses the need to consider different management strategies (Alhamad, Cheng, & Vijayan, 2021; NIDDK, 2017). Traditionally, at this stage of kidney disease, hemodialysis (HD), peritoneal dialysis (PD), or kidney transplant become the mainstays of treatment (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Bleyer, 2020; NIDDK, 2017). Depending on the patient's goals of care, conservative, supportive, or palliative care may be appropriate management strategies as dialysis and transplant interventions are notably invasive and costly (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Mandal, 2014).

In ESRD, patients will begin to develop *uremic symptoms* because of accumulating waste products and fluid in the body (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020; Norman, 2020). This results in patients experiencing; nausea, vomiting, lethargy, pruritis, impaired cognitive function, a metallic after-taste, edema, motor neuropathies and pericarditis (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). When the kidneys can no longer maintain their physiological function, dialysis can act as a replacement to clear uremic substances, adjust serum electrolytes and remove accumulation of fluid (Alhamad, Cheng, & Vijayan, 2021; NIDDK, 2017; Norman, 2020). While the advent of renal replacement therapy has served as a viable life-sustaining intervention, compared to the general population, dialysis users have a seven to eight times higher mortality rate, necessitating every effort be made to preserve kidney function (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; Mandal, 2014; USRDS, 2020).

Hemodialysis

Hemodialysis is the most common form of renal replacement therapy (RRT) in the United States, with over 430,000 ESRD patients relying on this treatment (Alhamad, Cheng, & Vijayan, 2021; Burkart, 2019; CDC, 2017; USRDS, 2020). The largest group of HD users fall between the ages of 45 and 64 years old as younger patients are more likely to utilize PD or receive a kidney transplant (Alhamad, Cheng, & Vijayan, 2021; USRDS, 2020). The population using HD is predominantly white (56 percent) and male (57 percent), with 37 percent of HD users being Black and 5 percent being Asian (Alhamad, Cheng, & Vijayan, 2021). When patients have reached ESRD, mortality rates increase dramatically with a 63 percent probability of death for non-diabetics within five years of initiating HD and 71 percent for those with diabetes (Alhamad, Cheng, & Vijayan, 2021).

To begin maintenance HD, effective *dialysis access*, or system for blood delivery between the patient and machine, must be established (Alhamad, Cheng, & Vijayan, 2021; NIDDK, 2017; Schmidt, 2020). Three types of HD access exist: arteriovenous fistulas (AVF), arteriovenous grafts (AVG), and dialysis catheters (Alhamad, Cheng, & Vijayan, 2021; NIDDK, 2017; Norman, 2020). AVF, the most desirable form of access, and AVG, act as conduits where they are cannulated by two needles; one being for collection of arterial blood flow that will be dialyzed through a machine and the other being for return of blood into the venous system (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [1]; Schmidt, 2020). To establish AVF access, patients will need to go under regional anesthesia to have surgical manipulation of the patient's native vasculature (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [1]). This process involves interprofessional planning and a waiting period of three to four months after placement so the fistula can mature to withstand flow from large bore needles (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [1]). This procedure is not without risk, as complications like thrombosis, infection and vascular steal can occur (Alhamad, Cheng, & Vijayan, 2021). While AVF is preferred due to having lower rates of complications and higher potential for long-term patency, it is not uncommon for patients to undergo trials and failure of AVF in multiple sites due to a lack of healthy vasculature (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [1]).

If AVF access cannot be established, placement of a synthetic graft for AVG access can be used to bypass the need for healthy native vasculature (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [2]). The advantages of AVG include a large surface area for cannulations and a shorter maturation time of 2 to 3 weeks which allows for earlier dialysis use in time-sensitive situations (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [2]). While AVG access can act as a good alternative or a starting off procedure for earlier access to renal replacement therapy, the graft only has an average lifespan of about two years (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [2]).

As a last resort for HD access, a catheter can be placed, typically in the right internal jugular vein and looped to exit just below the ipsilateral clavicle (Alhamad, Cheng, & Vijayan, 2021). This form of HD access is least desirable as there is significant risk for infection, catheter dysfunction, difficulties with recirculation and variable success sustaining adequate flow (Alhamad, Cheng, & Vijayan, 2021).

Using patient preference, resources, and capabilities as a guide, a modality of HD is selected. This involves careful consideration of patient distance from the facility, independence, schedule, and capacity to sustain cumulative dialysis dosing (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Norman, 2020; Qunibi, 2020). *Intermittent In-center* HD is the most common modality which involves the patient receiving dialysis at a facility two to three times per week with each session being about 3 to 4 hours in duration (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020). This modality is especially popular among new HD users as dialysis facilities have trained staff to set up and supervise each treatment in a controlled environment (Alhamad, Cheng, & Vijayan, 2021). *Short Daily* HD is an alternative modality where patients have shorter durations of dialysis but need to receive more frequent treatments, typically six days per week, to achieve an adequate cumulative dialysis dose (Alhamad, Cheng, & Vijayan, 2021; Qunibi, 2020). This modality is typically performed at home, but some dialysis facilities can accommodate to provide this service (Alhamad, Cheng, & Vijayan, 2021). By dividing treatments into more frequent and shorter intervals, patients can often avoid intradialytic complications like hypotension and cramping (Alhamad, Cheng, & Vijayan, 2021; Qunibi, 2020). However, the drawbacks of sustaining daily treatments and increased risk for vascular complications are worth consideration (Alhamad, Cheng, & Vijayan, 2021; Allon, 2021 [1]; Allon, 2021 [2]; Burkart, 2019). The last modality, *Nocturnal* HD, involves a larger cumulative dialysis dose where patient receive an average of 6 to 8 hours of treatment nightly about six times per week (Alhamad, Cheng, & Vijayan, 2021; Qunibi, 2020). This modality can also be performed at home, allowing patients more freedom during the day, although it, like Short Daily HD, has the concern for burden of daily treatments and increased risk for vascular complications (Alhamad, Cheng, & Vijayan, 2021; Mailloux & Blagg, 2016).

Only three percent of RRT is achieved through home hemodialysis (HHD) in the U.S. (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; Mailloux & Blagg, 2016; USRDS, 2020). The small proportion of HHD users is largely due to the Social Security Act of 1972 that allowed for a rapid expansion of outpatient dialysis centers (Alhamad, Cheng, & Vijayan, 2021; Mailloux & Blagg, 2016). Along with improved patient satisfaction and QOL, the capacity to do more frequent sessions of dialysis and eliminate two-day interdialytic gaps provides measurable benefits in patient outcomes (Alhamad, Cheng, & Vijayan, 2021; Burkart, 2019; Mailloux & Blagg, 2016). HHD is a form of RRT that offers potential to achieve patient-centered care (Alhamad, Cheng, & Vijayan, 2021; Burkart, 2019; Mailloux & Blagg, 2016). However, there are stipulations worthy of consideration to ensure success of this therapy. With all home-based RRTs, patients and their caregivers need to be highly motivated and adequately prepared for the responsibility of independently managing their interventions (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Mailloux & Blagg, 2016; NIDDK, 2017). The Food and Drug Administration (FDA) require that patients (and their caregivers when indicated) complete roughly twenty HHD training sessions prior to initiation (Alhamad, Cheng, & Vijayan, 2021). Additionally, home water supply for safe dialyzing is critical and requires water testing prior to use of HHD machines (Alhamad, Cheng, & Vijayan, 2021). Ensuring patients and their support systems are informed on the cost of dialysis prescriptions and the need to maintain sterile technique is essential to HHD safety and success (Alhamad, Cheng, & Vijayan, 2021; Mailloux & Blagg, 2016; Schmidt, 2020). While HHD offers the convenience of completing RRT without frequent visits to dialysis centers, clinical monitoring of the patient's dialysis access site, blood pressure, symptoms, and dialysate saturation are still necessary aspects of care (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Mailloux & Blagg, 2016; Schmidt, 2020).

Peritoneal Dialysis

PD is a form of RRT that utilizes the patient's peritoneal membrane and its associated capillaries as a semipermeable membrane to sustain an equilibrium of solutes between the blood and the peritoneal space where dialysis solution is infused (Alhamad, Cheng, & Vijayan, 2021). PD is a sustainable and patient-centered form of RRT that is more affordable, requires fewer hospitalizations, fewer vascular complications and has greater patient satisfaction than in-center HD (Alhamad, Cheng, & Vijayan, 2021; Burkart, 2019; Pirkle, 2019). However, less than 15 percent of dialysis patients in the U.S. are enrolled in this form of RRT (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Pirkle, 2019; USRDS, 2020). Patient selection for PD involves careful assessment for relative and absolute contraindications. Generally, patients who are good candidates for PD are highly motivated, independent, and capable of performing regular home-based treatments, seven days a week (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). While PD allows for flexibility in schedules and is more conducive to work or travel, certain physiologic factors may bar patients from this option. Factors like recent or frequent intra-abdominal surgeries, uncorrectable abdominal defects, frequent intra-abdominal infections, adhesions, and abdominal wall cellulitis are contraindications to PD (Alhamad, Cheng, & Vijayan, 2021; Burkart, 2019; Pirkle, 2019).

To initiate PD, a silastic intraperitoneal catheter is placed either laparoscopically or percutaneously under ultrasound guidance (Alhamad, Cheng, & Vijayan, 2021). These catheters can be used immediately after placement, although a waiting period of ten to 28 days is preferred to allow for healing (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). Like HD, PD has modality options to choose from depending on the patient's peritoneal membrane type which is determined by a peritoneal equilibration test (Alhamad, Cheng, & Vijayan, 2021). High transport membranes are suited for short, repeated dwells while low transport membranes are better suited for long, evenly spaced dwells of *continuous ambulatory peritoneal dialysis* (CAPD) (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). CAPD is a manual type of exchange where dwell times range from six to eight hours (Alhamad, Cheng, & Vijayan, 2021). Patients using PD dialysis are typically taught CAPD when they initiate treatment as the knowledge and ability to perform this manual type of dialysis becomes critical should there be a power outage or machine malfunction (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). Depending on resources, patients can then opt for automated PD exchanges or *continuous cycling peritoneal dialysis* (CCPD). Although the nomenclature implies continuous exchanges, unlike CAPD, the continuous cycling refers to around the clock solute transfer following roughly three short cycles of dialysis overnight (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). Depending on the patient's membrane type, an extra daytime exchange of manual CAPD may be necessary (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019).

While PD functions as a viable form of RRT, it is not without complications. Characteristically, patients on PD are at increased risk for peritonitis, catheter site infections, outflow failure (from constipation, catheter migration, catheter kinking, adhesion formation, omental wrapping or fibrin plugging), back pain, hernias, fluid leaking, sclerosing encapsulating peritonitis, hyperglycemia, hyperlipidemia, malnutrition, and hypokalemia (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019). The inability to resolve these complications, along with failure to achieve adequate therapy targets and inadequate fluid removal, may necessitate a permanent switch to HD (Alhamad, Cheng, & Vijayan, 2021).

Risk Factors for ESRD

The renal system both influences and is influenced by a myriad of risk factors (CDC, 2019; Norman, 2020; Kiousi & Grapsa, 2015). The kidney is intricately bound to the homeostasis of nearly every other organ system creating a loop of cause and effect that is heavily influenced by social and economic factors (Alhamad, Cheng, & Vijayan, 2021; CDC, 2019; Kiousi & Grapsa, 2015; Norman, 2020; USRDS, 2020). Kidney diseases have been shown to affect males, those who are 65 years and older, obese, of lower socioeconomic status, and non-white persons at much higher rates and severity than their counterparts (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; CDC, 2019; USRDS, 2020).

While CKD is diagnosed with objective and mathematical measures, it is an ongoing, cyclical process of renal injury and compensatory hyperfiltration (Norman, 2020). Healthy nephrons (functional unit of the kidney) compensate net filtration for damaged nephrons and in turn sustain destruction from the offset (Norman, 2020). If left untreated, this process progressively causes destruction to the kidneys and other organs (Alhamad, Cheng, & Vijayan, 2021; Kiousi & Grapsa, 2015; Norman, 2020).

The pathophysiology of CKD largely depends on the underlying cause (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). Development of CKD and progression to ESRD is most commonly caused and exacerbated by diabetes and hypertension (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; CDC, 2019; Kiousi & Grapsa, 2015). Both Type 1 and Type 2 diabetes cause a distinct form of CKD referred to as diabetic nephropathy (DN), often manifesting as albuminuria and hyperfiltration in earlier stages (Alhamad, Cheng, & Vijayan, 2021; Kiousi & Grapsa, 2015). While the exact pathophysiologic processes of DN are unknown, it is postulated that hyperglycemia inflicts end-organ damage to the kidneys, causing glomerular damage and thickening of the basement membrane, afferent & efferent arterioles (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). Hypertensive nephropathy is known to induce kidney injury through a variety of mechanisms. The distinctive overactivity of the sympathetic system in hypertension leads to decreased outflow from the glomerulus of the nephron through constriction of the efferent arteriole (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). This process leads to increased oncotic pressure in the nephron resulting in injury (Norman, 2020). In a cyclical fashion, arterial stiffness and subsequent impaired salt and water excretion increase blood pressure and further kidney injury (Norman, 2020). Other causes of kidney injury and risk for subsequent CKD include immune complex deposition, genetic etiologies, and interstitial damage from nephrotoxic agents (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020).

Diabetes accounts for forty-four percent of ESRD cases while hypertension accounts for twenty-nine percent (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; CDC, 2019; USRDS, 2020). The development of DN before or after progression to ESRD imparts significant increases in morbidity and mortality, causing a 50 percent higher risk for mortality in those initiating dialysis (Alhamad, Cheng, & Vijayan, 2021). Moreover, diabetes and hypertension frequently occur together, causing an additive deleterious effect on renal health (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). Other causes of ESRD include glomerulonephritis, interstitial nephritis, autosomal dominant polycystic kidney disease, and collagen vascular disease (Alhamad, Cheng, & Vijayan, 2021; Norman, 2020). For all racial groups, cases of diabetes caused ESRD increase with age (Norman, 2020). However, there are dramatic racial disparities of ESRD prevalence, with non-white patients being four times more likely to require dialysis (Norman, 2020; USRDS, 2020). When compared to their white counterparts, prevalence is 9.5 times greater in Native Hawaiians/Pacific Islanders, 3.7 times greater in African Americans, 1.5 times greater in American Indians/Alaska Natives, and 1.3 times greater in Asian Americans (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; Norman, 2020, USRDS, 2020). While genetic factors, like the APOL1 gene in African Americans, are known to increase risk for kidney disease, socioeconomic factors play a major role in contributing to racial disparity (Alhamad, Cheng, & Vijayan, 2021; CDC, 2017; CDC, 2019; Norman, 2020).

Geographical distance from healthcare facilities and specialty nephrology care is another factor that has been shown to impede access and be associated with worse outcomes (Batsis *et al.*, 2019; Osman *et al.*, 2017). Patients with kidney disease who live substantial distances from a nephrology practice are more likely to have missed appointments and receive less treatment compared to those that live closer (Koraishy & Rohatgi, 2020). Consequently, these geographically isolated patients are also more likely to be hospitalized and experience mortality at higher rates (Koraishy & Rohatgi, 2020). Furthermore, for those initiating dialysis, adjusted death rates have been found to be significantly higher in those living further away from their nephrology clinic (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017).

Given the success of interventions proven to slow the progression of kidney disease and prevent its many complications, early identification of disease and proactive management is paramount to achieve better health outcomes (Alhamad, Cheng, & Vijayan, 2021; Kiousi & Grapsa, 2015; Shlipak *et al.*, 2021). However, in these high-risk groups, social factors often make accessing adequate care challenging, laying a framework for disparities in prevalence and severity (Kiousi & Grapsa, 2015; Norman, 2020; Shlipak *et al.*, 2021).

Standards of Care for End-Stage Renal Disease

The burden of kidney disease on both patients and healthcare systems is largely preventable. Through adequate preventive healthcare, appropriate management of comorbidities, early identification of disease and proactive care, the impact of renal disease could be ameliorated (Alhamad, Cheng, & Vijayan, 2021; CDC, 2019; Hirano *et al.,* 2019; Kiousi & Grapsa, 2015; Mandal, 2014; Shlipak *et al.*, 2021). While there is a significant body of evidence available to guide practice in the care of nephrology patients, renal syndromes are exceedingly complex and seldom have a sole effect on the kidney. This, along with trait risk factors, often create a necessity for interprofessional involvement and acknowledgement of socioeconomic impacts to individualize management and achieve standard of care (Hirano *et al.,* 2019; Mandal, 2014; Shlipak *et al.*, 2021; Zuniga *et al.*, 2020).

Chronic kidney disease is progressive in nature, where damage to kidney tissue causes permanent scaring and loss of function over time (CDC, 2019; NIDDK, 2017). Interventions prior to and following diagnosis of CKD largely dictate the rate and severity of progression to ESRD, making access to evidence-based care vital (Hirano *et al.,* 2019; Levin *et al.*, 2013; Mandal, 2014; Shlipak *et al.*, 2021). Early detection of CKD and referral to specialized nephrology care have been shown to improve outcomes and reduce costs of care, making screening a pivotal aspect of renal health (Hirano *et al.,* 2019; Levin *et al.*, 2013; Shlipak *et al.*, 2021).

KDIGO (Kidney Disease Improving Global Outcomes) guidelines offer an evidence-based algorithm that urges health care professionals to screen high-risk groups regularly, using urinary albumin-creatinine ratio (ACR) and eGFR (estimated glomerular filtration rate) in a distribution that is tailored to the community risk and demographics (Levin *et al.*, 2013; Shlipak *et al.*, 2021). Using eGFR and ACR values, patients are assigned to a stage of CKD, allowing for risk stratification and guidance of therapy (Levin *et al.*, 2013). KDIGO guidelines also recommend evaluation for other CKD criteria including urine sediment abnormalities, electrolyte imbalance, histological findings and structural abnormalities as indicated (Levin *et al.*, 2013). Through patient findings and history, a cause for CKD should be established to best guide therapy (Hirano *et al.,* 2019; Levin *et al.*, 2013). Following diagnosis, the frequency of measuring serum creatinine (sCr) to calculate eGFR will determine the confidence in assessing the rate of progression (Levin *et al.*, 2013). See Figure 1 for KDIGO guidelines on staging and frequency of monitoring.

Figure 1

Kidney Disease Improving Global Outcomes Guidelines for Chronic Kidney Disease Staging & Frequency of Monitoring

Guide to Frequency of Monitoring (number of times per year) by GFR and Albuminuria Category				Persistent albuminuria categories Description and range		
				A1	A2	A3
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30–300 mg/g 3–30 mg/mmol	>300 mg/g >30mg/mmol
GFR categories (ml/min/1.73 m^2) Description and range	G1	Normal or high	≥90	1 if CKD	1	2
	G2	Mildly decreased	60–89	1 if CKD	1	2
	G3a	Mildly to moderately decreased	45–59	1	2	3
	G3b	Moderately to severely decreased	30–44	2	3	3
	G4	Severely decreased	15–29	3	3	4+
	G5	Kidney failure	<15	4+	4+	4+

GFR and albuminuria grid to reflect the risk of progression by intensity of coloring (green, yellow, orange, red, deep red). The numbers in the boxes are a guide to the frequency of monitoring (number of times per year).

Note. GFR= glomerular filtration rate. (Levin *et al*., 2013).

When a patient's eGFR reaches 30 mL/min or lower (and in many cases 60 mL/min or lower in patients with high risk for disease progression) they should be referred to a nephrologist (Alhamad, Cheng, & Vijayan, 2021; Levin *et al.*, 2013; Stengel *et al.*, 2021). Factors associated with progression of renal disease include etiology, eGFR and albuminuria at diagnosis, age, sex, race/ethnicity, elevated blood pressure, smoking status, obesity, hyperglycemia, dyslipidemia, history of cardiovascular disease, and ongoing exposure to nephrotoxic agents (Alhamad, Cheng, & Vijayan, 2021; Levin *et al.*, 2013; Stengel *et al.*, 2021). Patients with CKD should be closely monitored and managed to achieve blood pressure control, RAS (renin-angiotensin system) inhibition, lowered salt and protein intake, glycemic control, diet optimization and lifestyle modification. (Alhamad, Cheng, & Vijayan, 2021; Hirano *et al.,* 2019; Levin *et al.*, 2013; Stengel *et al.*, 2021). See Table 1 within Appendix B for specific management strategies and medications. While specialized nephrology care practices often have more capacity and preparation to coordinate these aspects of care, PCPs are responsible for initiating these interventions early in disease course to provide potential for better outcomes (Alhamad, Cheng, & Vijayan, 2021; Hirano *et al.,* 2019; Levin *et al.*, 2013).

