IMPLEMENTING LEARNING HEALTH SYSTEMS IN THE NEPHROLOGY PROGRAM TO ENHANCE VALUE-BASED HEALTHCARE DELIVERY

By Michael Davis (Thesis) submitted

to the School of Graduate Studies in partial fulfillment of the

requirements for the degree of

Master of Science of Medicine – Clinical Epidemiology

Memorial University of Newfoundland

October 2024

St. John's, Newfoundland and Labrador

Abstract

The Health Accord for Newfoundland and Labrador recommended the creation of learning health system (LHS) to improve healthcare delivery in our province. The Nephrology Program identified two opportunities to collect data to implement improved care consistent with a local LHS: (1) decreased time on in-centre hemodialysis (ICHD) and (2) increased uptake of home dialysis. First, a direct method for calculating urea distribution volume in ICHD patients was compared to the current method of monitoring dialysis dose. The two volumes were used to calculate independent dialysis doses, Kt/V. The mean Kt/V difference was significantly higher for the direct method, a difference that was greater in obese patients and amputees. This suggests current methods overestimate volume, underestimate Kt/V, and lead to prescriptions for increased dialysis time. Second, metrics of newly started dialysis patients were analyzed for differences between ICHD and home dialysis patients and their care, to identify barriers to transitioning to home modalities. Five barriers were identified, including less pre-dialysis staff exposure and lower rates of discussions of home dialysis options. These data can be used to implement Nephrology Program LHS cycles in ongoing quality improvement initiatives, with multifaceted outcome goals in healthcare delivery, including patient care experience, population health, and health care delivery cost.

General Summary

Healthcare delivery assessment for dialysis patients requires the identification of barriers to improvement through collection of high-quality data. Two areas were identified where opportunities for improvement were known, but where barriers might exist.

First, I demonstrated the current method of monitoring dialysis dose (adequacy) overestimates the time per session in certain patients to achieve at least minimal dose requirement, compared to a more direct, but time-consuming method used in this study. Second, I reviewed existing dialysis patients, and identified five barriers that may decrease the likelihood of undertaking dialysis at home, which is associated with medically equivalent health outcomes, but with possible social and cost advantages to the patient, family, and system. These data are useful to design learning cycles of change to continue optimizing healthcare delivery in our program, with the goals to increase patient experience and value while maintaining health.

Acknowledgments

- Dr. Brendan Barrett, Supervisor
- Dr. Sean Murphy and Dr. Bryan Curtis, Supervisory Committee
- Dr. Hensley Mariathas, Statistician Consultant
- Patient Care Facilitators, Nursing Staff, and Ward Clerks at the Waterford Hospital Dialysis Unit for help including patient census acquisition, entering blood draw orders, and performing blood draws
- Lisa Emberley, the Patient Care Facilitator of the Home Dialysis Unit
- Patients of the Hemodialysis Unit of the Waterford Hospital, for consenting to participate in this study

Table of Contents

List of Tables

List of Figures

Abbreviations

1. AKI – acute kidney injury
2. APD – automated peritoneal dialysis
3. AVF – arterio-venous fistula
4. AVG – arterio-venous graft
5. BMI – body mass index
6. CAPD – continuous ambulatory peritoneal dialysis
7. CKD – chronic kidney disease
8. CKD-EPI – Chronic Kidney Disease Epidemiologic Collaboration
9. CORR – Canadian Organ Replacement Register
10. CVC – central venous catheter
11. eGFR – estimated glomerular filtration rate
12. ESKD – end stage kidney disease
13. HHD – home hemodialysis
14. HSC – Health Sciences Centre
15. ICHD – in-centre hemodialysis
16. Kt/V – dialysis dose formula
17. LHS – learning health system
18. NL – Newfoundland and Labrador
19. PD – peritoneal dialysis
20. PRI – progressive renal insufficiency
21. QOL – quality of life
22. RKF – residual kidney function
23. RR – relative risk
24. RRT – renal replacement therapy
25. STC – St. Clare's Hospital

Chapter 1: Introduction

1.1 Background – Chronic Kidney Disease and Dialysis

Chronic kidney disease (CKD) is defined as "the presence of abnormalities of kidney structure or function that persists for greater than three months"[1]. It is graded on a five-stage system based on estimated glomerular filtration rate and the amount of albumin in the urine[1]. As CKD progresses, it causes complications such as anemia, electrolyte abnormalities, mineral bone disease, fluid overload, and uremia. It also contributes to other comorbidities including cardiovascular disease and peripheral vascular disease[1].