Patients with CKD are at risk for various complications that can both affect and be affected by progression of disease (Alhamad, Cheng, & Vijayan, 2021; Kiousi & Grapsa, 2015; Mandal, 2014). These complications include hypertension, volume overload, hyperkalemia, metabolic acidosis, hyperuricemia, hyperlipidemia, anemia, cardiovascular events, acute kidney injury, and renal osteodystrophy (CKD Mineral and Bone Disorder [CKD-MBD]) (Alhamad, Cheng, & Vijayan, 2021). Detecting and treating these outcomes involves regular screening, frequent encounters with healthcare providers, procedures, and pharmacologic interventions (Hirano *et al.,* 2019; Mandal, 2014).

Given the risk for complications, care of the patient with progressive CKD involves efficiently coordinated interprofessional management (Alhamad, Cheng, & Vijayan, 2021; Hirano *et al.,* 2019; Levin *et al.*, 2013; Stengel *et al.*, 2021). In addition to nephrology care, multidisciplinary teams often provide services including preventive measures (i.e., immunizations, smoking cessation), dietary counseling, health education, RRT counseling, transplant planning, vascular access surgery, psychological and social care (Hirano *et al.,* 2019; Kiousi & Grapsa, 2015; Levin *et al.*, 2013; Mandal, 2014). As the severity of CKD increases, patients need to attend more frequent follow up visits to maintain standard of care (Hirano *et al.,* 2019; Kiousi & Grapsa, 2015; Mandal, 2014). In late stages of disease, it is not uncommon for patients with advanced CKD to have a healthcare encounter every three to four weeks, not including dialysis treatments (Hirano *et al.,* 2019; Mandal, 2014). While frequent visits offer benefit in continuity of care, increasing numbers of encounters simultaneously become burdensome to patients and their families (Hirano *et al.,* 2019; Kiousi & Grapsa, 2015; Mandal, 2014).

Registered dietitian and certified diabetes educator services.

Dietary and diabetes self-care counseling from trained and certified professionals have become a routine aspect of the evidence-based care for patients with renal disease (Alhamad, Cheng, & Vijayan, 2021). These ancillary services have largely become a mainstay in CKD management due to the effect diet and patient behaviors have on clinical outcomes (Alhamad, Cheng, & Vijayan, 2021; Beerendrakumar, Ramamoorthy & Haridasan, 2018; Kalantar-Zadeh, 2013; Paes-Barreto *et al.*, 2013). Prior to initiation of RRT, the level of glycemic control and adherence to protein, fat, phosphorus, calcium, potassium, and salt restriction have major implications on rates of progression, morbidity, and mortality (Alhamad, Cheng, & Vijayan, 2021; Beerendrakumar, Ramamoorthy & Haridasan, 2018; Chang *et al.*, 2020; Duncan *et al.*, 2011; Kalantar-Zadeh, 2013; Paes-Barreto *et al.*, 2013; Shurraw *et al.*, 2011). Once patients initiate RRT, glycemic control continues to have major implications for morbidity and mortality (Alhamad, Cheng, & Vijayan, 2021; Chang *et al.*, 2020; Shurraw *et al.*, 2011). However, initiation of dialysis involves adaptations to the pre-RRT diet that are equally important to patient outcomes (Beerendrakumar, Ramamoorthy & Haridasan, 2018; Kalantar-Zadeh, 2013; Paes-Barreto *et al.*, 2013). Even with the use of phosphorus binders, dietary intake of phosphorus remains one of the strongest predictors for morbidity and mortality in patients receiving RRT (Kalantar-Zadeh, 2013).

Providing Registered Dietitian (RD) counseling to support patient diet optimization has been shown to be associated with better adherence and improved clinical outcomes (Beerendrakumar, Ramamoorthy & Haridasan, 2018; Kalantar-Zadeh, 2013; Paes-Barreto *et al.*, 2013). Similar to frequent nephrologist visits, data suggest a dose-response relationship in frequency of RD encounters where patients have better adherence and clinical outcomes the more often they receive RD counseling (Beerendrakumar, Ramamoorthy & Haridasan, 2018; Kalantar-Zadeh, 2013). Furthermore, RD counseling that incorporates patients' support systems and family into education and planning provide even better outcomes in diet adherence and clinical outcomes (Beerendrakumar, Ramamoorthy & Haridasan, 2018). The disparities seen in CKD prevalence and severity are mirrored in the access to and success of RD counseling. Patients with CKD who are unemployed, smoke tobacco, have lower levels of education, speak English as a second language, and experience food insecurity have been shown to have less encounters with RDs and impaired adoption of dietary modifications due to socioeconomic barriers (Beerendrakumar, Ramamoorthy & Haridasan, 2018).

Due to the detrimental effects of poorly controlled diabetes in patients with CKD, optimizing glycemic control is paramount (Alhamad, Cheng, & Vijayan, 2021; Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011; Shurraw *et al.*, 2011). Patients who exhibit metabolic syndrome and diabetes are frequently prescribed lifestyle and dietary modifications in conjunction with various pharmacologic interventions to maintain healthy blood sugar levels and improve clinical outcomes (Alhamad, Cheng, & Vijayan, 2021; Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011; Shurraw *et al.*, 2011). However, patient capacity to adopt these interventions outside of the exam room will largely dictate their success (Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011).

Over the years, the literature has increasingly acknowledged the notion that the provision of information alone does not equate to behavior change (Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011). Certified diabetes educators (CDEs) are a specialized group of healthcare professionals (most commonly registered nurses, RDs, and pharmacists) that have been trained to apply models of behavior change in the care for patients with diabetes (Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011). While PCPs and nephrologists should and often do provide patients with information about their disease and care plans, these types of encounters typically do not provide adequate time to deliver behavior change coaching individualized to their patients' needs (Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011).

By incorporating CDEs into the patient's care team, patients are devoted time to receive further explanation of medications, additional monitoring, and coaching to incorporate exercise, adhere to medications, optimize diet, adopt healthy coping, and reduce risk that is individualized to the patient's personal goals and needs (Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011). Furthermore, CDEs are trained to assist patients in problem solving of specific barriers by coordinating solutions to food insecurity, physical, emotional, cognitive, and financial obstacles (Burke, Sherr & Lipman, 2014). Through this approach, CDEs can tailor support for patients, encouraging self-efficacy in managing their disease and achieve the fundamental outcome of behavior change (Burke, Sherr & Lipman, 2014). Nephrology patients who successfully incorporate behavior change derived from this patient-centered approach have been shown to have better sustainability of the behavior change and improved glycemic control that in turn have a positive impact on renal disease morbidity and mortality (Alhamad, Cheng, & Vijayan, 2021; Burke, Sherr & Lipman, 2014; Duncan *et al.*, 2011; Shurraw *et al.*, 2011).

Preparation for ESRD.

Another aspect of multidisciplinary CKD management is ESRD preparation. Shortly after CKD diagnosis, patients should be provided anticipatory guidance and counseling to convey typical disease course and ESRD management strategies specific to the patient's risk and needs (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020; Norman, 2020). The purpose of discussing these topics early in disease course is to ensure patients are adequately informed and prepared to participate in timely shared decision making for ESRD management should kidney dysfunction progress (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020; NIDDK, 2017).

While RRT is typically not initiated until patients reach a GFR of 10 to 15 mL/min, an ESRD education course should be provided when GFR reaches 30 mL/min or lower as the instigation of dialysis and renal transplant is a lengthy process involving various members of the care team (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020; NIDDK, 2017; Norman, 2020). These educational programs should provide thorough education for the patient and their support system regarding ESRD treatments options: HD, HHD, PD, renal transplant, and palliative care (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Bleyer, 2020; NIDDK, 2017; Norman, 2020).

Furthermore, to provide comprehensive preparation, consultation with RDs, CDEs, and social workers should be incorporated so that patients and their support systems are activated to make informed decisions and behavior changes (Alhamad, Cheng, & Vijayan, 2021; Beerendrakumar, Ramamoorthy & Haridasan, 2018; Berns, 2020; Bleyer, 2020; Kalantar-Zadeh, 2013; Paes-Barreto *et al.*, 2013).

Should patients choose to pursue renal transplant, they should be referred to a multidisciplinary nephrology clinic that specializes in transplant care (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020). Typically, patients cannot be listed to receive a kidney transplant until their GFR reaches 20 mL/min or lower (Alhamad, Cheng, & Vijayan, 2021). However, consultation with a specialty transplantation team is encouraged earlier in disease course if patients are eligible and interested in pursuing this treatment (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020).

Timing and type of RRT initiation is a difficult shared decision that should be individualized to the patient's GFR, presence of uremic symptoms, goals of care, preference, risk for poor outcomes, level of independence, supportive factors, and barriers (Alhamad, Cheng, & Vijayan, 2021; Bleyer, 2020). If patients are interested in pursuing HD, they should have early referral to a vascular surgeon (typically at a GFR of 30 mL/min) for vascular mapping and planning for timely placement of dialysis access (Alhamad, Cheng, & Vijayan, 2021; Berns, 2020; Bleyer, 2020). If PD is preferred, patients should be referred for specialized surgical evaluation when they reach a GFR of 30 mL/min, so they can receive timely placement of a catheter (Alhamad, Cheng, & Vijayan, 2021; Pirkle, 2019).

Rural Community Implications

Delivering and coordinating CKD standard of care can be challenging in rural and remote areas (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014). While racial, social, and economic inequities have been thoroughly evidenced to impair clinical outcomes in nephrology patients, examining these factors in the context of rural-urban differences can be difficult (Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008).

Characteristics of rural regions in the U.S. tend to compound structural and social inequities in healthcare access and outcomes (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; O'Hare, Johansen & Rodriguez, 2006; Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014). This phenomenon is postulated to arise from relative resource isolation, limited transportation, and widely dispersed healthcare facilities (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014). These added barriers to access are important determinants of health outcomes in both treatment and prevention of disease (Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014). This concept is supported by measured disparities of RD care in rural areas, poorer outcomes as distance from nephrology clinics increase, and lower rates of pre-ESRD care, all of which become more inequitable for non-white or lower income rural residents (Chang *et al.*, 2020; Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014).

Risk for poor renal health that is commonly measured in occupational and lifestyle factors may be more prevalent in rural areas as well (Smith, Humphreys & Wilson, 2008). For instance, in rural areas, patients are more likely to be employed by industries that have exposure to chemical, biological, physical, and mechanical hazards (Smith, Humphreys & Wilson, 2008). Furthermore, lifestyle factors like poor diet, smoking, low levels of exercise, and psychosocial stress are more prevalent in rural areas (Smith, Humphreys & Wilson, 2008; Rodriguez, Hotchkiss & O'Hare, 2014). While socioeconomic deprivation and racial inequity are more strongly associated with poor renal outcomes than rurality, the high level of heterogeneity in U.S. rural territories could affect national statistical analysis of this issue (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Smith, Humphreys & Wilson, 2008; Rodriguez, Hotchkiss & O'Hare, 2014; Yan *et al.*, 2014)

Progression to ESRD has been found to occur at higher rates in rural parts of the U.S. when compared to urban areas (Smith, Humphreys & Wilson, 2008). As previously discussed, providing early and evidence-based CKD management strategies requires time and resource intensive care. The disproportionate rates of ESRD in rural areas could arise from trait barriers in these regions that impede access to these intensive quality health services (Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008). Patients with kidney disease who live substantial distances from a nephrology practice are more likely to have missed appointments and receive less treatment compared to those that live closer (Koraishy & Rohatgi, 2020). Consequently, these geographically isolated patients are also more likely to be hospitalized and experience mortality at higher rates (Koraishy & Rohatgi, 2020). Additionally, while nephrologists practicing in rural areas are no less superior than their urban counterparts, the ratio of provider to patients can be highly disparate in regions with relative resource isolation, raising concern for nonoptimal workforce distribution (Rodriguez, Hotchkiss & O'Hare, 2014).

Although almost one-fourth of new dialysis patients reside in rural areas, distance between patients and dialysis centers are substantially greater than in metropolitan regions

(O'Hare, Johansen & Rodriguez, 2006; Rodriguez, Hotchkiss & O'Hare, 2014). Because most dialysis centers operate in a capitalistic framework, these private companies evaluate densities of patients requiring RRT to select location and number of facilities to maintain an economically sustainable patient volume (O'Hare, Johansen & Rodriguez, 2006; Rodriguez, Hotchkiss & O'Hare, 2014; Yan *et al.*, 2014). In more remote areas, this leads to fewer dialysis centers and central locality which in turn, results in longer commute times (Rodriguez, Hotchkiss & O'Hare, 2014; Yan *et al.*, 2014). For those initiating dialysis, adjusted death rate has been found to be significantly higher in those living further away from their facility (Koraishy & Rohatgi, 2020; Osman *et al.*, 2017). Furthermore, rural dialysis facilities are markedly less likely to offer PD or HHD training than urban facilities, despite travel distance being an issue for many of their patients (O'Hare, Johansen & Rodriguez, 2006).

Renal transplant is the most effective treatment for ESRD (Rodriguez, Hotchkiss & O'Hare, 2014; Yan *et al*., 2014; Tonelli *et al.*, 2009). However, access to transplantation services in rural areas may be compromised (Rodriguez, Hotchkiss & O'Hare, 2014; Yan *et al*., 2014). While some studies have shown that rurality alone is not a strong determinant in access to transplantation, areas of lower socioeconomic status and non-white racial groups living in rural areas are associated with lower rates of live donor renal transplant (O'Hare, Johansen & Rodriguez, 2006; Rodriguez, Hotchkiss & O'Hare, 2014; Tonelli *et al.*, 2009). Black patients with ESRD living in rural areas experience lower rates of renal transplant than any other group (O'Hare, Johansen & Rodriguez, 2006). Patients of all races in rural areas are more likely to live further distances away from specialty transplant clinics and have fewer transportation options which are known barriers to healthcare access (Koraishy & Rohatgi, 2020; O'Hare, Johansen &

Rodriguez, 2006; Osman *et al.*, 2017; Rodriguez, Hotchkiss & O'Hare, 2014; Smith, Humphreys & Wilson, 2008; Yan *et al.*, 2014).

Telenephrology in rural spaces.

Recent estimates for the U.S. suggest that 96% of adult Americans own a cellphone, 81% own a smartphone, three-quarters own a desktop or laptop, and nine out of ten adults regularly use the internet (Pew Research Center, 2019). While some small variations exist between factors of age, race, income, education and whether someone resides in a rural or urban area, Americans are connected to the world of digital information now more than ever (Pew Research Center, 2019). This preexisting infrastructure has ultimately allowed for implementation of virtual care services across the nation with the adoption of new policy through the CARES Act. However, even prior to the pandemic, strategies to incorporate telehealth in rural communities have shown benefit in patient outcomes, patient and provider satisfaction, and improved access to care (Osman *et al*., 2017; Tuot & Boulware, 2017; Zhai *et al.*, 2014).

In the pre-pandemic era, the United States' familiarity and application of telehealth services was largely limited to rural health institutions and single payer systems like Indian Health Services (IHS) & Veterans Health Administration (VHA) (Osman *et al.*, 2017; Rohatgi, Ross & Majoni, 2017). Through the 2018 Bipartisan Act, the beginnings of telenephrology policy advancement were realized so that beneficiaries of Medicare Advantage plans and Medicare Shared Savings Program could expect to use virtual care services from their homes starting in 2020 (Lazur, Bennett & King, 2019). Specific to the field of nephrology, the Bipartisan Act stipulated that starting in 2019, patients with ESRD would be allowed to receive virtual care services while at home so long as certain conditions were met (Lazur, Bennett & King, 2019). While steps were being taken to expand telenephrology services prior to the pandemic, there was still a dearth of adoption due to poor reimbursement and regulatory issues (Jain, Ahmad & Wallace, 2020).

Despite having obstacles to widespread adoption of telenephrology services before the pandemic, studies measuring outcomes in settings where it had been implemented, illustrated its benefit. Analysis of the VHA, a single-payer system that provides care to nearly 9 million veterans, 3 million of whom live in rural communities, has shown that patients who received nephrology care via video conferencing maintained clinical outcomes that were at least equivalent to in-person care while improved patient adherence to scheduled appointments and cost-effectiveness were observed in patients utilizing telenephrology (Osman *et al*., 2017; Rohatgi, Ross & Majoni, 2017).

With the spread of SARS-CoV-2, the Coronavirus Aid, Relief, and Economic Security (CARES) Act and its $2.3 trillion stimulus was signed into law on March 27, 2020. Through the CARES Act, Section 3705, statutory requirements for nephrologists to conduct a face-to-face evaluation of new and home dialysis patients before use of virtual care services were eliminated (Jain, Ahmad & Wallace, 2020; White & Kribs, 2020). Additionally, the CARES Act and Centers for Medicare and Medicaid Services (CMS) 1135 waiver adopted coding so that both new and existing patients would be eligible to use virtual care services and made full reimbursement for both telephone and video visits possible (White & Kribs, 2020). For patients using dialysis, this Act further allowed for in-center dialysis units to be sites that perform telehealth visits (Jain, Ahmad & Wallace, 2020). Private payers have principally followed suit and access to telenephrology services that previously appeared to be a chimera came to fruition overnight (Agarwal, 2020; Jain, Ahmad & Wallace, 2020).

Outside of virtual points of care with patients, interprofessional use of telehealth modalities in rural areas has also been shown to improve health outcomes for patients and provider satisfaction (Hardy *et al.*, 2019; Tuot & Boulware, 2017; Winocour *et al*., 2020). In rural regions where there is a relative scarcity of nephrologists, RDs, and CDEs, PCPs may be unable to connect patients with vital specialized care in a timely manner. With the implementation of virtual interprofessional meetings, PCPs can access nephrology consultant services for appraisal of patient panels, receive suggestions for management and have questions fielded (Hardy *et al.*, 2019; Winocour *et al*., 2020). These modalities have been shown to improve PCP satisfaction and increase access to specialized nephrology care for patients who historically experienced barriers specific to their rural community (Hardy *et al.*, 2019; Winocour *et al*., 2020).

Theoretical Framework

Based on Kurt Lewin's *Change Theory*, this project aims to examine and plan for change with the nephrology clinical process. Lewin's model utilizes an *unfreezing-change-refreeze* analysis (Lewin Change Theory, 2020). In this theory, driving, restraining, and equilibrium forces are assessed (Lewin Change Theory, 2020).

Driving forces are those that instigate change to occur and cause a shift in equilibrium (Lewin Change Theory, 2020). When driving forces increase over the sum of restraining forces, equilibrium is changed (Kaminski, 2011; Lewin Change Theory, 2020). This is the first step in the unfreezing process for change to occur (Kaminski, 2011; Lewin Change Theory, 2020). In the context of the Change Theory framework, change involves capitalizing on new thoughts, feelings, and behaviors so barriers or restraining forces can be approached from a fresh perspective. While overcoming individual resistance and group conformity is typically difficult and laborious, the driving forces of the COVID-19 pandemic were so strong that an equilibrium shift was inevitable (Lewin Change Theory, 2020).

U.S. nephrology clinics and their patients are presently in step two of the Change Theory, where the change has occurred. The unprecedented rate of a substantial change adoption left potential for barriers and restraining forces to remain within the phenomenon. This project aims to examine the remaining barriers to successful delivery of telenephrology services and propose a plan to ameliorate obstacles and progress towards meaningful, equitable *refreezing* of new practices and behaviors.

Review of literature

Telenephrology

A PubMed and Google Scholar search was performed with the key words “kidney disease”, “remote”, “rural”, “telehealth”, “dialysis”, “nephrology”, “end stage Renal disease” and “telemedicine” between 2000 and 2021. This was followed by a search of Journal of Medical Internet Research publications using the same key words between 2000 and 2021. Articles examining the implementation of telenephrology services were specifically examined. There were 52 articles deemed appropriate for this review and included in this section.

In reviewing the available telenephrology literature, various limitations of the evidence were realized. A relatively obvious limitation of the available literature is the novelty of virtual care delivery. This resulted in a dearth of large-scale and high-quality investigations of telenephrology interventions. Of the telenephrology studies available, the designs, aims, and findings are exceedingly heterogenous. While telenephrology programs have been more widely adopted in countries with universal healthcare like Canada and Australia, generalizing their cost effectiveness findings to the private health insurance dominated U.S. healthcare system is challenging. Additionally, telenephrology policy, reimbursement, barriers, and culture have changed dramatically in reaction to the COVID-19 pandemic. The present proximity to this catalyst event results in a paucity of telenephrology research that has been conducted within the pandemic phenomenon. Consequently, the current evidence for telenephrology interventions remains insufficient to develop nationally standardized guides for practice. As such, this review of the literature examines the available evidence and reports pertinent findings to direct implementation and evaluation of telenephrology programs during and beyond the pandemic paradigm in rural regions of Western Washington State. See Tables 4 through 7 within Appendix D for a summary of forty-five telenephrology interventions included in the literature review.

Diversity of telenephrology application.

Applications of telenephrology have mirrored the diverse and multidisciplinary nature of care for the patient with renal disease. From medication reminders to renal transplant interventions, telehealth modalities have been applied to improve access to timely care and optimize patient-centeredness (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Osman *et al*., 2017; Tuot & Boulware, 2017). The types of telehealth modalities applied to the field of nephrology can be divided into live (synchronous) and asynchronous domains. Live domains include videoconferencing and phone calls while asynchronous domains include *store-and-forward*, *remote patient monitoring* or *mobile health* (mHealth) applications (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Lazur, Bennett & King, 2019; Osman *et al*., 2017; Tuot & Boulware, 2017). See Table 2 within Appendix C for a summary of telenephrology formats, their application, advantages, and disadvantages.

Aspects of nephrology care have been efficiently deployed through mobile phones using text messaging, smart phone apps, phone calls and patient portal applications (Blakeman *et al.*, 2014; Diamantidis *et al.*, 2012; Hayashi *et al.,* 2017; McGillicuddy *et al.*, 2013; Ong *et al.*, 2016; Salgia *et al*., 2014; Stark *et al.*, 2011). Several studies have examined the use mobile phone functions to provide patient education, community resources, medication safety information, medication, and appointment reminders (Blakeman *et al.*, 2014; McGillicuddy *et al.*, 2013; Ong *et al.*, 2016; Reese *et al.*, 2017; Salgia *et al*., 2014; Singh *et al.*, 2019; Stark *et al.*, 2011). Alternatively, one smart phone app, Self-Management and Recording System for Dialysis (SMARTD), was developed to support patients in completing their own dialysis monitoring (Hayashi *et al.,* 2017). Through this app, dialysis users were enabled to self-monitor weight, serum potassium, and serum phosphorus at home (Hayashi *et al.,* 2017). Another smart phone app was developed to encourage health promoting behaviors in patients with advanced CKD (Ong *et al.*, 2016). Through the application, patients are prompted to monitor their blood pressure, manage medications, self-assess symptoms, and track their laboratory results (Ong *et al.*, 2016). In addition to phone-based applications, web-based programs have been used as vehicles to deliver nephrology education and resources (Diamnatidis *et al.*, 2013; Malkina & Tuot, 2018; Osman *et al*., 2017). One example is the VA's e-Kidney Clinic as an educational tool, designed for patients at any stage of CKD (Malkina & Tuot, 2018). Since the program's launch in 2013, the website traffic has tripled, illustrating demand for this type of educational platform (Koraishy & Rohatgi, 2020; Lederer *et al*., 2015; Malkina & Tuot, 2018)

The adoption of synchronous patient-to-provider telenephrology visits over telephone or videoconference has grown rapidly in response to the COVID-19 pandemic (Koraishy & Rohatgi, 2020). Historically, the majority of telenephrology encounters in the U.S. were made possible through programs implemented by the VA system, IHS, and rural healthcare networks (Crowley *et al.*, 2017; Gasparini *et al.*, 2019; Koraishy & Rohatgi, 2020; Osman *et al*., 2017;

Shen *et al.*, 2019; Tuot & Boulware, 2017). The VA has pioneered various telenephrology modalities, including *Renal Clinical Video Telehealth* (CTA) (Crowley *et al.*, 2017; Lederer *et al.*, 2015; Malkina & Tuot, 2018; McAdams, Cannavo, & Orlander, 2014; Salgia *et al.*, 2014; Tan *et al.*, 2017). Renal CTA was developed to reach geographically remote veterans with kidney disease through the use of video encounters and remote monitoring devices (i.e., sphygmomanometer, scale, ultrasound) (Crowley *et al.*, 2017; Koraishy & Rohatgi, 2020; Tan *et al.*, 2017). This program was designed to function in a multitude of settings including hospital-to-hospital, hospital-to-clinic, and hospital-to-home, depending on the location of the patient (Crowley *et al.*, 2017; Koraishy & Rohatgi, 2020; Tan *et al.*, 2017).

Internationally, telenephrology encounters have been widely adopted as a way to deliver care (Koraishy & Rohatgi, 2020). In the mid-1990s, Australia adopted telenephrology encounters to reach remote aboriginal populations and dialysis units, first through telephone, then through videoconferencing as technology advanced (Koraishy & Rohatgi, 2020; Michell *et al.*, 1997; Mitchel *et al.*, 2000). In Canada, remote management of patients using hemodialysis was adopted in the 1980s (Koraishy & Rohatgi, 2020; Ovtcharenko & Thomson, 2019). Since its infancy, these telenephrology encounters have advanced from telephone calls and faxes to videoconferencing and telerounds to bridge high-quality care to isolated rural communities (Beiber & Weiner, 2018; Berstein *et al.*, 2008; Ovtcharenko & Thomson, 2019; Sicotte *et al.*, 2011).

A growing body of evidence has reflected better rates of survival, cost-effectiveness, and quality of life with home dialysis compared to in-center dialysis, especially for patients residing in rural communities (Beiber & Weiner, 2018; Lew & Sikka, 2019; Mailloux & Blagg, 2016; Whitlow & Wallace, 2019). This along with advances in remote monitoring devices has made

HHD and home-PD an increasingly desirable choice to both patients and providers (Berman *et al*., 2011; Kiberd *et al.*, 2018; Kooman *et al.*, 2020; Lew & Sikka, 2019; Mailloux & Blagg, 2016; Malkina & Tuot, 2018; Whitlow & Wallace, 2019). Internationally and nationally, various home-dialysis telenephrology programs have been adopted to improve access and efficiency in the highly resource intensive intervention of RRT (Bernstein *et al.*, 2010; Hayashi *et al.,* 2017; Kiberd *et al.*, 2018; Kooman *et al.*, 2020; Lew & Sikka, 2019; Lunney *et al*., 2018; Mailloux & Blagg, 2016; Malkina & Tuot, 2018; Shen *et al.*, 2019; Sicotte *et al*., 2011; Whitlow & Wallace, 2019). These home-dialysis telenephrology interventions can include virtual encounters, education and training programs, remote monitoring, and ancillary services (Ensell, 2017; Hayashi *et al.,* 2017; Kiberd *et al.*, 2018; Kooman *et al.*, 2020; Lew & Sikka, 2019; Lunney *et al*., 2018; Mailloux & Blagg, 2016; Malkina & Tuot, 2018; Sicotte *et al*., 2011; Stark *et al.*, 2011; Wallace *et al.*, 2017; Whitlow & Wallace, 2019).

Telenephrology programs tailored to patients who could benefit from or who have received renal transplant are growing in utilization (Cabacungan *et al.*, 2018; McGillicuddy *et al.*, 2013; Reese *et al.*, 2017). These programs include pre-transplant education and resources, and post-transplant medication adherence, blood pressure control, and immune suppressive therapy maintenance (Cabacungan *et al.*, 2018; McGillicuddy *et al.*, 2013; Reese *et al.*, 2017).

While many telenephrology programs direct interventions with patients, virtual provider-to-provider interventions have been utilized in the field of nephrology as well (Ensell, 2017; Hardy *et al.*, 2019; Lea & Tannenbaum, 2020; McAdams *et al.*, 2014; Salgia *et al.*, 2014; Winocour *et al.*, 2020). The majority of interprofessional telenephrology applications have been deployed to rural or remote areas where there is a dearth of nephrology providers (Ensell, 2017; Hardy *et al.*, 2019; Lea & Tannenbaum, 2020; McAdams *et al.*, 2014; Salgia *et al.*, 2014;

Winocour *et al.*, 2020). Examples of these programs include the VA's eConsult and SCAN-ECHO (Specialty Care Access Network – Extension of Community Healthcare Outcomes) programs, Sanderling Renal Services, and ENHIDE (East and North Herts Institute of Diabetes and Endocrinology) diabetes renal telehealth (Hardy *et al.*, 2019; Lea & Tannenbaum, 2020; McAdams *et al.*, 2014; Salgia *et al.*, 2014; Winocour *et al.*, 2020).

Executing large-scale screening programs to identify patients who could benefit from nephrology care has historically been a huge undertaking (Shlipak *et al.*, 2021). With the advent of artificial intelligence (AI) applications, patient data can be used to efficiently screen patient panels for at-risk individuals (Hao *et al.*, 2017; Sheng *et al.*, 2020; Song *et al.*, 2020). Using telenephrology modalities, social marketing of prevention and screening campaigns could be efficiently distributed to patients with high-risk for renal disease through mHealth and patient portal technology (Osman *et al*., 2017; Shlipak *et al.*, 2021; Swee *et al.*, 2020; Tuot *et al*., 2020).

In reviewing various examples of telenephrology delivery, the literature collectively serves as evidence that each application should be evaluated in its respective context. Consideration of the study quality, sample population (age, race, comorbidities, in-patient vs. out-patient, and stage of CKD), intended use, and outcomes will allow for more meaningful telenephrology program guidance.

Benefits of telenephrology.

Implementation of telenephrology allows for capitalizing on the flexible, adaptable, and accessible nature of virtual care services to mitigate barriers in rural communities while harboring the potential to improve health outcomes of nephrology patients in a cost-effective way (Batsis *et al*, 2019; Ensell, 2017; Crowley *et al.*, 2017; Koraishy & Rohatgi, 2020; Lea & Tannenbaum, 2020; McAdams *et al.*, 2014; Osman *et al*., 2017; Tan *et al.*, 2017; Tuot &

Boulware, 2017; Wallace *et al.*, 2017; Whitlow & Wallace, 2019; Zhai *et al*., 2014). Given the heterogenous nature of telenephrology studies, evidence of their benefit is examined by intended use as well as primary and secondary outcome measures.

Telenephrology modalities adopted outside of the clinical delivery process have been widely studied. Development of educational and behavioral telehealth interventions tailored to nephrology patients are presumably less of a logistical endeavor than adapting clinical care delivery as their utility does not hinge on policy and reimbursement. Nevertheless, these modalities harbor potential for benefits in patient outcomes (Blakeman *et al.*, 2014; Diamantidis *et al.*, 2012; Diamantidis *et al.*, 2013; Malkina & Tuot, 2018; McGillicuddy *et al.*, 2013; Ong *et al.*, 2016; Stark *et al.*, 2011; Tuot *et al*., 2020). Smartphone apps and web-based portals have been used to improve patient knowledge and awareness, encourage positive behaviors, provide community support, encourage self-monitoring and self-management, medication adherence, and appointment adherence (Blakeman *et al.*, 2014; Bowman *et al.*, 2020; Cabacungan *et al.*, 2018; Chang *et al.*, 2020; Diamantidis *et al.*, 2018; Diamantidis *et al.*, 2013; Diamantidis *et al.*, 2012; Donald *et al.*, 2021; Dubin & Rubinsky, 2019; El Khoury *et al.*, 2020; Ellis *et al.*, 2019; Fink *et al.*, 2016; Hayashi *et al.*, 2017; Kaiser *et al.*, 2020; Kiberd *et al.*, 2018; Kobe *et al.*, 2020; Kyte *et al.,* 2020; Li *et al.,* 2020; Liu *et al.*, 2017; Malkina & Tuot, 2018; McGillicuddy *et al.*, 2013; Minatodoni & Berman, 2013; Ong *et al.*, 2016; Reddy & Aronoff, 2016; Reese *et al.*, 2017; Som *et al.*, 2011; Stark *et al.*, 2011; Swee *et al.*, 2020; Tuot *et al*., 2020; Warner *et al.*, 2018). These interventions have been measured to improve blood pressure, patient self-efficacy, patient decision-making, diet, behaviors, rates of hospitalization, rates of missed appointments, lab values, safety, weight, and patient satisfaction (Blakeman *et al.*, 2014; Bowman *et al.*, 2020; Cabacungan *et al.*, 2018; Chang *et al.*, 2020; Diamantidis *et al.*, 2018; Diamantidis *et al.*, 2013;

Diamantidis *et al.*, 2012; Donald *et al.*, 2021; Dubin & Rubinsky, 2019; El Khoury *et al.*, 2020; Ellis *et al.*, 2019; Fink *et al.*, 2016; Hayashi *et al.*, 2017; Kaiser *et al.*, 2020; Kiberd *et al.*, 2018; Kobe *et al.*, 2020; Kyte *et al.,* 2020; Li *et al.,* 2020; Liu *et al.*, 2017; Malkina & Tuot, 2018; McGillicuddy *et al.*, 2013; Minatodoni & Berman, 2013; Ong *et al.*, 2016; Reddy & Aronoff, 2016; Reese *et al.*, 2017; Som *et al.*, 2011; Stark *et al.*, 2011; Tuot *et al*., 2020; Warner *et al.*, 2018). Furthermore, many of these interventions proved to be cost-effective when accounting for their outcomes (Blakeman *et al.*, 2014; Chang *et al.*, 2020; Dubin & Rubinsky, 2019; Ellis *et al.*, 2019; Fink *et al.*, 2016; Hayashi *et al.*, 2017; Ong *et al.*, 2016; Song *et al.*, 2020; Swee *et al.*, 2020; Tuot *et al.*, 2020; Warner *et al.*, 2018).

Adoption of synchronous telenephrology modalities for care delivery through videoconference or telephone visits has proven to be feasible, patient-centered, and effective (Belcher, 2020; Blakeman *et al.*, 2014; Chang *et al.*, 2020; Ishani *et al.*, 2016; Kaiser *et al.*, 2020; Kelly *et al.*, 2018; Kiberd *et al.,* 2018; Ensell, 2017; Ladino *et al.*, 2016; Rohatgi, Tan & Mehrotra, 2018; Sicotte *et al.*, 2011; Swee *et al.*, 2020; Tan *et al.*, 2018; Whitten & Buis, 2008). Regardless of disease stage or severity, providing the option for virtual or telephone visits with specialized members of the nephrology care team can improve patient outcomes and experience (Blakeman *et al.*, 2014; Chang *et al.*, 2020; Ishani *et al.*, 2016; Kaiser *et al.*, 2020; Krishna *et al.*, 2016; Kelly *et al.*, 2018; Kiberd *et al.,* 2018; Ensell, 2017; Ladino *et al.*, 2016; Rohatgi, Tan & Mehrotra, 2018; Sicotte *et al.*, 2011; Swee *et al.*, 2020; Tan *et al.*, 2018; Whitten & Buis, 2008). The benefit of these services is often amplified for patients who experience geographical or socioeconomic barriers to care (Chang *et al.*, 2020; Ishani *et al.*, 2016; Kelly *et al.*, 2018; Krishna *et al.*, 2016; Ensell, 2017; Ladino *et al.*, 2016; Rohatgi, Tan & Mehrotra, 2018; Sicotte *et al.*, 2011; Swee *et al.*, 2020; Tan *et al.*, 2018; Whitten & Buis, 2008). For example, a VA health system in Iowa innovatively linked telenephrology modalities to survey their patient panel for patients at risk for kidney disease to then provide early virtual nephrology consultation (Swee *et al.*, 2020). This particular patient panel experienced rural and geographical barriers to nephrology care. Through this intervention, 459 of 1,284 patients were detected to be at risk for kidney disease and were provided access to nephrology services early in their disease course (Swee *et al.*, 2020). The study found that with this intervention, patients saved between $21.60 and $63.90 per trip by using virtual consult, workflow was made to be more efficient, and rates of early detection and identification of disease were improved (Swee *et al.*, 2020).

Randomized control trials (RCT) investigating the effectiveness of telenephrology visits have shown that virtual and telephone encounters meet or exceed patient outcomes seen in standard in-person care (Berman *et al.*, 2011; Blakeman *et al.*, 2014; Ishani *et al.*, 2016; Kelly *et al.*, 2018; Kobe *et al.*, 2020; Minatodoni & Berman, 2013). Furthermore, providers and institutions frequently benefit from reduced travel time to facilities, cost savings from appointment adherence and fewer emergency or in-patient care needs, and efficient patient workflow (Crowley *et al*., 2017; Ishani *et al.*, 2016; Kelly *et al.*, 2018; Krishna *et al.*, 2016; Ensell, 2017; Ladino *et al.*, 2016; Pichler *et al.*, 2016; Rohatgi, Tan & Mehrotra, 2018; Sicotte *et al.*, 2011; Swee *et al.*, 2020; Tan *et al.*, 2018; Whitten & Buis, 2008).

For patients with ESRD, telenephrology offers substantial benefit in access to care, clinical outcomes, and quality of life (Beiber & Weiner, 2018; Dubin & Rubinsky, 2019; Ensell, 2017; Hayashi *et al.*, 2017; Kaiser *et al.*, 2020; Kiberd *et al.*, 2018; El Koury *et al.*, 2020; Krishna *et al.*, 2016; Reddy & Aronoff, 2016; Sicotte *et al.*, 2011; Whitten & Buis, 2008). This is especially true for patients living in rural communities (Beiber & Weiner, 2018; Dubin & Rubinsky, 2019; Ensell, 2017; Hayashi *et al.*, 2017; Kaiser *et al.*, 2020; Kiberd *et al.*, 2018; El

Koury *et al.*, 2020; Krishna *et al.*, 2016; Reddy & Aronoff, 2016; Sicotte *et al.*, 2011; Thompson *et al.*, 2012; Whitten & Buis, 2008; White & Kribs, 2020). Of all chronic diseases, ESRD therapies prove to be the most disruptive to patients' lives requiring daily time- and resource-intensive interventions (Lew *et al.*, 2020; Thompson *et al.*, 2012; Wallace *et al.*, 2017; White & Kribs, 2020). Moving RRT into the patient's home not only improves quality of life but also affords significant improvement in clinical outcomes and cost-savings (Burkart, 2019; Bernstein *et al.*, 2010; Colbert, Venegas-Vera & Lerma, 2020; Dubin & Rubinsky, 2019; Kaiser *et al.*, 2020; Kiberd *et al.*, 2018; Krishna *et al.*, 2016; Glickman & Chan, 2021; Lew *et al.*, 2020; Mailloux & Blagg, 2016; Moist *et al.*, 2008; Wallace *et al.*, 2017). Furthermore, with advances in technology patients can now use remote monitoring devices to make home-based disease assessment and management more comprehensive (Berman *et al.*, 2011; Colbert, Venegas-Vera & Lerma, 2020; Hayashi *et al.*, 2017; Kooman *et al.*, 2020; Liu *et al.*, 2017; Minatodoni & Berman, 2013; Reddy & Aronoff, 2016; White & Kribs, 2020; Whitlow & Wallace, 2019). Studies have shown adding remote monitoring devices to home dialysis therapy can improve individualization of therapy, number of hospitalizations, number of emergency department (ED) visits, patient perception of provider co-presence, and provider satisfaction (Berman *et al.*, 2011; Hayashi *et al.*, 2017; Liu *et al.*, 2017; Minatodoni & Berman, 2013; Reddy & Aronoff, 2016; White & Kribs, 2020; Whitlow & Wallace, 2019). One RCT measured a $91,000 savings in hospital and ED charges by adding remote monitoring to HHD care (Berman *et al.*, 2011; Minatodoni & Berman, 2013).

While renal transplant is the most effective intervention for treatment of ESRD, rates of transplantation in the U.S. are significantly lower than RRT (Bello *et al.*, 2012; Cabacungan *et al.*, 2018; O'hare, Johansen & Rodriguez, 2006; Tonelli et al., 2006;). Of all ESRD patients, Black Americans living in rural areas have the lowest rates of receiving renal transplant and are more likely to receive kidneys from deceased doners than living (Bello *et al.*, 2012; Cabacungan *et al.*, 2018; O'hare, Johansen & Rodriguez, 2006; Tonelli *et al.*, 2006). One pilot program sought to target rural dwelling African Americans to receive tablet-based education on options for live donor kidney transplant, paired with telephone social worker counseling to improve access and support decision making in this at-risk population (Cabacungan *et al.*, 2018). Participants reported this cost-effective intervention was preferred to in-person education and counseling (Cabacungan *et al.*, 2018). Once patients have received a renal transplant, adherence to medications and immunosuppressive therapy is paramount to safety and success (McGillicuddy *et al.*, 2013; Reese *et al.*, 2017). Studies have shown that by incorporating mHealth technology, patients can improve adherence to blood pressure control and immunosuppressive therapies (McGillicuddy *et al.*, 2013; Reese *et al.*, 2017).

Provider-to-provider applications of telenephrology have been shown to be integral in improving access to specialty care in rural and resource isolate regions (Beste *et al.*, 2016; Colbert, Venegas-Vera & Lerma, 2020; Crowley *et al*., 2017; Hardy *et al.*, 2019; Pichler *et al.*, 2016; Salgia *et al*., 2014; Tuot & Boulware, 2017; Winocour *et al*., 2020). Nephrologist eConsults, mentorship, and patient panel appraisal have proven to be cost-effective, improve patient outcomes, and improve provider and specialist satisfaction (Beste *et al.*, 2016; Crowley *et al*., 2017; Hardy *et al.*, 2019; Pichler *et al.*, 2016; Salgia *et al*., 2014; Winocour *et al*., 2020). One of the first and most expansive adoptions of provider-to-provider telenephrology in the U.S. is the VA's Specialty Care Access Network – Extension of Community Healthcare Outcomes (SCAN-ECHO) program (Beste *et al.*, 2016; Crowley *et al*., 2017; Salgia *et al*., 2014). The Pacific Northwest Veteran Integrated Service Network (VISN) branch serves 135 counties between Alaska, Washington, Oregon, Idaho, Montana, and California (Crowley *et al.*, 2017). By adding kidney specialty care to the Seattle and Portland hubs, SCAN-ECHO has successfully overcome geographical barriers to care by serving four VA medical centers, 28 VA community-based outpatient clinics, and twelve VA outreach clinics (Crowley *et al*., 2017).