In 2019, the prevalence of CKD in Canada was 71.9 per 1000 individuals. The highest prevalence was in rural settings (86.2 per 1000), and prevalence increased in individuals with three or more chronic diseases (281.7 per 1000)[2]. In late-stage CKD, called end stage kidney disease (ESKD), renal replacement therapy (RRT) is required to partially replace some of the functions of the kidney. RRT includes dialysis or a kidney transplant. Dialysis is an artificial treatment that replaces kidney function by removing fluid and waste products that would continue to build up in the blood and body. The general principles include filtering blood across a semi-permeable membrane against a synthetically created dialysate solution. This causes the removal of excess fluid, the removal of waste products and electrolytes that would otherwise accumulate, and in some cases the replenishment of substances that are diminished in patients[3].

Renal replacement therapy (RRT) is comprised of in-centre hemodialysis (ICHD), home dialysis, or kidney transplant. ICHD can be performed as conventional hemodialysis, with a typical dose of four hours per day, three days per week, or nocturnal hemodialysis, performed eight hours per night, three nights per week[4]. ICHD is the most common dialysis modality in Newfoundland and Labrador. Home dialysis can be performed in two ways: peritoneal dialysis (PD) and home hemodialysis (HHD)[3].

In 2021, more than 48,000 people in Canada were diagnosed with ESKD, of which 29,835 people received dialysis. There was a 24% increase in the number of patients receiving RRT between 2012-2021[5]. The proportion of people performing dialysis at home varies by country, province, and centre. It is measured as a percentage of the total dialysis population. There are currently nine countries with home dialysis prevalence greater than 20%, including Canada, Mexico, Hong Kong, Netherlands, Iceland, Finland, Denmark, Australia, and New Zealand, with Australia and New Zealand having the highest, at a combined prevalence of 29%[6]. There are practice differences in certain countries, like Australia, Mexico, and Hong Kong, where higher prevalence reflects the patient's lack of modality choice when starting dialysis. In Canada, the average prevalence of home dialysis was 24% in 2021. In the same year in Newfoundland and Labrador, the prevalence was 10.2%. In St. John's, in January 2021, there were 216 patients on dialysis, of which 20 were on home dialysis and 196 were on ICHD. Over a three-year period, the average number of patients who start on home dialysis was 9 and the average number of patients who start on ICHD was 66.

Peritoneal dialysis (PD) occurs across a semi-permeable membrane called the peritoneal membrane. Dialysate fluid is infused into the peritoneal cavity via a port, called the PD catheter, where diffusion and ultrafiltration occur across the peritoneal membrane, and the fluid is removed and discarded before the process is repeated. This can occur as continuous ambulatory peritoneal dialysis (CAPD), with manual exchanges several times per day, or automated peritoneal dialysis (APD), with a machine called a cycler that infuses and discards fluid automatically, usually during the overnight period[3]. After having a PD catheter placed by a general surgeon, interventional radiologist, or nephrologist, patients and/or their home caregivers train with home dialysis nurses for one to two weeks, before performing dialysis at home with the support of the home dialysis team. Patients are monitored at home using a connectivity platform that uploads daily data including vital signs, fill volumes, and system alarms, where nursing teams help monitor and troubleshoot issues. Absolute contraindications for PD candidacy include a non-functioning peritoneal membrane, significant adhesions or scarring from pervious surgeries, uncorrected abdominal wall hernias, or uncorrected pleuro-peritoneal or vesiculo-peritoneal shunts[7,8]. However, most patients with ESKD are eligible for assessment for PD.