Limitations of adopting telenephrology.

While telenephrology programs have exhibited potential for benefit, there are essential considerations to take when implementing these services. Factors like access to internet, user ability and preference, physical exam limitations, literacy and language barriers, infrastructure, security, and fragmentation of healthcare are worthy of attention when implementing and evaluating telenephrology programs (Batsis *et al.*, 2019; Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Lew *et al.*, 2021; Osman *et al*., 2017; Ovtcharenk & Thomson, 2019; Tuot & Boulware, 2017).

Inherently, there is an ethical dilemma to rolling out telenephrology services at a large scale. Decades of population health data suggest that marginalized groups of people are at the highest risk for developing kidney disease and having more severe outcomes (CDC, 2019; Colbert, Venegas-Vera & Lerma, 2020; Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020; Lew *et al.*, 2021; Osman *et al*., 2017; Rodriguez, Hotchkiss & O'Hare, 2013; Rucker *et al.*, 2011; Shlipak *et al.*, 2021; Tonelli *et al.*, 2006; Tuot & Boulware, 2017; Yan *et al.*, 2013). However, risk factors for kidney disease may simultaneously overlap with barriers to effective use of the many forms of telenephrology (Batsis *et al.*, 2019; Diamantidis & Becker, 2014; Lederer *et al.*, 2015; Lew *et al.*, 2021; Osman *et al*., 2017; Rodriguez, Hotchkiss & O'Hare, 2013; Sarkar *et al.*, 2011; Shlipak *et al.*, 2021; Yan *et al.*, 2013). For example, patients living in rural areas with relative resource isolation are at risk for having poor access to necessary infrastructure (internet, cell coverage and technology devices), limited computer literacy, and language barriers (Batsis *et al.*, 2019; Lew *et al.*, 2021; Osman *et al*., 2017; Rodriguez, Hotchkiss & O'Hare, 2013; Sarkar *et al*., 2011; Shlipak *et al.*, 2021; Yan *et al.*, 2013).

Many of the larger trials conducted in the U.S. have been completed through the VA system. While results from VA telenephrology service implementation support its use in rural communities, their sample populations are often overwhelming male and white, raising concern for generalizing application to other populations (Beste *et al.*, 2016; Crowley *et al*., 2017; Dubin & Rubinsky, 2019; Ishani *et al.*, 2016; Ladino *et al.*, 2016; McAdams, Cannavo & Orlander, 2014; Pichler *et al.*, 2016; Rohatgi, Tan & Mehrotra, 2015; Salgia *et al.*, 2014; Swee *et al.*, 2020; Tan *et al.*, 2018; Tuot *et al.*, 2020). One study conducted outside of the VA system found older adults, those with lower levels of education, African Americans, Latinos and Filipinos are less likely to request a password to access their patient portal and are less likely to employ the functions of it even if they had (Sarkar *et al*., 2011). The existing literature serves as evidence that many studies exclude patient populations who are most likely to experience care access barriers from their samples (Beste *et al.*, 2016; Batsis *et al.*, 2019; Dubin & Rubinsky, 2019; Ishani *et al.*, 2016; Ladino *et al.*, 2016; McAdams, Cannavo & Orlander, 2014; Pichler *et al.*, 2016; Rodriguez, Hotchkiss & O'Hare, 2013; Rohatgi, Tan & Mehrotra, 2015; Salgia *et al.*, 2014; Sarkar *et al*., 2011; Yan *et al.*, 2013). This creates challenges in elucidating impact and utility of these interventions in the most vulnerable nephrology patient populations.

There is concern for deploying telenephrology modalities through state-of-the-art technology in a patient population that is generally over the age of 65. While many younger patients navigate new technologies with ease, older adults may have trouble in obtaining care through novel devices (Batsis *et al.*, 2019; Colbert, Venegas-Vera & Lerma, 2020; Koraishy &

Rohatgi, 2020; Lew *et al.*, 2021; Osman *et al.*, 2017; Ovtcharenk & Thomson, 2019; Tuot & Boulware, 2017). To examine the *technology divide*, a systemic review of telehealth utilization in geriatric patients examined the implication of age to maintaining feasible and acceptable care (Batsis *et al.*, 2019). They found that while older adults living in the United States are the fastest growing user group of technology, this patient population may be limited by less experience in using emerging technologies, considerable age-related barriers (impaired sensory, memory and cognitive function), and the presence of multiple co-morbidities that require in-person care (Batsis *et al.*, 2019). Ultimately, the review concluded that for older adults living in rural communities, access to virtual care services can yield long-term cost-effectiveness and reduce hospital utilization and emergency department visits (Batsis *et al.*, 2019). However, there is evidence of technological literacy barriers that have strong implications for individualizing telenephrology delivery to meet the needs of nephrology patient populations.

Another limitation to telenephrology is the inability to do a comprehensive physical examination as well as an impaired ability to evaluate non-verbal communication. While this limitation is a rather obvious notion of virtual care, its implications involve a great deal of decision making from health care institutions, healthcare professionals and patients (Batsis *et al.*, 2019; Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Zuniga *et al.*, 2020). For healthcare providers, making clinical decisions to hold encounters virtually or in-person involves careful consideration of risk and benefits (Batsis *et al.*, 2019; Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Osman *et al.*, 2017; Zuniga *et al.*, 2020). While there have been advances in developing remote monitoring equipment to aid in assessing patients outside of the exam room, there presently is no technology available to replace a comprehensive physical exam (Kooman *et al.*, 2020). Ultimately, the liability and responsibility for patient safety falls upon clinicians to make judgments on when virtual care services will be unacceptable (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020).

Given the momentum of technological advancement in healthcare and everyday life, optimizing care to further incorporate the option for telehealth modalities is inevitable. However, routine assessment of the nuanced barriers and limitations to telehealth are essential so their operations can appropriately meet the needs of patients and providers and produce equitable outcomes for those with the highest risk for poor outcomes.

Telenephrology infrastructure.

Successful implementation of telenephrology services requires specific patient population and institution infrastructure. Ensuring patients and providers have the access and ability to use technological devices for the delivery of telenephrology services is fundamental (Batsis *et al.*, 2019; Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Lew *et al.*, 2021; Osman *et al*., 2017; Ovtcharenk & Thomson, 2019; Sarkar *et al*., 2011; Tuot & Boulware, 2017; Zuniga *et al.*, 2020). Distinct infrastructure requirements heavily depend on the intended use for telenephrology services. However, nearly all telenephrology interventions require healthcare institution teams to coordinate planning, implementation, and evaluation of the service (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Lew *et al.*, 2021). Furthermore, for all telenephrology interventions, there must be infrastructure in place to ensure patient information is kept private and devices are reliable (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi, 2020; Lew *et al.*, 2021).

To use telenephrology for non-dialysis interventions, much of the needed infrastructure is already positioned for use (Bowman *et al.*, 2020; Chang *et al.*, 2020; Diamantidis *et al.*, 2012;

Diamantidis *et al.*, 2013; Donald *et al.*, 2021; Ellis *et al.*, 2019; Kelly *et al.*, 2018; Kyte *et al.*, 2020; Li *et al.*, 2020; Ong *et al.*, 2016; Pew Research Center, 2019). mHealth interventions depend on patients having the access and ability to use a mobile phone (Bowman *et al.*, 2020; Diamantidis *et al.*, 2012; Diamantidis *et al.*, 2013; Ellis *et al.*, 2019; Kelly *et al.*, 2018; Li *et al.*, 2020; Ong *et al.*, 2016). With the vast majority of nephrology patients already owning and regularly using mobile or smartphone devices, these types of interventions generally do not require investment in new infrastructure but rather optimize what already exists (Bowman *et al.*, 2020; Diamantidis *et al.*, 2012; Diamantidis *et al.*, 2013; Ellis *et al.*, 2019; Kelly *et al.*, 2018; Li *et al.*, 2020; Ong *et al.*, 2016; Pew Research Center, 2019). Similarly, web-based interventions can often rely on patients having access to a smartphone, computer, and internet or cell service (Donald *et al.*, 2021; Fink *et al.*, 2016; Kyte *et al.*, 2020; Li *et al.*, 2020). Institutional infrastructure for mHealth and web-based interventions typically require personnel to plan for program implementation and evaluation as well as resources to develop websites, apps, and text messaging campaigns (Bowman *et al.*, 2020; Chang *et al.*, 2020; Diamantidis *et al.*, 2012; Diamantidis *et al.*, 2013; Donald *et al.*, 2021; Ellis *et al.*, 2019; Kelly *et al.*, 2018; Kyte *et al.*, 2020; Li *et al.*, 2020; Ong *et al.*, 2016).

To successfully implement synchronous telenephrology services, additional infrastructure is needed. While patients typically can rely on existing infrastructure like mobile phones, smartphones, landlines, and computers, institutions need to develop policies and plans for telephone or videoconference encounters (Chang *et al.*, 2020; Kelly *et al.*, 2018; Lew *et al.*, 2021; Li *et al.*, 2020; Tan *et al.*, 2018; Wallace *et al.*, 2017). Additionally, institutions may need to purchase new software or optimize existing platforms to deploy these services (Lew *et al.*, 2021; Wallace *et al.*, 2017; Warner *et al.*, 2018). Often, planning for these services will involve assigning roles to institution personnel to provide training and tech support for patients and providers (Lew *et al.*, 2021; Wallace *et al.*, 2017).

Adding remote monitoring devices to patient care introduces another level of infrastructure. While some telenephrology interventions opt to have patients use consumer accessible devices like store-bought sphygmomanometers, pulse oximeters, or scales, others incorporate devices that can transmit data directly to the patient's EMR (Donald *et al.*, 2021; Ellis *et al.*, 2019; Kooman *et al.*, 2020; Lew *et al.*, 2021; Wallace *et al.*, 2017). Regardless of choice, institutions are required to consider which devices are Food and Drug Administration (FDA) approved and whether investment in more advanced devices is economically feasible (Kooman *et al.*, 2020; Lazur, Bennet & King, 2019; Lew *et al.*, 2021; Wallace *et al.*, 2017). Furthermore, some telenephrology interventions are designed for providers to be notified if patient-monitoring devices detect out of therapeutic range recordings (Lew *et al.*, 2021). This requires institutions to develop policies for when and how often this data should be reviewed and how providers will be reimbursed for their time.

For dialysis-focused telenephrology interventions, infrastructure needs become more intensive. While patient-managed dialysis largely occurs outside of healthcare facilities, personnel and often physical space is required to initiate a home dialysis program (Burkart, 2019; Glickman & Chan, 2021; Lew *et al.*, 2021; Mailloux & Blagg, 2016; Wallace *et al.*, 2017; Young *et al.*, 2012). As PD and HHD training, encounters, and care coordination are similar, it may be beneficial to integrate their management within the same physical clinical space and processes (Lew *et al.*, 2021; Glickman & Chan, 2021). Regardless of location or process, both patients and providers need to be trained to safely operate devices and have necessary equipment available (Glickman & Chan, 2021; Lew *et al.*, 2021; Mailloux & Blagg, 2016; Wallace *et al.*, 2017; Young *et al.*, 2012). In the United States, HHD programs can be initiated and delivered by hospital- or nephrology group-owned facilities, however, the vast majority of outpatient dialysis facilities with pre-existing infrastructure are private companies, like DaVita or Fresenius (Glickman & Chan, 2021; Levin, Lingam & Janiga, 2020). Thus, development of ESRD Seamless Care Organization (ESCO) partnerships between nephrologists, dialysis clinics, and suppliers in a contiguous geographical area may prove to be the most cost-effective (Glickman & Chan, 2021; Levin, Lingam & Janiga, 2020).

In the U.S., FDA approved HHD machines include the Fresenius 2008K@home, Tablo Hemodialysis system, or NxStage (Glickman & Chan, 2021). The Fresenius 2008K@home machine comes with the most stipulations requiring patients to have a care partner, significant space for the device, electrical and plumbing modifications, and the ability to cover water and electricity costs (Glickman & Chan, 2021).

Methods

This project offers a proposal for implementation and evaluation of telenephrology services in rural settings, using the Pan-American Health Organization – World Health Organization (PAHO-WHO) Framework for the Implementation of a Telemedicine Service and Model for Assessment of Telemedicine Application (MAST) as a guide (Kidholm *et al.*, 2012; PAHO-WHO, 2016). Given the heterogenous nature of rural spaces in the U.S., implementation and evaluation strategies are presented in a way that allows for adaptation to meet the individual needs of nephrology practices operating in rural Western Washington.

Telenephrology Program Implementation

Program implementation begins with a strategic analysis of the context, setting needs, culture, and sustainability. This analysis then becomes the foundational guide to organize formation of a coordination team including the necessary authorities, stakeholders, and work team. The coordination team works collaboratively towards program implementation through planning for policy development, evaluation and monitoring, communication systems, business models, technology, infrastructure, legal, and regulatory issues. Once telenephrology services have been implemented, evaluation and monitoring of the program commence. See Figure 2 for a detailed illustration of these processes with order of operation.

Given the unique circumstances imposed by the COVID-19 pandemic, many facilities have already worked through or bypassed steps in the planning process and are currently offering some form of telenephrology service. For institutions at or beyond the service implementation phase, these critical steps in program planning can still serve as a guide for building program capacity and sustainability for current services, as well as application of new telenephrology modalities and practices.

Logistics

Intended use of telenephrology program.

The potential application of telenephrology services is highly diverse in scale and intended use. Healthcare institutions must assess the needs of their respective patient populations to determine which telenephrology services would provide the best outcomes. Furthermore, an understanding of the existing healthcare service platforms both inside and outside of network is necessary to avoid redundancy and fragmentation. Through careful appraisal, an institution can identify the intended use or uses of a telenephrology program. Depending on resources and needs, institutions may need to plan for expanding the scale of services over time.

Ideally, institutions should strive to deploy telenephrology modalities to execute interventions across the span of renal disease severity. In other words, by introducing these services across the spectrum of CKD screening to ESRD management, the potential for efficiency, cost-effectiveness, and familiarity increases.

Infrastructure.

While telenephrology services afford the benefit of avoiding major construction and building projects, renovation of devices and systems will likely be required. The necessary infrastructure will rely heavily on the intended use of telenephrology services. Capitalizing on existing technology and personnel is paramount to cost-effectiveness and efficiency. For example, if a nephrology practice wanted to add remote monitoring to an existing home dialysis program, ideally the institution’s technical and EMR support services would collaborate with key stakeholders to ensure data collected in the patient’s home transmits directly into the existing EMR platform. Through this approach, resources are not wasted on transferring data between systems, learning a new platform, or recruiting new staff to achieve standard of care.

Ethical implications of telenephrology programs should be considered and mitigated for early in implementation. Infrastructure for personnel to assess need for language services and appraise age-, socioeconomic-, and disability-barriers to access are essential to achieve equitable outcomes across the receiving patient population.

Special consideration should be given to the reliability and security of new technology. Whether an institution is investing in HHD machines, remote monitoring devices, or videoconferencing software, ensuring technology meets standards and regulations is paramount. Coordination teams should review relevant FDA approval of devices and new technology accordance with HIPAA standards to ensure telenephrology services are not compromised.

To make sure telenephrology programs realize their full potential, institutions should plan for social marketing of new services. Again, this is most efficiently accomplished if institutions can capitalize on pre-existing systems and personnel. For instance, marketing of a new service with relevant information and ways to access it could be added to an institution's website or EMR patient portal.

Coordination teams should clearly identify roles of its members as well as auxiliary staff. Both staff and patients will require adequate training to appropriately deploy and use new telenephrology services. Each individual interacting with the new service should be fully aware and prepared to carry out their role and responsibilities. Coordination teams should have systems in place to regularly communicate implementation phases, outcomes, goals, and future planning.

Timeline

Timeline for telenephrology service implementation will vary greatly depending on each institution's goals for intended use, scale, pre-existing infrastructure, and prior use of telenephrology modalities. However, the order of operations generally remains unchanged regardless of context. See Figure 2 for telenephrology service implementation order of operations.

Budget

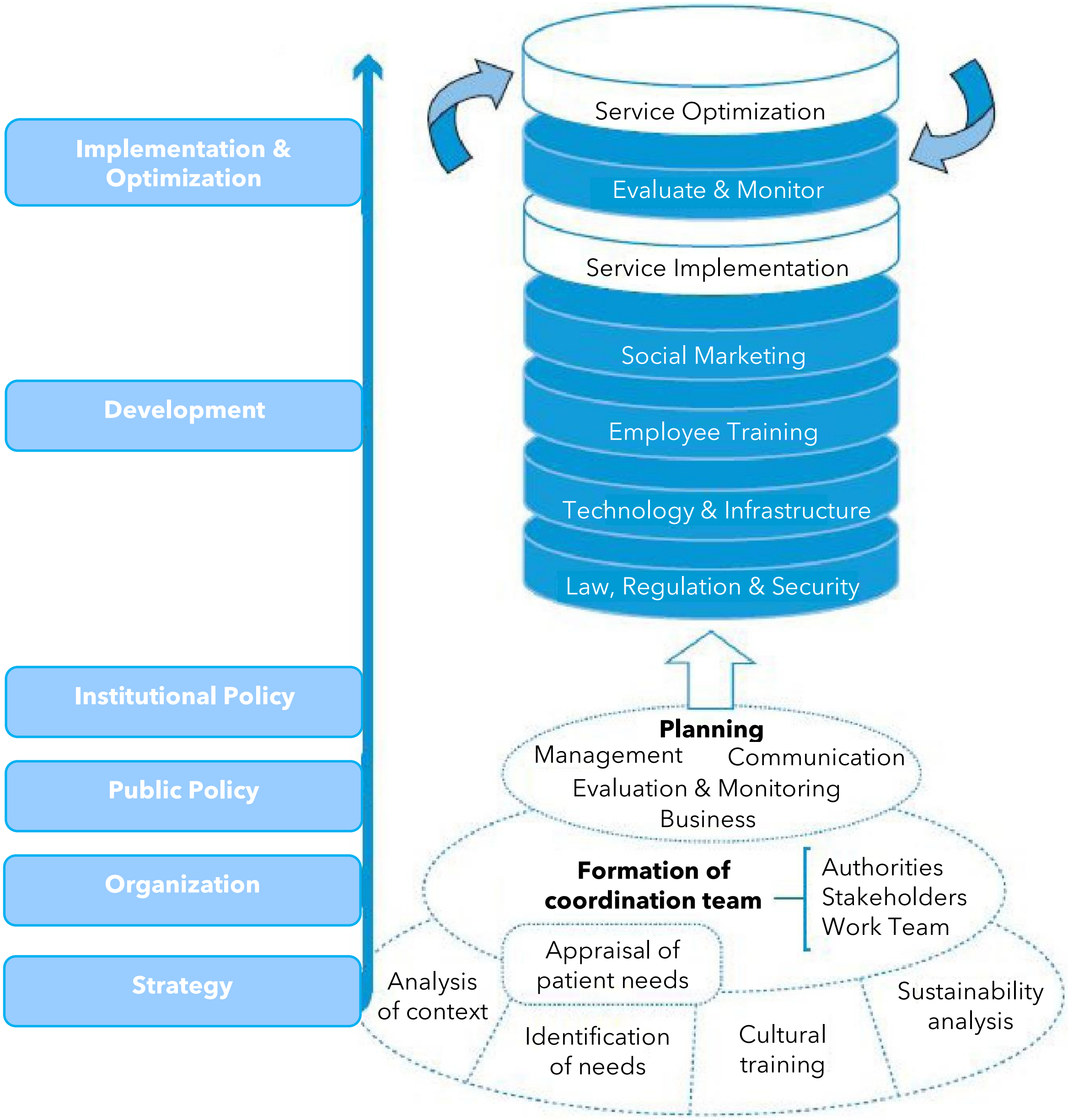
Budgeting for a new service involves various assumptions of costs, revenues, and outcomes. To appropriately inform these assumptions and subsequent cost-benefit analysis (CBA), thorough appraisal of historical budget data, new service cost, and budget projection timeline must occur. This project chose to incorporate a five-year budget timeline and pulled cost and revenue data from existing nephrology and telehealth budget data to reflect adoption of home dialysis telenephrology services. (CostHelper, 2021; Howard *et al.*, 2015; Parkman, 2014; Penner, 2016; Salary.com, 2021; Srivatana, Liu, Levine & Kalloo, 2020; Trnka *et al.*, 2015;

Zelman, McCue, Glick & Thomas, 2014). See Table 8 within Appendix E for a telenephrology services budget template.

Budgeting and CBA strategy will differ depending on whether clinics choose to offer telenephrology services in addition to standard in-person visits or adopt a service delivery that incorporate namely virtual visits and monitoring with minimal in-person encounters. Furthermore, consideration for frequency of remote-monitoring data assessment, dialysis prescription, and virtual visits with any member of the patient's nephrology care team should be made to accurately project reimbursement.

Figure 2

Telenephrology Program Model



Note. Adapted Pan-American Health Organization – World Health Organization (PAHO-WHO) Framework for the Implementation of a Telemedicine Service model for the implementation of telenephrology services.

Evaluation Plan

Considering the novelty of telenephrology services, comprehensive evaluation is critical to the success and sustainability of the program. Furthermore, reporting evaluation findings to inform and guide adoption outside of the institution is fundamental to stewarding access to these services. Using MAST as a guide for program evaluation, seven domains will be described to illustrate the necessary planning and deliverables.

Health problem and description of application.

To appropriate evaluate a telenephrology program, institutions will need to ground their evaluation in the findings of their needs assessment, goals, planning, and implementation procedures. Kidney disease in the context of an institution's particular patient population should be thoroughly described. Additionally, description of the application of the telenephrology services, technical characteristics, and current use should be included.

Safety.

The evaluation should then investigate the safety of telenephrology services. This will include the safety of patients, staff, and reliability of devices. In the program planning phase, the coordination team should arrange for systems to report and store incidents for evaluation.

Clinical effectiveness.

To ensure telenephrology services are meeting or exceeding outcomes of standard care, aspects of patient health should be routinely evaluated. These would include effects on morbidity, mortality, health-related quality of life, behavioral outcomes, and usage of services. Ideally, this would also include rates of hospitalization, days of hospitalization, and number of ED visits.

Perceptions.

Perceptions of patients, their support systems, and healthcare providers are important aspects of evaluating telenephrology services. Satisfaction, acceptance, understanding, confidence, ability, access, and self-efficacy should all be measured to inform how the program is perceived.

Economic aspects.

A societal and institution cost-benefit analysis of telenephrology services compared to standard care should be completed to identify areas in need of more efficient processes and to sustain institutional buy-in. There should be careful documentation of resource cost, resource amount, related changes in use of healthcare, and clinical effectiveness to analyze expenditures and revenues. Furthermore, economic evaluation will inform potential for scalability and expansion of services.

Organizational aspects.

From the planning phase through implementation and use of telenephrology services, documentation of resources that have been mobilized as well as resulting organizational changes should take place. In doing this, systems involved with telenephrology services can be evaluated to inform iterative assessment of processes and necessary corrections to workflow or staff roles.

Socio-cultural, ethical, and legal aspects.

Given the disparities that exist in patients with renal disease, assessment of telenephrology implications in vulnerable populations are essential to ensure equitable patient outcomes. This aspect of evaluation would include investigation of socio-cultural arenas of where the patient population dwells, ethical appraisal of service consequences, and required legal obligations.

Discussion

While the pandemic brought on an unthinkable amount of hardship across the globe, diligent community collaboration allowed for innovation of solutions to maintain the safety and wellbeing of those most vulnerable in society. Amidst the devastation, there was a catalyst to achieve revolutionary strides in healthcare technology and practice advancement that will benefit generations to come. The achievements of healthcare progression are undoubtedly groundbreaking, but widespread adoption of novel services like telenephrology require thorough planning and evaluation to ensure their future efficacy in practice.

Although telenephrology services are a relatively new and novel way of delivering healthcare, their benefit has been made evident in the literature. Studies have shown, implementation of telenephrology optimizes care to be more flexible, adaptable, and accessible. These benefits become exceedingly important in rural communities where mitigating for geographical barriers can have a positive impact on clinical outcomes. Beyond clinical outcomes, telenephrology services have been shown to improve patient quality of life and self-efficacy. Ultimately, the personal and societal impact of renal syndromes and their respective therapies can be ameliorated by removing the necessity to frequently travel to healthcare facilities and by facilitating self-monitoring and -management. When implemented appropriately, various modalities of telenephrology have proven to be a cost-benefit by reducing the number of missed appointments, airlift transportations, hospitalizations, and emergency room visits. Simultaneously, providers frequently benefit from improved workflow and reduced travel requirements to provide care.

The literature used to inform this project produced limitations of the telenephrology program plan and evaluation. The novelty of virtual care delivery resulted in a dearth of large-scale and high-quality investigation of telenephrology interventions. Adoption of telenephrology programs in the U.S. have been relatively low when compared to countries with universal healthcare like Canada and Australia. This makes generalizing more abundant reports of international program cost-effectiveness findings to the United States' private health insurance-dominated system difficult. With the majority of U.S. telenephrology studies being conducted within the VA system, findings from these investigations are limited by non-diverse samples, being predominately male and white. Furthermore, the designs, intended use, and findings from telenephrology programs are exceedingly heterogenous creating challenges in holistic appraisal. Finally, telenephrology policy, reimbursement, barriers, and culture have changed dramatically because of the COVID-19 pandemic. The short timeframe between this catalyst event and the development of this project consequently led to a paucity of evidence for telenephrology programs that have been conducted within the pandemic phenomenon. Of the literature produced during the pandemic, very few have reported clinical outcomes and cost-effectiveness, presumably due to inadequate time for assessment of these aspects. While this program plan and evaluation had to rely on historical clinical outcomes data, mitigation for the aforementioned limitations was attempted by appraising current reimbursement policy for the budget and telehealth ethical implications for the program planning, implementation, and evaluation.

Professional societies in nephrology have thwarted a call to action to consider implementation and reporting of telenephrology services in rural and underserved populations (Jain, Ahmad & Wallace, 2020; Koraishy & Rohatgi, 2020; Osman *et al.*, 2017). Furthermore, the existing literature has expressed a resounding recommendation to evaluate and mitigate for disparities in telenephrology access (Agarwal, 2020; Batsis *et al.*, 2019; Koraishy & Rohatgi, 2020; Osman *et al.*, 2017). This project was completed to satisfy the need for comprehensive review of past implementation, evidence-informed program planning, and ethical evaluation of telenephrology delivery in rural settings of Western Washington State where caring for vulnerable patient populations is the norm.

As there is a relative paucity of literature for telenephrology implementation and subsequent findings, institutions are strongly encouraged to report their processes, outcomes, and lessons learned to substantiate the need for evidence-based practice. Future studies would make meaningful contributions to the literature by planning to measure clinical outcomes, cost analyses, and ethical implications.

Conclusions

The author created this project with the purpose of developing a telenephrology program plan and evaluation for rural settings in Western Washington State, informed by relevant epidemiology, pathophysiology, standards of care, and evidence in the literature. Lewin's Change Theory was used as a theoretical framework for the telenephrology program proposal to illustrate driving and resisting forces to service delivery change. Appraisal of barriers to care for this patient population was reported and used to guide aspects of telenephrology program planning and evaluation with special consideration of access to devices, internet and cell coverage, technological literacy, and first language.

Nephrology patients constitute a group of people who are characteristically burdened with comorbidities, high costs of care, impaired quality of life and invasive interventions. In rural settings of Western Washington, many patients are living with factors shown to impede access to quality, timely management of their disease resulting in a negative compounding effect on patient outcomes. This project provides evidence to support the adoption a *new normal* for nephrology care by incorporating telenephrology services and supplies guidance for planning, implementation, and evaluation to assist healthcare providers and their institutions for successful integration of this beneficial service.

References

Agarwal, R. (2020). The aftermath of coronavirus disease of 2019: devastation or a new dawn for nephrology? *Nephrology Dialysis Transplantation*, 1-4. https://doi.org/10.1093/ndt/gfaa094

Alhamad, T., Cheng, S., & Vijayan, A. (2021). *The Washington Manual of Nephrology Subspecialty Consult*. Lippincott Williams & Wilkins.

Allon, M. (2021). Overview of hemodialysis arteriovenous fistula maintenance and thrombosis prevention. *UpToDate*.

Allon, M. (2021). Overview of hemodialysis arteriovenous graft maintenance and thrombosis prevention. *UpToDate.*

Batsis, J. A., DiMilia, P. R., Seo, L. M., Fortuna, K. L., Kennedy, M. A., Blunt, H. B., ... & Bartels, S. J. (2019). Effectiveness of ambulatory telemedicine care in older adults: a systematic review. *Journal of the American Geriatrics Society, 67*(8), 1737-1749. doi:10.1111/jgs.15959

Beerendrakumar, N., Ramamoorthy, L., & Haridasan, S. (2018). Dietary and fluid regime adherence in chronic kidney disease patients. *Journal of Caring Sciences*, *7*(1), 17.

Bieber, S. D., & Weiner, D. E. (2018). Telehealth and home dialysis: a new option for patients in the United States. *Clinical Journal of the American Society of Nephrology, 13*(8), 1288-1290.

Belcher, J. M. (2020). The Role of Telenephrology in the Management of Chronic Kidney Disease. *Kidney360, 1*, 1310–1315.

Bello, A. K., Hemmelgarn, B., Lin, M., Manns, B., Klarenbach, S., Thompson, S., ... & Alberta Kidney Disease Network. (2012). Impact of remote location on quality care delivery and relationships to adverse health outcomes in patients with diabetes and chronic kidney disease. *Nephrology Dialysis Transplantation, 27*(10), 3849-3855.

Berman, S. J., Wada, C., Minatodani, D., Halliday, T., Miyamoto, R., Lindo, J., & Jordan, P. J. (2011). Home-based preventative care in high-risk dialysis patients: a pilot study. *Telemedicine and e-Health, 17*(4), 283-287.

Berns, J. S. (2020). Maintenance dialysis in the older adult. *UpToDate*.

Bernstein, K., Zacharias, J., Blanchard, J. F., Yu, B. N., & Shaw, S. Y. (2010). Model for equitable care and outcomes for remote full care hemodialysis units. *Clinical Journal of the American Society of Nephrology, 5*(4), 645-651.

Beste, L. A., Mattox, E. A., Pichler, R., Young, B. A., Au, D. H., Kirsh, S. F., ... & Chang, M. F. (2016). Primary care team members report greater individual benefits from long-versus short-term specialty telemedicine mentorship. *Telemedicine and e-Health, 22*(8), 699-706.

Blakeman, T., Blickem, C., Kennedy, A., Reeves, D., Bower, P., Gaffney, H., ... & Rogers, A. (2014). Effect of information and telephone-guided access to community support for people with chronic kidney disease: randomised controlled trial. PloS one, 9(10), e109135.

Bleyer, A. B. (2020). Indications for initiation of dialysis in chronic kidney disease. *UpToDate*.

Bodenheimer, T., Wagner, E. H., & Grumbach, K. (2002). Improving primary care for patients with chronic illness. *JAMA*, *288*(14), 1775-1779.

Bowman, C., Lunyera, J., Alkon, A., Boulware, L. E., Russell, J. S. C., Riley, J., ... & Diamantidis, C. (2020). A Patient Safety Educational Tool for Patients With Chronic

Kidney Disease: Development and Usability Study. *JMIR Formative Research, 4*(5), e16137.

Burkart, J. M. (2019). Dialysis modality and patient outcome. *UpToDate*.

Burke, S. D., Sherr, D., & Lipman, R. D. (2014). Partnering with diabetes educators to improve patient outcomes. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *7*, 45.

Cabacungan, A. N., Diamantidis, C. J., Russell, J. S. C., Strigo, T. S., Pounds, I., Alkon, A., ... & Boulware, L. E. (2019). Development of a telehealth intervention to improve access to live donor kidney transplantation. *Transplantation Proceedings, 51*(3), 665-675.

Centers for Disease Control and Prevention. (2019). Chronic kidney disease in the United States. Retrieved April 26, 2020 from https://www.cdc.gov/kidneydisease/pdf/2019_National-Chronic-Kidney-Disease-Fact-Sheet.pdf

Centers for Disease Control and Prevention. (2017). Chronic Kidney Disease Surveillance System—United States. Retrieved April 26, 2020 from http://www.cdc.gov/ckd

Chang, A. R., Bailey-Davis, L., Hetherington, V., Ziegler, A., Yule, C., Kwiecen, S., ... & Anderson, C. (2020). Remote dietary counseling using smartphone applications in patients with stages 1-3a chronic kidney disease: a mixed methods feasibility study. *Journal of Renal Nutrition*, *30*(1), 53-60.

Colbert, G. B., Venegas-Vera, A. V., & Lerma, E. V. (2020). Utility of telemedicine in the COVID-19 era. *Reviews in Cardiovascular Medicine, 21*(4), 583-587.

Crowley, S. T., Belcher, J., Choudhury, D., Griffin, C., Pichler, R., Robey, B., ... & Mielcarek, B. (2017). Targeting access to kidney care via telehealth: The VA experience. *Advances in Chronic Kidney Disease, 24*(1), 22-30.

Diamantidis, C. J. & Becker, S. (2014). Health information technology (IT) to improve the care of patients with chronic kidney disease (CKD). *BMC Nephrology*, *15*(1), 1-6. https://doi.org/10.1186/1471-2369-15-7

Diamantidis, C. J., Bosworth, H. B., Oakes, M. M., Davenport, C. A., Pendergast, J. F., Patel, S., ... & Patel, U. D. (2018). Simultaneous Risk Factor Control Using Telehealth to Slow Progression of Diabetic Kidney Disease (STOP-DKD) study: protocol and baseline characteristics of a randomized controlled trial. Contemporary Clinical Trials, 69, 28-39.

Diamantidis, C. J., Fink, W., Yang, S., Zuckerman, M. R., Ginsberg, J., Hu, P., ... & Fink, J. C. (2013). Directed use of the internet for health information by patients with chronic kidney disease: prospective cohort study. *Journal of Medical Internet Research, 15*(11), e251.

Diamantidis, C. J., Zuckerman, M., Fink, W., Aggarwal, S., Prakash, D., & Fink, J. C. (2013). Usability testing and acceptance of an electronic medication inquiry system for CKD patients. *American Journal of Kidney Diseases, 61*(4), 644-646.

Donald, M., Beanlands, H., Straus, S. E., Smekal, M., Gil, S., Elliott, M. J., ... & Hemmelgarn, B. R. (2021). A Web-Based Self-Management Support Prototype for Adults With Chronic Kidney Disease (My Kidneys My Health): Co-Design and Usability Testing. *JMIR Formative Research, 5*(2), e22220.

Donelan, K., Barreto, E. A., Sossong, S., Michael, C., Estrada, J. J., Cohen, A. B., ... & Schwamm, L. H. (2019). Patient and clinician experiences with telehealth for patient follow-up care. *Am J Manag Care, 25*(1), 40-44.

Dubin, R. & Rubinsky, A. (2019). A digital modality decision program for patients with advanced chronic kidney disease. *JMIR Formative Research, 3*(1), e12528.

Duncan, I., Ahmed, T., Li, Q., Stetson, B., Ruggiero, L., Burton, K., ... & Fitzner, K. (2011). Assessing the value of the diabetes educator. *The Diabetes Educator*, *37*(5), 638-657.

El Khoury, C. F., Crutzen, R., Schols, J. M., Halfens, R. J., & Karavetian, M. (2020). A Dietary Mobile App for Patients Undergoing Hemodialysis: Prospective Pilot Study to Improve Dietary Intakes. *Journal of Medical Internet Research, 22*(7), e17817.

Ellis, R. J. B., Hill, J. H., Kerley, K. D., Sinha, A., Ganci, A., & Russell, C. L. (2019). The Feasibility of a Using a Smart Button Mobile Health System to Self-Track Medication Adherence and Deliver Tailored Short Message Service Text Message Feedback. *JMIR Formative Research, 3*(2), e13558.

Ensell G. (2019). Arizona Telemedicine Program Blog. Rural, inpatient dialysis is the telemedicine trifecta: improving access, improving outcomes and saving millions. https://telemedicine.arizona.edu/ blog/rural-inpatient-dialysis-telemedicine -trifecta-improving-accessimproving- outcomes-and-saving.

Fink, J. C., Doerfler, R. M., Yoffe, M. R., Diamantidis, C. J., Blumenthal, J. B., Siddiqui, T., ... & Zhan, M. (2016). Patient-reported safety events in chronic kidney disease recorded with an interactive voice-inquiry dial-response system: monthly report analysis. *Journal of Medical Internet Research, 18*(5), e125.

Gasparini, M. E., Chang, T. W., St Lezin, M., Skerry, J. E., Chan, A., & Ramaswamy, K. A. (2019). Feasibility of a telemedicine-administered, pharmacist-staffed, protocol-driven, multicenter program for kidney stone prevention in a large integrated health care system: results of a pilot program. *The Permanente Journal, 23*. doi: 10.7812/TPP/19.023

Gervera, K., & Graves, B. A. (2015). Integrating diabetes guidelines into a telehealth screening tool. *Perspectives in Health Information Management, 12*(Summer).

Hao, S., Fu, T., Wu, Q., Jin, B., Zhu, C., Hu, Z., ... & Ling, X. B. (2017). Estimating one-year risk of incident chronic kidney disease: retrospective development and validation study using electronic medical record data from the state of Maine. *JMIR Medical Informatics, 5*(3), e21.

Hardy, D., Winocour, P., Moore-Haines, K., Currie, A., Solomon, A., & Renshaw, C. (2019). ENHIDE telehealth primary care support of adults with diabetes and chronic kidney disease. *Future Healthcare Journal, 6*(1), 143.

Hayashi, A., Yamaguchi, S., Waki, K., Fujiu, K., Hanafusa, N., Nishi, T., ... & Ohe, K. (2017). Testing the feasibility and usability of a novel smartphone-based self-management support system for dialysis patients: a pilot study. *JMIR, 6*(4), e7105. doi:10.2196/resprot.7105

Hirano, K., Kobayashi, D., Kohtani, N., Uemura, Y., Ohashi, Y., Komatsu, Y., ... & Hishida, A. (2019). Optimal follow-up intervals for different stages of chronic kidney disease: a prospective observational study. *Clinical and Experimental Nephrology*, *23*(5), 613-620.

How Much Does Dialysis Cost? (2021). CostHelper. Retrieved March 19, 2021, from https://health.costhelper.com/dialysis.html.

Howard, K., McFarlane, P. A., Marshall, M. R., Eastwood, D. O., & Morton, R. L. (2015). Funding and planning: What you need to know for starting or expanding a home hemodialysis program. *Hemodialysis International, 19*. https://doi.org/10.1111/hdi.12243

Hulscher, M. E. J. L., Laurant, M. G. H., & Grol, R. P. T. M. (2003). Process evaluation on quality improvement interventions. *BMJ Quality & Safety, 12*(1), 40-46.

Ishani, A., Christopher, J., Palmer, D., Otterness, S., Clothier, B., Nugent, S., ... & Weispfennig, C. (2016). Telehealth by an interprofessional team in patients with CKD: a randomized controlled trial. American Journal of Kidney Diseases, 68(1), 41-49.

Jain, G., Ahmad, M. & Wallace, E.J. (2020). Technology, telehealth, and nephrology: The time is now. *Kindey360*, *1*(8), 834-836. Retrieved from https://kidney360 .asnjournals.org/content/1/8/834

Kaiser, P., Pipitone, O., Franklin, A., Jackson, D. R., Moore, E. A., Dubuque, C. R., ... & De Mory, A. C. (2020). A Virtual Multidisciplinary Care Program for Management of Advanced Chronic Kidney Disease: Matched Cohort Study. *Journal of Medical Internet Research, 22*(2), e17194.

Kalantar-Zadeh, K. (2013). Patient education for phosphorus management in chronic kidney disease. *Patient Preference and Adherence*, *7*, 379.

Kaminski, J. (2011). Theory applied to informatics Lewin's Change Theory. CJNI: Canadian *Journal of Nursing Informatics, 6*(1) 1-4.

Kelly, J. T., Warner, M. M., Conley, M., Reidlinger, D. P., Hoffmann, T., Craig, J., ... & Campbell, K. L. (2019). Feasibility and acceptability of telehealth coaching to promote healthy eating in chronic kidney disease: a mixed-methods process evaluation. *BMJ Open, 9*(1).

Kiberd, J., Khan, U., Stockman, C., Radhakrishnan, A., Phillips, M., Kiberd, B. A., ... & Tennankore, K. K. (2018). Effectiveness of a web-based eHealth portal for delivery of care to home dialysis patients: A single-arm pilot study. *Canadian Journal of Kidney Health and Disease, 5*, 1-11. https://journals-sagepub-com.proxy.seattleu.edu/ doi/pdf/10.1177/2054358118794415

Kidholm, K., Ekeland, A. G., Jensen, L. K., Rasmussen, J., Pedersen, C. D., Bowes, A., ... & Bech, M. (2012). A model for assessment of telemedicine applications: mast. *International Journal of Technology Assessment in Health Care, 28*(1), 44-51.