Home hemodialysis (HHD) also occurs across a semi-permeable membrane, called a dialyzer. Contrasting the peritoneal membrane, this is a synthetic membrane outside the body, in the hemodialysis machine. While it is like ICHD in terms of access, dialyzer, and setup, HHD often occurs more frequently and for longer times. Therefore, blood flow, dialysis flow, and electrolyte concentrations are sometimes adjusted to account for this[9]. Suitable patients are assessed and selected on several criteria, much of which are more

stringent than for PD. The housing and social situation of a patient must be suitable to store the dialysis machine and water must be suitable for appropriate sterilization. Patients must have the willingness and ability to maintain equipment and monitor water quality, as well as the dexterity and vision to operate the machine regularly. Dialysis vascular access is provided through vascular surgery or interventional radiology, in the form of arterio-venous fistula (AVF), arterio-venous graft (AVG), or central venous catheter (CVC), and training occurs over a longer period of six to twelve weeks. Absolute medical contraindications include uncontrolled cardiac arrhythmia, uncontrolled seizure disorder, uncontrolled psychosis or anxiety disorder, ongoing injected substance use, or severe and unstable intra-dialytic hypotension[10]. Most patients are deemed eligible for assessment for HHD.

The burden of dialysis is significant and chronic. Once diagnosed with ESKD and started on dialysis, most patients require treatment for the rest of their life. The only routes to dialysis discontinuation include renal recovery (usually within the first three months of beginning dialysis), kidney transplant, or transitioning to conservative management and palliative care. Patients with CKD and those on dialysis report lower levels of quality of life (QOL) and increased mental health disorders. Hospitalizations from depression, anxiety, and substance abuse are 1.5-3x higher in patients with CKD compared to other chronic diseases[11]. Depression is the most common psychiatric disorder in ESKD patients where 26.5% of patients reported depressive symptoms by questionnaire, and 21.5% had clinically significant symptoms when assessed by clinical interviews[12]. Other factors, including duration of dialysis, number of comorbid illnesses and medications, and age, have

also been shown to be related to lower QOL in hemodialysis patients[13]. The chronicity and time-consuming characteristics of dialysis treatment have a significant impact on the QOL of patients in Newfoundland and Labrador.

1.2 Learning Health Systems

The Health Accord for Newfoundland and Labrador (NL) was published on February 17th, 2022[14]. It is a process aimed at "improving the awareness of and intervention in the social factors that influence health, and the balance of community-based and hospital-based care in Newfoundland and Labrador" over the next ten years[14]. A main recommendation by the authors was the implementation of comprehensive, effective, and sustainable learning health system (LHS)[14]. An LHS is a framework strategy that provides value-based healthcare, or high-quality and better care at a lower cost. The framework consists of the creation and routinization of learning cycles as fundamental processes of an LHS. It involves the conversion of data to knowledge, applying that knowledge to affect performance, and then collecting and analyzing changes in performance into new data to repeat the cycle[15]. This is supported by multiple pillars including scientific excellence, social engagement, technological infrastructure, policy and structure, and legal and ethical responsibility[15]. The desired outcomes of an LHS are the quintuple aims for health care improvement: patient care experience, provider care experience, population health, cost, and health equity[16]. The implementation of the LHS cycle begins with a data driven approach to the problem or opportunity. This requires the creation of data infrastructure to collect and maintain high-quality data including those derived from the day-to-day

execution of healthcare. The analysis of these data should drive decision making by applying this knowledge to create small and stepwise changes in performance and intervention at the right time for the right patient. By continuing to monitor outcomes over time, goals are reviewed, and the cycle is repeated.

The CKD and dialysis population of NL lends itself well to the implementation of an LHS. There are robust data available through the frequent interaction of patients with the health care system in clinic, for CKD patients, and in dialysis units, for dialysis patients. There is already infrastructure in place to maintain data collection and a willingness to implement change. There is also significant outcome potential through the quintuple aim. The prevalence and burden of dialysis patients provides room for improvement in both patient care experience and population health. Additionally, there is a large taxpayer cost associated with providing dialysis which may be impacted. The use of LHS cycles in our province has been prioritized. Quality of Care NL was a system created to provide "the right treatment, for the right patient at the right time"[17], and Newfoundland and Labrador Health Services has acted on the Health Accord's recommendations by creating new structures and positions aimed at incorporating LHS into practice. The basis of an LHS is high quality data.