Kiousi, E., & Grapsa, E. (2015). The role of an out-patient renal clinic in renal disease management. *Journal of Translational Internal Medicine*, *3*(1), 3-7.

van Klaveren, C. W., de Jong, P. G. M., Hendriks, R. A., Luk, F., de Vries, A. P. J., van der Boog, P. J. M. & Reinders, M. E. J. (2020). Topics, Delivery Modes, and Social-Epistemological Dimensions of Web-Based Information for Patients Undergoing Renal Transplant and Living Donors During the COVID-19 Pandemic: Content Analysis. *Journal of Medical Internet Research, 22*(10), e22068.

Kobe, E. A., Diamantidis, C. J., Bosworth, H. B., Davenport, C. A., Oakes, M., Alexopoulos, A. S., ... & Crowley, M. J. (2020). Racial Differences in the Effectiveness of a Multifactorial Telehealth Intervention to Slow Diabetic Kidney Disease. *Medical Care, 58*(11), 968-973.

Kochanek, K. D., Murphy, S. L., Xu, J. Q. & Arias, E. (2019). Deaths: Final data for 2017. *National Vital Statistics Reports, 68*(9), 1-13. Hyattsville, MD: National Center for Health Statistics. https://www.cdc.gov/nchs/data/nvsr/nvsr68/nvsr68_09-508.pdf

Kooman, J. P., Wieringa, F. P., Han, M., Chaudhuri, S., van der Sande, F. M., Usvyat, L. A., & Kotanko, P. (2020). Wearable health devices and personal area networks: can they improve outcomes in haemodialysis patients?. *Nephrology Dialysis Transplantation*, *35*(2), ii43-ii50.

Koraishy, F. M., & Rohatgi, R. (2020). Telenephrology: an emerging platform for delivering renal health care. *American Journal of Kidney Diseases*.

Krishna V. N., Griffin R., Smith M. L. & Wallace E. L. (2016). Telemedicine in the Provision of Remote Peritoneal Dialysis Care: Preliminary Results. *Chicago Alternative Schools Network.*

Kyte, D., Anderson, N., Auti, R., Aiyegbusi, O. L., Bishop, J., Bissell, A., ... & Williams, J. (2020). Development of an electronic patient-reported outcome measure (ePROM) system to aid the management of patients with advanced chronic kidney disease. *Journal of Patient-reported Outcomes, 4*(1), 1-9.

Ladino, M. A., Wiley, J., Schulman, I. H., Sabucedo, A. J., Garcia, D., Cardona, J. M., ... & Echeverri, R. J. (2016). Tele-nephrology: a feasible way to improve access to care for patients with kidney disease who reside in underserved areas. *Telemedicine and e-Health, 22*(8), 650-654.

Lazur, B., Bennet, A. & King, V. (2019). The evolving policy landscape of telehealth services delivered in the home and other nonclinical settings. *Milbank Quarterly*. Retrieved from https://www.milbank.org/publications/the-evolving-policy- landscape-of-telehealth-services-delivered-in-the-homeand-other-nonclinical-settings/

Lea, J. P. & Tannenbaum, J. (2020). The role of telemedicine in providing nephrology care in rural hospitals. *Kidney360, 10*(34067). 1-10.

Lederer S, Fischer MJ, Gordon HS,Wadhwa A, Popli S, Gordon EJ. (2015). Barriers to effective communication between veterans with chronic kidney disease and their healthcare providers. *Clinical Kidney Journal, 8*(6), 766-771.

Levin, A., Stevens, P. E., Bilous, R. W., Coresh, J., De Francisco, A. L., De Jong, P. E., ... & Winearls, C. G. (2013). Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney International Supplements, 3*(1), 1-150. Retrieved from https://kdigo.org/wp-content/uploads/2017/02/KDIGO_2012_CKD_GL.pdf

Levin, D. I., Lingam, T., & Janiga, N. J. (2020). 2020 Outlook: Dialysis clinics and ESRD. *HealthCare Appraisers*. Retrieved from https://healthcareappraisers.com/2020-outlook-dialysis-clinics-and-esrd/

Lew, S. Q. & Sikka, N. (2019). Operationalizing telehealth for home dialysis patients in the United States. *American Journal of Kidney Diseases, 74*(1), 95-100.

Lew, S. Q., Wallace, E. L., Srivatana, V., Warady, B. A., Watnick, S., Hood, J., ... & Schreiber, M. J. (2021). Telehealth for home dialysis in COVID-19 and beyond: A perspective from the American society of nephrology COVID-19 home dialysis subcommittee. *American Journal of Kidney Diseases, 77*(1), 142-148.

Lewin's change theory. (2020, July 19). Nursing Theory. Retrieved March 19th, 2021, from https://nursing-theory.org/theories-and-models/lewin-change-theory

Li, W. Y., Chiu, F. C., Zeng, J. K., Li, Y. W., Huang, S. H., Yeh, H. C., ... & Yang, F. J. (2020). Mobile Health App With Social Media to Support Self-Management for Patients With Chronic Kidney Disease: Prospective Randomized Controlled Study. *Journal of Medical Internet Research, 22*(12), e19452.

Liu, N., Kim, J., Jung, Y., Arisy, A., Nicdao, M. A., Mikaheal, M., ... & Sud, K. (2017). Remote monitoring systems for chronic patients on home hemodialysis: field test of a copresence-enhanced design. *JMIR Human Factors, 4*(3), e21.

Lunney, M., Lee, R., Tang, K., Wiebe, N., Bello, A. K., Thomas, C., ... & James, M. T. (2018). Impact of telehealth interventions on processes and quality of care for patients with ESRD. *American Journal of Kidney Diseases, 72*(4), 592-600.

Mailloux, L. U. & Blagg, C. R. (2016). Home hemodialysis. *UpToDate*.

Malkina, A., & Tuot, D. S. (2018). Role of telehealth in renal replacement therapy education. In Seminars in Dialysis, 31(2), 129-134.

Mandal, A. K. (2014). Frequent office visits of patients with chronic kidney disease: Is a prelude to prevention of dialysis. *World Journal of Nephrology*, *3*(1), 1.

Manns, B. J., Taub, K., Vanderstraeten, C., Jones, H., Mills, C., Visser, M., & Mclaughlin, K. (2005). The impact of education on chronic kidney disease patients' plans to initiate dialysis with self-care dialysis: a randomized trial. *Kidney International*, *68*(4), 1777-1783.

McAdams, M., Cannavo, L., & Orlander, J. D. (2014). A medical specialty e-consult program in a VA health care system. *Federal Practitioner, 31(*5), 26-31.

McGillicuddy, J. W., Gregoski, M. J., Weiland, A. K., Rock, R. A., Brunner-Jackson, B. M., Patel, S. K., ... & Treiber, F. A. (2013). Mobile health medication adherence and blood pressure control in renal transplant recipients: a proof-of-concept randomized controlled trial. *JMIR, 2*(2), e32.

McKenzie, J. F., Neiger, B. L., & Thackeray, R. (2013). Planning, Implementing, and Evaluating Health Promotion Programs (6th ed.). Pearson.

Minatodani, D. E., & Berman, S. J. (2013). Home telehealth in high-risk dialysis patients: a 3-year study. *Telemedicine and e-Health, 19*(7), 520-522.

Mitchell, J. G., & Disney, A. P. S. (1997). Clinical applications of renal telemedicine. *Journal of Telemedicine and Telecare, 3*(3), 158-162.

Mitchell, J. G., Disney, A. P. S., & Roberts, M. (2000). Renal telemedicine to the home. *Journal of Telemedicine and Telecare, 6*(1), 59-62.

Moist, L. M., Bragg-Gresham, J. L., Pisoni, R. L., Saran, R., Akiba, T., Jacobson, S. H., ... & Port, F. K. (2008). Travel time to dialysis as a predictor of health-related quality of life, adherence, and mortality: the Dialysis Outcomes and Practice Patterns Study (DOPPS). *American Journal of Kidney Diseases, 51*(4), 641-650.

Molzahn, A. E., Bruce, A., & Shields, L. (2008). Learning from stories of people with chronic kidney disease. *Nephrology Nursing Journal, 35*(1), 13.

National Institute of Diabetes and Digestive and Kidney Diseases. (2017). Chronic Kidney Disease. Retrieved from https://www.niddk.nih.gov/health-information/kidney-disease/chronic-kidney-disease-ckd

Newcomer, K. E., Hatry, H. P., & Wholey, J. S. (2015). Handbook of practical program evaluation (4th ed.). John Wiley & Sons.

Norman, J. C. (2020). Pathophysiology: The renal system. *NetCE*. 41-77.

O'hare, A. M., Johansen, K. L., & Rodriguez, R. A. (2006). Dialysis and kidney transplantation among patients living in rural areas of the United States. *Kidney International*, *69*(2), 343-349.

Ong, S. W., Jassal, S. V., Miller, J. A., Porter, E. C., Cafazzo, J. A., Seto, E., ... & Logan, A. G. (2016). Integrating a smartphone–based self–management system into usual care of advanced CKD. *Clinical Journal of the American Society of Nephrology, 11*(6), 1054-1062.

Osman, M. A., Okel, J., Okpechi, I. G., Jindal, K. & Bello, A. K. (2017). Potential application of telenephrology to enhance global kidney care. *BMJ Global Health, 2*(e000292). doi:10.1136/bmjgh-2017-000292.

Ovtcharenko, N., & Thomson, B. K. A. (2019). Interventions to Improve Clinical Outcomes in Indigenous or Remote Patients With Chronic Kidney Disease: A Scoping Review. *Canadian Journal of Kidney Health and Disease, 6*, 1-13.

Paes-Barreto, J. G., Silva, M. I. B., Qureshi, A. R., Bregman, R., Cervante, V. F., Carrero, J. J., & Avesani, C. M. (2013). Can renal nutrition education improve adherence to a low-protein diet in patients with stages 3 to 5 chronic kidney disease?. *Journal of Renal Nutrition*, *23*(3), 164-171.

Pan American Health Organization & World Health Organization. (2016). Framework for the implementation of a telemedicine service. Washington DC: PAHO.

Parkman, T. D. (2014). United dialysis foundation Inc. business plan for Dialysite Inc. (ESRD) kidney dialysis center. *Community Health Care and Youth and Adult Education*. Retrieved March 19, 2021, from http://udfhelps.org/assets/udf_business_plan_6-16_for_clinic.pdf

Penner, S.J. (2016). Economics and Financial Management for Nurses and Nurse Leaders (3rd ed.)

Pirkle, J. L. (2019). Evaluating patients for chronic peritoneal dialysis and selection of modality. *UpToDate*.

Pichler R. H., Harris N. M., Germani M., et al. (2016). Telenephrology May Improve Rural Primary Care Provider (PCP) Satisfaction and Nephrology Care Within Veterans Affairs. *Chicago Alternative Schools Network*

Perlman, R. L., Finkelstein, F. O., Liu, L., Roys, E., Kiser, M., Eisele, G., ... & Saran, R. (2005). Quality of life in chronic kidney disease (CKD): a cross-sectional analysis in the Renal Research Institute-CKD study. *American Journal of Kidney Diseases, 45*(4), 658-666.

Pew Research Center. (2019). *Internet & Technology*. Retrieved from https://www.pewresearch .org /internet/fact-sheet/mobile/

Physician Nephrology Salary in Washington. (2021). *Salary.com*. Retrieved March 19, 2021, from https://www.salary.com/research/salary/benchmark/physician-nephrology-salary/wa.

Qunibi, W. Y. (2020). Prescribing and assessing adequate hemodialysis. *UpToDate*.

Reese, P. P., Bloom, R. D., Trofe-Clark, J., Mussell, A., Leidy, D., Levsky, S., ... & Volpp, K. (2017). Automated reminders and physician notification to promote immunosuppression adherence among kidney transplant recipients: a randomized trial. *American Journal of Kidney Diseases, 69*(3), 400-409.

Reddy, N., & Aronoff, G. R. (2016). Telehealth monitoring decreases missed treatments in new dialysis patients. *Nephrology News & Issues, 30*(8), 35-36.

Rodriguez, R. A., Hotchkiss, J. R., & O'Hare, A. M. (2013). Geographic information systems and chronic kidney disease: racial disparities, rural residence and forecasting. *Journal of Nephrology*, *26*(1), 3.

Rohatgi, R., Ross, M. J. & Majoni, S. W. (2017). Telenephrology: Current perspectives and future directions. *Kidney International*, *92*(6), 1328-1333. https://www.kidney-international.org/article/S0085-2538(17)30501-X/abstract

Rohatgi, R., Tan, J. K., & Mehrotra, A. (2015). Telenephrology for the remote management of chronic kidney disease (CKD): a retrospective cohort study. *Journal of the American Society of Nephrology, 26*(Suppl), 791A.

Rucker, D., Hemmelgarn, B. R., Lin, M., Manns, B. J., Klarenbach, S. W., Ayyalasomayajula, B., ... & Tonelli, M. (2011). Quality of care and mortality are worse in chronic kidney disease patients living in remote areas. *Kidney International, 79*(2), 210-217.

Salgia, R. J., Mullan, P. B., McCurdy, H., Sales, A., Moseley, R. H., & Su, G. L. (2014). The educational impact of the specialty care access network–extension of community healthcare outcomes program. *Telemedicine and e-Health, 20*(11), 1004-1008.

Salsberg, E., Quigley, L., Masselink, L., Wu, X., & Collins, A. (2015). The US Nephrology Workforce 2016: Developments and Trends. Washington DC*: American Society of Nephrology.*

Sarkar, U., Karter, A. J., Liu, J. Y., Adler, N. E., Nguyen, R., López, A., & Schillinger, D. (2011). Social disparities in internet patient portal use in diabetes: evidence that the digital divide extends beyond access. *Journal of the American Medical Informatics Association, 18*(3), 318-321.

Schmidt, R. J. (2020). Overview of the hemodialysis apparatus. *UpToDate*.

Shen, H., Van Der Kleij, R. M., van der Boog, P. J., Chang, X., & Chavannes, N. H. (2019). Electronic health self-management interventions for patients with chronic kidney disease: systematic review of quantitative and qualitative evidence. *Journal of Medical Internet Research, 21*(11), e12384.

Sheng, K., Zhang, P., Yao, X., Li, J., He, Y., & Chen, J. (2020). Prognostic Machine Learning Models for First-Year Mortality in Incident Hemodialysis Patients: Development and Validation Study. *JMIR Medical Informatics, 8*(10), e20578.

Shurraw, S., Hemmelgarn, B., Lin, M., Majumdar, S. R., Klarenbach, S., Manns, B., ... & Alberta Kidney Disease Network. (2011). Association between glycemic control and adverse outcomes in people with diabetes mellitus and chronic kidney disease: a population-based cohort study. *Archives of Internal Medicine*, *171*(21), 1920-1927.

Shlipak, M. G., Tummalapalli, S. L., Boulware, L. E., Grams, M. E., Ix, J. H., Jha, V., ... & Zomer, E. (2021). The case for early identification and intervention of chronic kidney disease: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference. *Kidney International, 99*(1), 34-47. Retrieved from https://www.sciencedirect.com/science/article/pii/S0085253820312102

Sicotte, C., Moqadem, K., Vasilevsky, M., Desrochers, J., & St-Gelais, M. (2011). Use of telemedicine for haemodialysis in very remote areas: the Canadian First Nations. *Journal of Telemedicine and Telecare, 17*(3), 146-149.

Singh, K., Diamantidis, C. J., Ramani, S., Bhavsar, N. A., Mara, P., Warner, J., ... & Wright-Nunes, J. (2019). Patients' and nephrologists' evaluation of patient-facing smartphone apps for CKD. *Clinical Journal of the American Society of Nephrology, 14*(4), 523-529.

Smith, K. B., Humphreys, J. S., & Wilson, M. G. (2008). Addressing the health disadvantage of rural populations: how does epidemiological evidence inform rural health policies and research?. *Australian Journal of Rural Health*, *16*(2), 56-66.

Som, A., Groenendyk, J., An, T., Patel, K., Peters, R., Polites, G., & Ross, W. R. (2017). Improving dialysis adherence for high risk patients using automated messaging: Proof of concept. *Scientific Reports, 7*(1), 1-7.

Song, X., Waitman, L. R., Alan, S. L., Robbins, D. C., Hu, Y., & Liu, M. (2020). Longitudinal Risk Prediction of Chronic Kidney Disease in Diabetic Patients Using a Temporal-Enhanced Gradient Boosting Machine: Retrospective Cohort Study. *JMIR Medical Informatics, 8*(1), e15510.

Srivatana, V., Liu, F., Levine, D. M., & Kalloo, S. D. (2020). Early Use of Telehealth in Home Dialysis during the COVID-19 Pandemic in New York City. *Kidney360, 1*(6), 524–526. https://doi.org/10.34067/kid.0001662020

Stark, S., Snetselaar, L., Piraino, B., Stone, R. A., Kim, S., Hall, B., ... & Sevick, M. A. (2011). Personal digital assistant-based self-monitoring adherence rates in 2 dialysis dietary intervention pilot studies: BalanceWise-HD and BalanceWise-PD. *Journal of Renal Nutrition, 21*(6), 492-498.

Stengel, B., Muenz, D., Tu, C., Speyer, E., de Pinho, N. A., Combe, C., ... & Zee, J. (2021). Adherence to the Kidney Disease: Improving Global Outcomes CKD Guideline in Nephrology Practice Across Countries. *Kidney International Reports, 6*(2), 437-448. Retrieved from https://www.sciencedirect.com/science/article/pii/S2468024920317964

Swee, M. L., Sanders, M. L., Phisitkul, K., Bailey, G., Thumann, A., Neuzil, N., ... & Dixon, B. S. (2020). Development and implementation of a Telenephrology dashboard for active surveillance of kidney disease: a quality improvement project. *BMC Nephrology, 21*(1), 1-10.

Tan, J., Mehrotra, A., Nadkarni, G. N., He, J. C., Langhoff, E., Post, J., ... & Rohatgi, R. (2018). Telenephrology: providing healthcare to remotely located patients with chronic kidney disease. *American Journal of Nephrology*, *47*(3), 200-207.

Tonelli, M., Klarenbach, S., Rose, C., Wiebe, N., & Gill, J. (2009). Access to kidney transplantation among remote-and rural-dwelling patients with kidney failure in the United States. *JAMA*, *301*(16), 1681-1690.

Tonelli, M., Hemmelgarn, B., Culleton, B., Klarenbach, S., Gill, J. S., Wiebe, N., ... & Alberta Kidney Disease Network. (2007). Mortality of Canadians treated by peritoneal dialysis in remote locations. *Kidney International, 72*(8), 1023-1028.

Thompson, S., Gill, J., Wang, X., Padwal, R., Pelletier, R., Bello, A., ... & Tonelli, M. (2012). Higher mortality among remote compared to rural or urban dwelling hemodialysis patients in the United States. *Kidney International, 82*(3), 352-359.

Trnka, P., & White, M., Renton, W., McTaggart, S., Burke, J., & Smith, A., (2015). A retrospective review of telehealth services for children referred to a paediatric nephrologist. *BMC Nephrology*. 16. 125. doi: 10.1186/s12882-015-0127-0.

Tuot, D.S. & Boulware, L.E. (2017). Telehealth applications to enhance chronic kidney disease knowledge and awareness among patients and providers. *Advanced Chronic Kidney Disease, 24*(1), 39-45. doi:10.1053/j.ackd.2016.11.017

Tuot, D. S., Crowley, S. T., Katz, L. A., Leung, J., Alcantara-Cadillo, D. K., Ruser, C., ... & Vassalotti, J. A. (2020). The Kidney Score Platform for Patient and Clinician Awareness, Communication, and Management of Kidney Disease: Protocol for a Mixed Methods Study. *JMIR Research Protocols, 9*(10), e22024.

Villarroel, M. A., Blackwell, D. L. & Jen, A. (2018). Tables of summary health statistics for U.S. Adults: 2018 National Health Interview Survey. *National Center for Health Statistics.* http://www.cdc.gov/nchs/nhis/SHS/tables.htm

Wallace, E. L., Rosner, M. H., Alscher, M. D., Schmitt, C. P., Jain, A., Tentori, F., ... & Sloand, J. A. (2017). Remote patient management for home dialysis patients. *Kidney International Reports, 2*(6), 1009-1017.

Warner, B. E., Velardo, C., Salvi, D., Lafferty, K., Crosbie, S., Herrington, W. G., & Haynes, R. (2018). Feasibility of telemonitoring blood pressure in patients with kidney disease (Oxford Heart and Renal Protection Study-1): Observational Study. *JMIR Cardio, 2*(2), e11332.

Washington State Department of Health. (2019). 2019 Diabetes data supplement. Retrieved April 26, 2020 https://www.doh.wa.gov/Portals/1/Documents/Pubs/140-222-DiabetesDataSupplement2019.pdf

Washington State Department of Health. (2017). Skagit County chronic disease profile. Retrieved April 26, 2020 from https://www.doh.wa.gov/portals/1/Documents/Pubs/345-271-ChronicDiseaseProfileSkagit.pdf

White, D. & Kribs, Z. (2020). CARES Act to improve options for people on home dialysis. American Society of Nephrology. Retrieved from https://www.kidneynews.org/ policy-advocacy/leading-edge/cares-act-to-improve-options-for-people-on-home-dialysis

Whitlow, M., & Wallace, E. (2019). Remote Patient Monitoring: An Important Tool in Advancing Home Dialysis. Kidney Medicine, 1(6), 327-328.

Whitten, P., & Buis, L. (2008). Use of telemedicine for haemodialysis: perceptions of patients and health-care providers, and clinical effects. *Journal of Telemedicine and Telecare, 14*(2), 75-78.

Winocour, P. H., Moore-Haines, K., Sullivan, K., Currie, A., Solomon, A., & Hardy, D. (2020). Holistic review of people with diabetes and chronic kidney disease reveals important multimorbidity and unmet clinical need: The ENHIDE diabetes renal telehealth pilot study. *Clinical Medicine, 20*(2), 133.

Ueki, K., Sasako, T., Okazaki, Y., Miyake, K., Nangaku, M., Ohashi, Y., ... & J-DOIT3 Study Group. (2021). Multifactorial intervention has a significant effect on diabetic kidney disease in patients with type 2 diabetes. *Kidney International, 99*(1), 256-266. https://doi.org/10.1016/j.kint.2020.08.012

United States Renal Data System [USRDS]. (2020). US Renal Data System 2019 Annual Data Report: Epidemiology of Kidney Disease in the United States. Retrieved from https://www.usrds.org/media/2371/2019-executive-summary.pdf

Yan, G., Cheung, A. K., Ma, J. Z., Alison, J. Y., Greene, T., Oliver, M. N., ... & Norris, K. C. (2013). The associations between race and geographic area and quality-of-care indicators in patients approaching ESRD. *Clinical Journal of the American Society of Nephrology*, *8*(4), 610-618.

Young, B. A., Chan, C., Blagg, C., Lockridge, R., Golper, T., Finkelstein, F., ... & ASN Dialysis Advisory Group. (2012). How to overcome barriers and establish a successful home HD program. *Clinical Journal of the American Society of Nephrology, 7*(12), 2023-2032.

Zelman, W. N., McCue, M. J., Glick, N. D., & Thomas, M. S. (2014). *Financial management of health care organizations: an introduction to fundamental tools, concepts, and applications*. John Wiley & Sons.

Zhai, Y. K., Zhu, W. J., Cai, Y. L., Sun, D. X., & Zhao, J. (2014). Clinical-and cost-effectiveness of telemedicine in type 2 diabetes mellitus: a systematic review and meta-analysis. *Medicine, 93*(28): e312. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4603080/

Zuniga, C., Riquelme, C., Muller, H., Vergara, G., Astorga, C., & Espinoza, M. (2020). Using telenephrology to improve access to nephrologist and global kidney management of CKD primary care patients. *Kidney International Reports, 5*(6), 920-923.

Appendix A

Key Term Definitions

Telenephrology: the application of telehealth or virtual care services to the management of nephrology patients; a modality used between the patient and their nephrologists, registered dietitians, certified diabetes educators, and other specialized members of a nephrology care team.

Telehealth: the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health, and health administration.

Virtual care: a broad term that encompasses all the ways healthcare providers remotely interact with their patients.

Nephrologist: an internist who treats disorders of the kidney, both chronic and acute, disorders of high blood pressure, fluid, electrolyte and mineral balance, and manages complications of kidney failure necessitating dialysis (removal of fluid and body wastes) when the kidneys do not function.

Certified Diabetes Educator: a health professional who specializes in educating, supporting, and promoting self-management of diabetes.

Registered Dietitian: food and nutrition experts who can translate the science of nutrition into practical solutions for healthy living.

Kidney Disease: impaired kidney function often characterized by nephrosis (severe loss of plasma protein in the urine) and/or nephritic (inflammation often presenting with blood in the urine) syndromes.

Chronic Kidney Disease: the gradual loss of kidney function evidenced by the syndromes of kidney disease. Symptoms usually do not become apparent until the kidney has become significantly impaired.

End Stage Renal Disease: the final and permanent stage of chronic kidney disease, where kidney function has declined to the point that the kidneys can no longer function on their own. Patients with end stage renal disease then rely on renal replacement therapies like dialysis or kidney transplantation.

Estimated Glomerular Filtration Rate: a calculated estimation of kidney function using a serum creatinine blood test. The calculation factors in serum creatinine, age, body size and sex. This rate is used to stage kidney disease and guides many therapeutic interventions.

Renal Replacement Therapy: replaces nonendocrine kidney function in patients with acute or end stage renal failure. Renal Replacement Therapy can include continuous hemofiltration and hemodialysis, intermittent hemodialysis, and peritoneal dialysis.

Diabetic Kidney Disease: a type of chronic kidney disease caused by diabetes.

Renin Angiotensin System Inhibition: inhibition of a hormone system that regulates blood pressure, fluid, and electrolyte balance through the use of drugs like angiotensin receptor blockers and angiotensin converting enzyme inhibitors.

Glycemic Control: management of blood glucose levels through diet, lifestyle, and medications.

Hemoglobin A1c: a blood test to measure the average blood glucose over a three-month period.

Albuminuria: albumin (a protein) found in the urine, indicating kidney disease.

Serum Creatinine: a blood test used to calculate estimated glomerular filtration rate and assess kidney function.

Appendix B

Table Summarizing Kidney Disease Improving Global Outcomes Guidelines for Chronic Kidney Disease Management

Table 1

Summary of Kidney Disease Improving Global Outcomes Chronic Kidney Disease Management & Pharmacologic Guidelines

Blood Pressure Control & RAS inhibition	BP targets for both diabetic & non-diabetic adults with CKD o uAE < 30mg/24h → <140/<90 mmHg o uAE > 30mg/24h → <130/<80 mmHg Preference for ARB or ACEi antihypertensives o In all diabetic patients with CKD and uAE 30-300 mg/24h o In both diabetic & non-diabetic adults with CKD and uAE >300 mg/24h
AKI Risk	Consider all people with CKD at risk for AKI
Dietary Protein, Sodium & advice	All individuals with CKD o Receive expert dietary advice and information in the context of an education program, tailored to severity of CKD and the need to adjust sodium, phosphate, potassium, and protein intake where indicated For diabetic or non-diabetic adults with eGFR <30 mL/min o Reduce protein intake to 0.8 g/kg per day For adults with CKD o Avoid diet high in protein (>1.3 g/kg per day) o Lower dietary sodium intake to <2 g per day (5 g/day of NaCl) in adults, unless contraindicated
Glycemic Control	• Target HgbA1c of ~7% to prevent or delay progression of microvascular complications of diabetes • In patients at risk for hypoglycemia, avoid HgbA1c targets <7% • Raise HgbA1c target >7% in patients with comorbidities, limited life expectancy and risk for hypoglycemia
Lifestyle	For all adults with CKD o Undertake physical activity appropriate to cardiovascular health and tolerance o Achieve a healthy weight

Note. ARB: angiotensin receptor blocker, ACEi: angiotensin converting enzyme inhibitor, AKI: acute kidney injury, RAS: renin-angiotensin system, uAE: 24-hour urine albumin excretion, HgbA1c: hemoglobin A1c, NaCl: Sodium Chloride. (Levin et al., 2013; Stengel et al., 2021).

Appendix C

Table Summarizing the Formats and Applications of Telenephrology

Table 2

Formats of Telenephrology

Domains		Definition	Application	Advantages	Disadvantages
Synchronous (Live)	Interactive Videoconference	Use of real-time video and audio to carry out healthcare operations	• Virtual patient appointments • Provider training • Consults & referrals • Interprofessional team communication • Virtual support groups	• Reduces exposure to ID • Events take place in real- time • Potential to visually assess • Efficient communication • Reduces geographical and transportation barriers to care	• Requires internet or cell coverage • Requires technology and infrastructure for patients and providers • Unable to do hands-on assessment or management of patient
	Phone	Use of real-time audio over phone or computer application	• Patient appointments • Consults & referrals	• Reduces exposure to ID • Events take place in real- time • Efficient communication • Reduces geographical and transportation barriers to care	• Requires cell coverage • Requires technology and infrastructure for patients and providers • Unable to do hands-on assessment or management of patient
Asynchronous	Store-and-Forward	Transmission of pre-recorded or pre-developed video, audio, health data and/or images via email or patient portal for remote review	• Conveying information to patients • Consults & referrals • Screening/ prevention programs • Provider training • Compliance improvement	• Large amounts of data can be shared • Opportunity to provide individualized care	• Requires internet or cell coverage • Requires technology and infrastructure for patients and providers • Potential for misinterpretation
	Mobile Health (mHealth)	Use of SMS or other mobile messaging for communication	• Appointment and medication reminders • Screening/ prevention programs	• Opportunity to provide individualized care • Opportunity to improve compliance	• Requires cell coverage • Requires technology and infrastructure for patients and providers
	Self-monitoring and management	Integration of technology (remote monitoring devices) to measure and capture patient health data	• Management of patients in remote areas • Promoting appropriate disease management • Ex: uploaded captures of blood pressure data from home monitoring	• Opportunity to provide individualized care • Allows for long-term and continuous monitoring of health status • Reduces geographical and transportation barriers to care • Reduces exposure to ID	• Requires technology and infrastructure for patients and providers • Burden of always wearing or using device • Potential for false alarm or misuse

Note. ID: infectious disease. (Colbert, Venegas-Vera & Lerma, 2020; Koraishy & Rohatgi; 2020; Lazur, Bennett & King, 2019; Osman *et al.*, 2017; Tuot & Boulware, 2017

Appendix D

Tables 3 through 7 Summarizing the Evidence for Telenephrology Implementation by Intended Use

Table 3

Telenephrology Implementation for Screening and Primary Prevention

Intervention	Benefits	Limitations
Summary		
- Total of 6 studies - 3 studies using AI to screen or risk stratify - 4 studies using telenephrology as an early prevention tool - 1 study using telenephrology to prevent kidney stone recurrence	- Can significantly improve identifying patients who are at risk for CKD - Presumably cost-effective compared to human-powered screening - Means to achieve primary and secondary prevention	- AI models may have more utility in patients who regularly access care - Newer studies do not yet have outcomes available to guide current practice - Some study samples make it difficult to generalize outcomes to other populations
Song *et al.*, 2020		
- AI analysis of EHR for 1-year CKD diagnosis prediction - Dynamically updates with new events in patient timeline - Patients with diabetes - Based in U.S.	- Out-performed validated models - Can significantly improve identifying patients who are at risk for CKD - Presumably cost-effective compared to human-powered screening	- Favors patients who follow up with provider as recommended → utility concern for patients with barriers to standard care
Swee *et al.*, 2020		
- Telenephrology dashboard for active surveillance of kidney disease - Use of EMR data for screening - Linked identified patients with virtual nephrology consult - VA branch patient panel - Based in U.S.	- Identified 459 of 1284 patients that were at risk for kidney disease - Identified patients were offered virtual consult with nephrologist - Patients saved between \$21.60 and \$63.90 per trip by using virtual consult - Number of steps to complete a consult request decreased from 13 to 9 - Improved early detection and identification of disease - Improved access to care for rural populations	- Number of days for completion of consultation did not change - 97.4% male sample - Measures for clinical outcomes forthcoming - Pilot program
Sheng *et al.*, 2020		
- Prognostic AI for 1st year mortality in patients using HD - Model performance testing - Based in China	- Developed and validated 2 machine learning models to predict 1st year mortality in patients undergoing HD	- Relationships between data may change over time with advances in treatments and changes in the population - Training data was taken from a single dialysis center

	- Helps identify high-risk patients beginning HD and allows for risk stratification - Sample from 97 different dialysis centers - Presumably cost-effective	- Non-diverse sample; Chinese patients only - Only designed to predict 1st year mortality
	Tuot *et al.*, 2020	
- App to encourage behavior change, awareness, education, and enabling for patients at risk for and living with CKD - Pilot study through the VA - Based in U.S.	- Used patient and clinician input to identify behavior changes suitable for intervention and barriers to behavior change - Provides patients a risk calculator that outputs information individualized to the patient's calculated risk - Provides clinicians with a clinical practice toolkit that assist in discussing and managing patients' risk for CKD - Aimed to prevent disease - Aimed to encourage self-efficacy	- Results forthcoming
	Gasparini *et al.*, 2019	
- Kidney stone prevention organized by urologists and implemented by clinical pharmacists - Metabolic workup and dietary counseling via telephone - Northern California Kaiser Permanente - Feasibility pilot program - Based in U.S.	- 99% of the 500 patients enrolled in the program reported compliance with dietary advice - 80% completed a metabolic workup within a year - Significant improvement in all urinary parameters in patients with calcium stones - Patients with major risk factors for renal tubular acidosis were referred to nephrology - Potentially cost-effective	- Males>females
	Hao *et al.*, 2017	
- Screening for 1-year relative risk for CKD with EHR data - Retrospective Cohort study - Evaluated model with health records of 95% of the population in the state of Maine - Based in U.S.	- Stratifies patients into three levels of risk - Study showed the model was effective a risk classification - Can significantly improve identifying patients who are at risk for CKD - Presumably cost-effective compared to human-powered screening	- Patients with unidentified presence of CKD may have been included in the study - Did not factor in geographical, environmental, and racial disparities

Table 4
Telenephrology Implementation for General Nephrology Care

Intervention	Benefits	Limitations
Summary		
- Total of 17 interventions - 8 interventions incorporated virtual visits - 7 interventions incorporated self-management - 8 interventions incorporated self-monitoring - 6 interventions incorporated educational information - 5 interventions had a focus on rural or remote populations	- Improved access to care for patients in rural areas - Improved access to care for patients with transportation issues or who are frail or disabled - Efficient and accessible patient education - High patient and provider satisfaction - Improved surrogate measures - Clinical outcomes meet or exceed standard care - Cost-effective modalities of care	- Lack of long-term outcomes data - Many study samples make it difficult to generalize outcomes to other populations - Many studies had small sample sizes - Limited physical exams - Unknown reliability of smartphone apps and some remote monitoring devices - Initial cost of equipment and infrastructure
Donald *et al.*, 2021		
- Web-based self-management support for adults with CKD - (My Kidneys My Health) - Prototype co-design and usability testing - Patients with CKD (non-dialysis and non-transplant) - Based in Canada	- Usability scores were high (mean= 90/100) - Patient reported useful features including the personalized food tool, healthcare provider question list, symptom guidance based on CKD severity, and medication advice - Designed for patients and their caregivers/support system - Content is tailored to the patient - Used patient, caregiver, clinician, researcher, software developer, graphic designer and policy maker input to design the system and study - Patient-centered and theory informed design - Encourages self-monitoring and self-management	- Small sample size; 18 participants for focus groups and 5 participants for usability testing - Males>females - Urban participants>rural participants - All white participants - All participants had internet and electronic device access - Feasibility and larger study forthcoming

	- Addresses barriers with in-person visits and management	
Bowman *et al*., 2020		
- Mobile tablet-based educational tool to promote patient awareness of CKD safety; NSAIDS, hypoglycemia, AKI prevention, and contrast dye risk - Patients with any stage of CKD - Development and usability pilot study - Based in U.S.	- 10 patients completed at least 90% of the modules - 7 participants rated the system as "very easy to use" - 10 participants said the activity length was appropriate and helpful - All participants said they would recommend the system to others - Incorporated patient feedback to enhance the system - Median rating of the system was 8 out of 10 (10 being the best)	- Small sample size; 12 - All participants already owned a mobile phone and used it daily - Pilot study
Chang *et al.*, 2020		
- RD tele-counseling in rural settings - Smartphone app and phone calls - Based in U.S.	- Participants reported high satisfaction with the intervention - Improved dietary sodium intake, weight, daytime blood pressure and healthy eating index (HEI)-2015 scores - Addressed barriers of dietitian availability, travel distance, and cost	- 8-week intervention - No clinical outcomes measured
Diamantidis *et al.*, 2018 & Kobe *et al.*, 2020		
- Simultaneous risk factor control using telehealth to slow progression of DKD (STOP-DKD) - Multifactorial behavioral and medication management intervention to mitigate kidney function decline at 3 years compared to usual care - Patients with DM, uncontrolled HTN, and evidence of kidney dysfunction - RCT	- Among African American participants, the intervention arm had significantly greater preservation of eGFR - May be a beneficial intervention for African Americans - Patients from 7 primary care clinics	- No difference in attenuation of kidney function decline of the sample as a whole - Non-African Americans paradoxically had worse outcomes (potentially type 1 error or there may be a threshold for interventions becoming detrimental in populations that already have good access to care at baseline)

- Pharmacist telephone education modules, home blood pressure monitoring, and medication management recommendations delivered electronically to PCPs - Based in U.S.		
Kyte *et al.*, 2020		
- electronic Patient-Reported Outcome Measure (ePROM) system: remotely self-report - symptoms using a secure online platform and share data with the clinical team in real-time via the electronic patient record - patients with advanced CKD (pre-dialysis) - pilot trial - based in U.S.	- Optimizes care - Potential to improve outcomes and reduce health service costs - incorporates longitudinal ePROM symptom data into the electronic patient record - encourages self-monitoring	- Results forthcoming
Li *et al.*, 2020		
- mHealth with social media to support self-management - patients with stage 1-4 CKD - prospective RCT - based in Taiwan	- Intervention group had higher scores of self-efficacy, self-management, QOL, steps per day, and eGFR - Decline of eGFR was significantly slower in the intervention group - Provided education and fostered community support - Encourages self-management and self-efficacy	- 49 participants (25 intervention group and 24 in control group) - Patients were provided with a wearable device → concern for cost
Ellis *et al.*, 2019		
- Smart button mHealth system to self-track medication adherence and deliver feedback over text message - Patients with stages 1-4 CKD - Pilot study - Based in U.S.	- Measured to be a feasible system to encourage medication adherence - Participants reported the text messages were encouraging - Encourages self-management and medication adherence - Presumably cost-effective	- Small sample size; 5 participants - 80% white sample - Males>females - 52-day study - Pilot study

Kelly *et al*., 2018		
- Text and phone diet coaching - Patients with stage 3-4 CKD vs standard care - RCT - Based in Australia	- Measured to be feasible and acceptable - Facilitated self-monitoring and encouraged adoption of goal setting - Patients recruited from 3 communities - Made ancillary services more accessible to rural populations	- No clinical outcomes measured
Tan *et al*., 2018; Rohatgi, Tan & Mehrotra, 2015		
- Telenephrology for remotely located patients - Telenephrology management vs in-person care - VA Renal CVT program - Retrospective review - Based in U.S.	- Improves clinic visit adherence while maintaining renal outcomes - Cancelled or no-show appointments had a significantly significant decrease (53.1% missed appointments prior to implementation and 28.5% missed appointments during intervention) in the telenephrology group - Frequency of attending appointments was greater in the telenephrology group than the in-person group - No change in composite end points (all-cause mortality, ESRD, or doubling of sCr) between groups - Improves access to rural or remote populations - Cost-effective	- Underpowered in number and follow up time to detect small differences in renal outcomes - Males>females
Warner *et al*., 2018		
- Telemonitoring blood pressure with Bluetooth device - Mean eGFR of sample; 36 - Observational study - Based in U.K.	- 52% participants provided >90% of the expected data and 72% provided >80% of the expected data. - The usability of the telemonitoring system was rated highly - Encourages self-monitoring - Efficient data collection and storage	- 25 participants - Study time of 90 days - Provided patients with the device → cost concerns - Improvements in blood pressure monitoring appeared to be short term - No measures for clinical outcomes - Males>females - Did not report race or ethnicity - Pilot study