In the nephrology program, there have been two areas identified where high quality data collection was deemed appropriate, necessary, and significant. The first was on the impact of calculating dialysis dosing of ICHD patients and how this affected the time patients spent

having each hemodialysis session. The second was the robustness of the nephrology clinic pathway and how this affected the proportion of patients receiving home dialysis.

1.3 Dialysis Dose

Dialysis dose is one method to monitor the adequacy of dialysis. It represents the amount of volume per time that must travel through the dialysis machine for the dialyzer to adequately replace the function of the kidneys. This number is calculated based on three variables: clearance (K), time (t), and volume (V), which is formed into the equation Kt/V[18]. The constant, K, represents in-vivo clearance, which is influenced by the dialyzer and its properties, including effective blood flow rate, ultrafiltration, recirculation, and dialysis fluid flow rate. This constant is calculated and observed in the properties of the dialyzer. The variable, t, represents the effective dialysis time in minutes, which is the time that the patient's blood is circulating through the dialyzer. Premature ending of treatment, alarms in the system when parts are affected, or bypass conditions can alter this. The final variable, V, represents urea distribution volume. This is proportional to the total body fluid throughout which urea is distributed, including blood, interstitial fluid, and intravascular fluid[18]. Urea, which is an organic compound comprised of carbon, oxygen, hydrogen, and nitrogen, is produced in the liver as part of protein metabolism[19]. It is used as a marker for volume as it freely crosses a cell and is therefore not considered osmotically active. By not changing osmolarity, there is no shift in water balance[19]. Located in the denominator of the Kt/V equation, volume is inversely related to dialysis dose.

In 1985, the National Cooperative Dialysis Study (NCDS) demonstrated that Kt/V calculations did have a strong effect on short-term patient outcomes including the removal from trial for medical reasons, or hospitalization within a year, leading to the adoption of Kt/V as a main method for measuring dialysis adequacy[20]. Along with several other observational data sets, reanalysis of the NCDS demonstrated that a single-pool Kt/V level of <0.8 had significantly worse outcomes of death, removal from the trial for medical reasons, or hospitalization within a year, compared to a single-pool Kt/V of 1.2[20]. The HEMO trial, published in The New England Journal of Medicine in 2002, was the only randomized control trial to compare high dose dialysis (single-pool Kt/V 1.65) with standard dose dialysis (single-pool Kt/V 1.25). There was no difference between the two groups for the primary outcome of all-cause mortality (risk reduction 4%, p=0.53), along with multiple secondary outcomes including hospitalizations from cardiac causes, infection, or non-vascular access related causes[21].

This established a Kt/V of 1.2 as a benchmark for dialysis adequacy for patients who receive a hemodialysis schedule of three times per week for four hours per treatment. Beyond 1.2, other markers such as electrolyte balance, fluid balance, and patient-reported outcomes are used to dose dialysis. It is imperative to accurately calculate dialysis dose. Achieving a higher dose may be redundant, resulting in a lower QOL and unnecessarily prolonging time spent receiving dialysis. The opportunity to decrease the length of time required for dialysis is optimal and often sought by patients.

1.4 Methods for Calculating Urea Distribution Volume

Currently the dialysis machines in St. John's use the Watson Equation to calculate urea distribution volume[22].

1.4.1 Watson Equation for Calculating Urea Distribution Volume [Litres][22]

$$Male = 2.447 - (0.09156 \times age\ [years]) + (0.1074 \times height\ [cm]) + (0.3662 \times weight\ [kg])$$

$$Female = -2.097 + (0.1069 \times height\ [cm]) + (0.2466 \times weight\ [kg])$$

The Watson Equations require data on sex, age, weight, and height, and using known constants based on population studies, calculate the urea distribution volume automatically[22]. However, this is likely not the most accurate method[19]. Dialysis populations differ largely from average. For example, in obese patients, it is hypothesized that the distribution of water in the body is not linearly proportional to the average distribution of a non-obese individual. Also, in patients with disproportionate amounts of muscle mass, such as individuals with amputations, or those suffering from paralysis, the distribution of body fluids is different from average. Therefore, it is thought that the urea distribution volume, if calculated using population-based demographic formulae, may not be accurate[23].