Fink *et al*., 2016		
- Patient-reported safety events with interactive voice-inquiry dial-response system (Safe Kidney Care study) - Patients went from using paper diary to digital diary - Patients with stage 3-5 CKD - 6-month analysis report	- 54% of the 52 participants reported safety events with digital diary when only 15% reported events in paper diary previously - Physician adjudicators found about half of the reports were clinically significant with about a quarter of them requiring action - Participants reported satisfaction with the digital diary and safety reporting - Encourages self-monitoring - Presumably cost-effective	- Data is limited by patient motivation to use the system - The self-reporting system elicited a response - No measure for clinical outcomes
Ishani *et al*., 2016		
- Interprofessional team (nephrologist, nurse practitioner, nurses, clinical pharmacy specialist, psychologist, social worker, and dietitian) telehealth vs usual care - patients with moderate to advanced CKD - telehealth devices (touch screen computer and remote monitoring devices) - VA Renal CVT program - RCT - Based in U.S.	- Feasible care delivery strategy in this population - No statistically significant worsening of primary composite end point (all-cause mortality, hospitalization, ED visits, or nursing home admission - Large sample size; 451 intervention participants and 150 control participants - Oversampled patients living in rural areas to provide improved access to care	- No statistically significant evidence of superiority - Mostly white male participants; 97.3% white, 98.5% male - Potentially underpowered - High cost associated with equipment and infrastructure (installing broadband into patients' homes)
Ladino *et al*., 2016		
- VA Telenephrology for patients residing in underserved areas - Retrospective and descriptive study - All stages of CKD - Based in U.S.	- Statistically significant lowering of blood pressure - Renal function stabilized - Statistically significant improvement of potassium - Modality to overcome geographical barriers to care - Facilitated access to care for rural populations - Two-year study with participants from three counties	- 95% of patients were male - No statistically significant sCr changes over time or improvement of phosphorous and bicarbonate

Ong *et al.*, 2016		
- Smartphone based self-management system integrated into nephrology care - Non-dialysis dependent patients with advanced CKD - Behavioral elements; blood pressure monitoring & medication management, symptom assessment, and tracking lab results - Providers received alerts when treatment thresholds were crossed or critical changes occurred - Based in U.S.	- High user adherence - Statistically significant blood pressure reductions - 27% of masked hypertension cases identified - 127 medication discrepancies identified; 59% of which could have caused harm - Patients reported feeling more confident and in control - Providers perceived patients were better informed and engaged	- 6-month study - Not an RCT
Blakeman *et al.*, 2014		
- Telephone guided access to community support - RCT - Patients with stage 3 CKD	- Health-related QOL significantly higher in intervention group - Significantly better proportion of blood pressure control in intervention group - Reported cost benefit in intervention group - Supports self-management - Provides support in cost effective way - 436 sample from 24 general practices	- 6-month study - No measure for clinical outcomes
Diamantidis *et al.*, 2013		
- Directed use of internet for health information (Safe Kidney Care study) - Patients with CKD - Prospective cohort study - Based in U.S.	- Patients were able to access information about CKD safety concerns	- 28.7% of the 108 Phase I participants visited the website during the one-year observation period
Diamantidis *et al.*, 2012		
- Text, PDA, and website for medication safety - Non-dialysis dependent patients with CKD - Based in U.S.	- Patients reported satisfaction with the resource	- Findings are dated with advances in technology - Small sample; 20 participants - All participants already owned cellphones

Table 5
Telenephrology Implementation for Dialysis Care

Intervention	Benefits	Limitations
	Summary	
- A total of 16 interventions, 14 of which were studies - 5 interventions had a focus for home dialysis - 5 interventions incorporated virtual visits - 7 interventions incorporated self-management - 7 interventions incorporated self-monitoring - 4 interventions incorporated patient education - 2 interventions had a focus for appointment adherence - 3 interventions had rural or remote patient samples	- Self-management - Self-monitoring - Cost-effective - Better clinical outcomes - Improved QOL - Improved access for patients in rural or remote areas - Improved access for patients with transportation issues or who are frail or disabled - Improvement in clinical outcomes and surrogate measures - Encourage and support transplantation - Encourage and support home dialysis - Improve patient knowledge - Improve appointment and treatment adherence - Increased patient satisfaction	- Many studies did not have measures for clinical outcomes - Many studies had small sample sizes - Many were pilot studies - Many study samples make it difficult to generalize outcomes to other populations - Many interventions require significant planning and infrastructure
	El Khoury *et al.*, 2020	
- mHealth app (KELA.AE) for dietary assessment and self-monitoring - patients using HD - Pilot study - Based in United Arab Emirates	- Protein and sodium intakes improved with use of the app - Serum iron improved with use of the app	- Small sample; 23 participants - No relevant change in serum phosphorus, potassium, and albumin levels - Short timeline; 2 weeks - Pilot study
	Kaiser *et al.*, 2020	
- Virtual multidisciplinary care program for the management of ESRD (Cricket Health Program) - Mean baseline eGFR of 19 - Matched Cohort study - Based in U.S.	- Patients in the intervention cohort had significantly higher rates of starting a home dialysis treatment than in the control cohort - Patients who completed the program had significantly higher disease knowledge levels and were more likely to choose a home modality as their first dialysis choice	- Majority white male participants - Observational study → concern for unmeasured confounders - Did not systematically assess transplant and conservative care - Pilot study

	- High levels of patient satisfaction with the intervention - Incorporated a multidisciplinary team approach	
	Dubin & Rubinsky, 2019	
- Online education program to improve patient knowledge and facilitate ESRD treatment option decision making - Patients with stage 4 & 5 CKD - Pilot study through the VA - Based in U.S.	- 8 out of the 25 participants could not make an ESRD treatment choice, all participants were able to make a choice after the intervention - Proportion of participants choosing transplant nearly doubled after the intervention - Choosing PD increased from 16% before the intervention to 52% after - Significant increase in knowledge and self-efficacy score - Provided support for difficult decision making - Facilitates timely planning - Presumably cost-effective	- Small sample; 25 participants - Pilot study - No measures for clinical outcomes - Predominately white and male sample
	Kiberd *et al.*, 2018	
- eHealth portal (RelayHealth) for delivery of care to home dialysis patients - Single-arm pilot study - Patients receiving either home HD or PD - Based in Canada	- Patients reported a positive experience with the service - Patients reported satisfaction with the eHealth portal - Median monthly phone consult time decreased after adoption of the portal	- Small sample; 27 participants - High rate of patient drop-out - No clinical outcomes measured - Pilot study
	Malkina & Tuot, 2018	
- VA eHealth website - RRT education - Based in U.S.	- High website traffic suggesting consumer demand - Increases health literacy	- No study data available
	Ensell, 2017	
- In-patient dialysis telehealth - Solution to closing of dialysis unit at rural AZ hospital - Based in U.S.	- Cost-effective; transportation cost savings of ~$2.7 million - Providing specialized care to patients living in resource isolation - Provider satisfaction with service	- No study data available

Hayashi *et al.*, 2017		
- Smartphone platform (SMARTD) - Remote monitor & self-manage between in-center HD sessions vs. standard HD care - RCT - Based in Japan	- Improved QOL - Patients able to self-monitor weight, serum potassium and serum phosphorus → these surrogate measures were comparable or better than control group - Participants reported app was user friendly	- Small study size; 8 intervention participants and 10 control participants - No clinical outcomes measured
Liu *et al.*, 2017		
- Remote monitoring systems for patients using HHD - Patients using chronic/long-term HHD - Pilot program - Field test of copresence perceptions - Based in Australia	- Enhanced perception of health care professional copresence into the design to improve feelings of isolation - Overall this system improved patients' feelings of being connected with their healthcare providers - Enhanced self-monitoring and self-management - High levels of satisfaction reported from patients, providers, and nurses	- No comparison group - Only measured perceptions - Pilot study
Krishna *et al.*, 2016		
- Patients using PD in rural areas who transitioned from in-person to telehealth appointments - QOL surveys - Based in U.S.	- Improved QOL - Reduced patient travel time (~2 hrs per appointment) - Improve illness intrusiveness ratings scale	- No clinical outcomes measured
Reddy & Aronoff, 2016		
- Remote monitoring (AutheniDate software) + standard HHD care vs. standard HHD care - Patients receiving HHD - Cohort (exposed vs. not exposed) - Based in U.S.	- 44% less missed appointments with built in reminders - Patients were also able to receive education on the loaned android tablet - Allows for individualization of therapy - Encourages self-monitoring and self-management	- No statistically significant change in percent of HD sessions missed - 17 participants with intervention, 78 participants receiving standard care - Patients requiring palliative care, in long-term care centers, with cognitive deficits and who lacked support were excluded from the sample - 4-month intervention - 7/17 participants had 75% or more adherence to self-monitoring

		- Barriers technology literacy impaired participant use of program
Minatodoni & Berman, 2013; Berman *et al.*, 2011		
- Remote monitoring + standard HHD care vs. standard HHD care - RCT - Based in U.S.	- Improvement in number of hospitalizations, number of ED visits, number of hospital days if admitted - Risk for hospitalization, hospital days per study day, and Karnofsky score were comparable or better than control group - Cost effective; $91,000 savings in hospital and ED charges - Extra support for HHD care - Encourages self-monitoring and self-management	-
Sicotte *et al.*, 2011		
- Remote and satellite nephrology clinic access via videoconferencing - Patients receiving in-center HD - Cohort (pre & post) - Based in Canada	- Improvement in number of medication changes - No statistically significant change in number of transfers to hospital, number of HD sessions, blood chemistry or Kt/V - Providing telenephrology to patients in remote areas	- Small study size; 11 participants
Som *et al.*, 2011		
- Text and voice messaging + standard in-center HD care - Patients receiving in-center HD - RCT cross-over - Based in U.S.	- Median appointment adherence increased 75% - Median number of unintended hospitalization days fell by 31% - 1:36 savings ratio from appointment adherence - Low risk intervention - Targeted to high-risk, low-income and vulnerable patients - Determined visits were being missed because of feeling ill, lack of childcare resources and lack of transportation - Primarily non-white patients	- No statistically significant change in number of days hospitalized or HD attendance - Small study size; 19 participants - 12-week study
Stark *et al.*, 2011		
- Personal digital assistant dietary self-monitoring - Pilot studies for HD and PD - Based in U.S.	- Patients using both HD and PD demonstrated excellent rates of self-monitoring	- Pilot study - No measures for clinical outcomes

	- Provides support for a complicated dietary regimen	
Whitten & Buis, 2008		
- Telemedicine for HD - Cohort (cross-sectional) - Dialysis centers - Based in U.S.	- Providers and patients had positive perceptions of program - Clinical measures (Hgb, URR, albumin, Pi) met or exceeded recommendations made by Renal Network 11 - Across three centers, conducted 747 clinical consultations - Included educational events	- Despite success of program it was discontinued in 2007 due to Medicaid and Medicare policies affirming dialysis centers were not approved sites for telemedicine

Table 6
Telenephrology Implementation for Renal Transplant Care

Intervention	Benefits	Limitations
	Summary	
- A total of 3 interventions - 2 interventions had a focus for medication adherence - 1 intervention had a focus for increasing access to transplantation in vulnerable populations - 1 intervention had a rural patient sample - All 3 interventions had a focus for self-management	- Improved medication adherence - Improvement in surrogate measures - Encourage self-management - Promote access to transplantation in rural dwelling African Americans - Improved provider management of pharmacological therapies	- No studies measured for clinical outcomes - Two out of three studies did not use rural populations in their sample - Some studies have samples that excluded vulnerable populations
	Cabacungan *et al.*, 2018	
- Tablet-based education program on options for live donor kidney transplant - Translated the traditionally in-person TALK-SWI education program to virtual format with social worker counseling over phone call - African American patients with ESRD - Pilot program - Based in U.S.	- 73% of participants preferred digital version of education - 80% of participants reported they would use the digital version over in-person education - Cost-effective way to deliver information - Targeted to patients with the lowest rates of live donor kidney transplant - Focus on rural dwelling participants	- Small sample size; 15 participants - Most participants had 2+ years of college education, had internet access at home, and use the internet at least once a day → findings may not translate to different - Did not measure changes in rate of transplantation - Pilot study
	Reese *et al.*, 2017	
- Automated reminders and physician notification to promote immunosuppression adherence - Wireless-enabled pill bottles with customized reminders and provider notification - RCT (1:1:1)	- Patients in the group with wireless enabled pill bottle + reminders + provider notifications had the highest rates of medication adherence - Assists patients and providers in avoiding unintentional medication non-adherence - Creates a social incentive for adherence - Intervention aimed at timeframe with highest risk for rejection (first 6 months)	- Did not have clinical outcome measures - Patients from a single center - Exclusion criteria; poor English comprehension, and patients living 120+ miles from the center → concern with generalizing findings to relevant populations - Only measures pill bottle opening, not pill ingestion
	McGillicuddy *et al.*, 2013	
- mHealth medication adherence and blood pressure control	- Significant improvements in medication adherence and systolic blood pressures in intervention group	- 3-month trial

- notifications sent to participants reminding them to take medication - renal transplant recipients - RCT	- Physicians made more anti-hypertensive medication adjustments in intervention group - Reported to be highly acceptable and useful to patients and providers - Encourages self-management	

Table 7

Telenephrology Implementation for Provider-to-Provider

Intervention	Benefits	Limitations
Summary		
- A total of 4 interventions - 2 interventions were executed through the VA system - 1 intervention was strictly out-patient based	- Efficient and timely nephrology consults - Improve access to specialty care in rural communities - Reduce complications - More cost-effective than building new facilities - PCP/generalist education and support	- Require significant infrastructure to successfully implement - Very few studies measured for clinical outcomes
Lea & Tannenbaum, 2020		
- Connecting generalist physicians in rural hospitals with nephrologists - Provided consults for dialysis, CKD, AKI, and electrolyte disturbances - Physical exams over videoconferencing and use of electronic stethoscopes - Based in U.S.	- 78% complete or near complete renal recover after AKI - All patients had safe corrections of electrolyte disturbances within 24 hrs - Few HD complications were observed - Nephrologist satisfaction with quality of videoconference physical exam - Anecdotal evidence of hospitalist and nurse satisfaction - Improving access to nephrology care in rural hospitals in resource isolation - Review of services after two years of operation	- Nephrologists cannot remotely examine urine sediment - Lack of multi-specialty expertise at institution resulting in less complex patients - Lack of buy-in from nephrologists not employed at the hospital - Lack of EMR congruency limited implementation
Winocour *et al*., 2020; Hardy *et al*., 2019		
- ENHIDE (East and North Herts Institute of Diabetes and Endocrinology) diabetes renal telehealth - PCPs in rural areas - Focused to identify clinical needs of patients with diabetes and kidney disease - Pilot study - Based in U.S.	- specialist appraisal of PCP patient panel identified significant unmet clinical needs - Improved coordination of care - Improved provider satisfaction - Increased access to specialized care for patients in rural communities	- No measures for clinical outcomes - Pilot study
Pichler *et al*., 2016; McAdams, Cannavo & Orlander, 2014		
- VA eConsults; PCP can ask nephrologist focused clinical questions	- Saves travel time, reduces out-of-pocket expenses	- No measures for clinical outcomes

- Descriptive survey - Based in U.S.	(no-charge/co-pay clinic visits) - EMR makes eConsult and shared delivery of care feasible - Providers were satisfied with the program, endorsed improvement of knowledge, coordination of care, and felt consultation improved quality of care and job satisfaction - Reported to expedite diagnostic testing and treatment - Extends access to specialty care services - Directed adjustments to improve specialist satisfaction* → accounts for varying levels of complexity for 3 levels of RVUs	- Lower specialist satisfaction early in implementation (workload valuation) → directed adjustments* - Not a suitable delivery for all consult requests
Beste *et al.*, 2016; Salgia *et al.*, 2014		
- VA Specialty Care Access Network – Extension of Community Healthcare Outcomes (SCAN-ECHO) program with nephrology specialty - Participant (provider) survey - Based in U.S. with largest hub based out of Seattle serving the Pacific Northwest	- Strong agreement with trainings' impact on providers - strong agreement with trainings' impact on care delivery - participation for more than one year was associated with greater perceived impact, particularly perceived patient access to specialty care - extends specialized nephrology mentorship to regions experiencing resource isolation	- Clinical outcomes data reports were not found - Requires substantial infrastructure and planning - Providers serve a population that is mainly male and white

Appendix E

Table 8 Depicting a Budget Plan for Telenephrology Services

Operating Budget	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Telenephrology in Rural Healthcare Communities of Western Washington Costs						
Capital Expenditures for Telehealth	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Telehealth devices (BP monitors/Medical supplies)	10,000	0	0	0	0	10000
Hardware Packages	20,000	0	0	0	0	20000
IT training	2,000	0	0	0	0	2000
Capital Office Furniture	2500	0	0	0	0	2500
Capital Telecommunications	1000	0	0	0	0	1000
Sinking Fund (7%)	9000	0	0	0	0	9000
Miscellaneous	1000	0	0	0	0	1000
Total Capital Expenditures	**45500**	**0**	**0**	**0**	**0**	**45500**
Capital Home Health Costs to the Patient	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Equipment	7,500	0	0	0	0	7500
Plumbing costs for at home	2,000	0	0	0	0	2000
Total Home Capital Expenditures	**9,500**	**0**	**0**	**0**	**0**	**9500**
Recurring Non-salary Costs	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Apps/Software/Web Services	1800	1800	1800	1800	1800	$9,000.00
Telehealth Software (zoom)	2,400	2,400	2,400	2,400	2,400	$12,000.00
Home Hemodialysis	-7,200	-7,200	-7,200	-7,200	-7,200	-$7,200.00
Home Peritoneal Dialysis	-5,300	-5,300	-5,300	-5,300	-5,300	-$26,500.00
Medications home dialysis	-114	-114	-114	-114	-114	-$570.00
Business Insurance	6000	6000	6000	6000	6000	$30,000.00
Cleaning Services	3600	3600	3600	3600	3600	$18,000.00
Hazardous Waste Disposal	3600	3600	3600	3600	3600	$18,000.00
Laboratory Tests	13200	13200	13200	13200	13200	$66,000.00
Legal & Accounting Fees	3600	3600	3600	3600	3600	$18,000.00
Malpractice Insurance ($4 million liability)	7200	7200	7200	7200	7200	$36,000.00
Marketing	3000	3000	3000	3000	3000	$15,000.00
Medical Supplies	4000	4000	4000	4000	4000	$20,000.00
Non-Capital Laboratory Supplies	2500	2500	2500	2500	2500	$12,500.00
Non-Capital Medical Equipment	1500	1500	1500	1500	1500	$7,500.00
Non-Capital Office Equipment	1250	1250	1250	1250	1250	$6,250.00
Office Lease	48000	48000	48000	48000	48000	$240,000.00
Office Supplies	6000	6000	6000	6000	6000	$30,000.00
Professional Development	600	600	600	600	600	$3,000.00

Pharmaceuticals	4800	4800	4800	4800	4800	$24,000.00
Printing/Postage/Shipping	600	600	600	600	600	$3,000.00
Taxes & Licenses	300	300	300	300	300	$1,500.00
Telephone/Answering Service/Paging Services	5840	5840	5840	5840	5840	$29,200.00
Travel & Professional Meetings	3000	3000	3000	3000	3000	$15,000.00
Utilities	4800	4800	4800	4800	4800	$24,000.00
Miscellaneous	0	0	0	0	0	$0.00
Total Recurring Non-Salary Costs	**$114,976.00**					**$603,680.00**
Salary Costs	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Nephrologists → (5.0 FTE's) (271,761 per salary)	1358805	1358805	1358805	1358805	1358805	$6,794,025.00
Receptionist → (3.0 FTE) (32,000)	96000	96000	96000	96000	96000	$480,000.00
Nurses → (3.0 FTE) (87,000 per salary)	261000	261000	261000	261000	261000	$1,305,000.00
Medical Assistant → (3.0 FTE) (39,000 per salary)	30000	30000	30000	30000	30000	$150,000.00
Certified diabetes educators → (2.0 FTE) (87,000 per salary)	261,000	261,000	261,000	261,000	261,000	$1,305,000.00
Registered dietitians → (2.0 FTE) (68,000 per salary)	136,000	136,000	136,000	136,000	136,000	$680,000.00
Telenephrology Coordinator → (1.0 FTE) (66,000 per salary)	66,000	66,000	66,000	66,000	66,000	$330,000.00
Retirement Plan (7% matching)	2576	2576	2576	2576	2576	$12,880.00
Health Insurance	9000	9000	9000	9000	9000	$45,000.00
Miscellaneous	0	0	0	0	0	$0.00
Total Salary Costs	$2,220,381.00					$11,101,905.00
TOTAL COSTS						x
QUANTITATIVE BENEFITS	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Revenues						
Patient Care Reimbursement ($95/visit)	864,500	546000	546000	546000	546000	$3,048,500.00
Federal/State Grants	75000	75000	0	0	0	$150,000.00
Total Revenues						$3,198,500.00
Cost Avoidance	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
$ 9,900/Emergent Dialysis Cost	9,900	9,900	9,900	9,900	9,900	$49,500.00
$31,837/travel compensation	31,837	31,837	31,837	31,837	31,837	$159,185.00
Total Cost Avoidance						$208,685.00
Total Benefits						
NET						x
Cost/Benefit Ratio						x

Common Procedural Technology (CPT) code; 90966 for usual monthly home dialysis assessment.
Formulas are embedded in table to offer institutions an adaptable budget template.