Alternative methods of calculating urea distribution volume exist. The urea kinetic model, for example, is considered a more precise estimate of the urea distribution volume[19].

However, the calculations are more complex and require more time. In addition, some data required such as serum urea concentrations, are not readily available, and its use is required prior to starting dialysis, creating potential delays. Currently, it is not used in practice in St. John's, NL.

1.4.2 Urea Kinetic Model for Calculating Urea Distribution Volume (Single Pool)[24]

$$\frac{Kt}{V_{SP}} = -\ln(R - 0.008 \times t) + (4 - 3.5 \times R) \times \frac{U_F}{W}$$

R = ratio of post-dialysis urea to pre-dialysis urea; t = time (hours),
U_F = ultrafiltration, W = post dialysis weight (kilograms)

The urea kinetic model requires knowledge of serum urea concentrations prior to and following the first dialysis session of the week and prior to the second dialysis session of the week. In addition, it requires pre-dialysis and post-dialysis body weights and the clearance and time variables previously discussed[24]. Using standardized formulae, the urea distribution volume can be calculated more precisely on an individual basis. Additional equations such as the equilibrated Kt/V equation exist where the single pool value calculated can be modified based on different populations, estimated from arterial or venous access, seen below.

1.4.3 Equilibrated Kt/V Estimation based on Single Pool Formula (AV)[24]

$$\frac{eKt}{V} = \frac{{}_{art}Kt}{V_{SP}} - \left(0.6 \times \frac{{}_{art}Kt / V_{SP}}{T}\right) + 0.03$$

T = time (hours), t = time (minutes)

1.4.4 Equilibrated Kt/V Estimation based on Single Pool Formula (Venous)[24]

$$\frac{eKt}{V} = \frac{\overset{\square}{ven}Kt}{V_{SP}} - \left(0.47 \times \frac{\overset{\square}{ven}Kt / V_{SP}}{T} \right) + 0.02$$

T = time (hours), t = time (minutes)

Two of the leading causes of CKD in Canada, diabetic kidney disease, secondary to diabetes mellitus, and hypertensive kidney disease, secondary to hypertension, make up more than 70% of the cases of CKD[25], and constitute a disease process called metabolic syndrome. Comorbid states of diabetes mellitus and hypertension, such as obesity and peripheral neuropathies or peripheral vascular disease, which sometimes lead to lower limb amputations, accompany this syndrome in many patients[23]. These patients have disproportionate amounts of adipose tissue and muscle mass. The current calculation of dialysis dose contains variables that do not take these differences into account[26]. A group in Ontario, Canada, compared volumes calculated with the Watson Equations to those determined by bioimpedance spectroscopy, a technology that determines total body water using different rates of electric current flows through the body. They found that volume was overestimated, and Kt/V was underestimated using the Watson Equations, particularly for those with larger waist circumferences, a surrogate marker for obesity[27]. There is no literature available that looked at Kt/V differences in relation to obesity directly or patients with amputations.

1.5 Part 1 – Purpose

The first part of this project was to compare standard and alternative methods for calculating urea distribution volume in ICHD patients, to see if there was a statistical and clinical difference in estimation of dialysis dose, especially in populations with disproportionate amounts of adipose tissue and muscle mass. By collecting these data and creating an LHS cycle, this may lead to alterations in dialysis time for certain patients, with impacts on patient care experience and cost within the quintuple aim of outcomes.

1.6 Home Dialysis Equivalencies and Advantages

A systematic review in 2020 compared QOL of patients on PD and ICHD using the 36-Item Short Form Survey (SF-36). It consisted of eight subdomains and 36 questions including: limitations due to physical health, pain, general health, energy, social functioning, emotional problems, physical functioning, and emotional well-being. In all domains, the pooled estimates were either equal to ICHD or favoured PD[28]. There have been several studies showing QOL outcomes improving on HHD as well. Kidney specific QOL outcomes improved[29] as well as an improvement in the Beck Depression Index[30] compared to ICHD. This is unsurprising as performing dialysis at home requires less weekly travel to hospitals or dialysis centres, provides more flexible scheduling, allows more privacy, and allows maintenance of employment. The benefits of home dialysis are not limited to QOL, but also patient health benefits, improvements in physical space, and cost savings.

PD has several clinical equivalencies to hemodialysis, including mortality and transition to and from renal transplant. Canadian data compiled between 2001-2004 determined the cumulative hazard ratio for death between PD and hemodialysis patients for 60 months after initiation. The hazard ratio was as low as 0.67 (favouring PD) at 6 months follow-up, and trended towards 1.0 at 30 months follow-up, remaining there until the end of follow-up[31]. These data were replicated in Australia and New Zealand[32] suggesting there is mortality equivalency between the two modalities. This likely points to the clinical situation that patients who start PD are often previously followed in clinic by a nephrologist and kidney care team and educated on CKD. This is contrasted by some of those who start with hemodialysis, which include the urgent starts in hospital and the intensive care unit. For renal transplant recipients, there was no difference in patient [Relative risk; RR = 0.95 (0.85-1.06)] or graft survival out to five years [RR = 1.05 (0.97=1.13)] between patients who had been on PD versus ICHD[33]. Similarly, after renal transplant failure, patients who subsequently dialyze with ICHD versus those who subsequently dialyze with PD have similar survival [RR = 1.05 (0.85-1.13)][34].

There are also clinical advantages to dialyzing with PD. Lysaght et al. (1991), found that residual kidney function (RKF), the function that the kidney maintains once started on dialysis, fell by 0.029ml/min/month on CAPD, compared to 0.058ml/min/month on hemodialysis. The RKF of patients on hemodialysis decreased twice as fast as those on PD[35]. Secondary analysis of the CANUSA study, showed that the relative risk of death for every 5L/week/1.73m^2 (or 0.5ml/min/1.73m^2) of RKF was 0.88, 95% CI (0.829-0.943)[36]. It appears the greater maintenance of RKF seen in in PD patients, confers a decreased relative

risk of death. When comparing PD catheter placement with arterio-venous fistula (AVF) creation, there are surgical outcome advantages. In 2012, it was found that primary failure of AVFs was 32% compared with 4.6% of PD catheters [37]. There was a trend toward significant intervention rate differences (p=0.06), with AVFs requiring 1.22 interventions per patient-year, and PD catheters requiring 0.88 interventions per patient-year[37]. This results in less visits to interventional radiology suites and operating rooms for patients on PD. Finally, there are well-established disadvantages associated with the risk of having a permanent CVC in place, which often required the patient to undergo hemodialysis. Those include sepsis and bacteremia, and the hospitalizations associated with this[38]. These risks are avoided in PD patients, who do not require permanent CVC access. In addition, Foley (2011) showed in The New England Journal of Medicine that all-cause mortality increased by 2.5-5% after the commonly scheduled two-day gap between sessions for those on hemodialysis[39]. Perl et al. (2012) analyzed Canadian Registry Data and showed that patients on PD between 2001-2010 showed no change in mortality based on day of week[40]. In summary, there is evidence to show that patients on PD have equivalent mortality and transition to and from transplant rates, as well as benefits in RKF maintenance, surgical access success, and avoidance of hemodialysis risks.

Home hemodialysis (HHD) also has multiple clinical benefits compared to ICHD. There are observational data from multiple countries showing a survival benefit for HHD. In Australia and New Zealand, the adjusted mortality hazard ratio was 0.53, 95% CI (0.41-0.68) for HHD compared to ICHD, for patients reviewed between 1996-2007[41]. A Canadian cohort review in 2010 of nocturnal HHD patients showed a 1-year survival of 95% and a 5-year

survival of 80% in these patients[42]. There are no randomized trials assessing mortality differences between HHD and ICHD, and there are likely confounding factors in these observation data.

Patients on HHD have been shown to have several reductions in cardiovascular risk factors. The Frequent Hemodialysis Network in 2011 showed an overall decreased systolic blood pressure at 12 months after dialysis initiation of 9.7mmHg, 95% CI (0.25, 16.9) in nocturnal HHD patients versus ICHD[43]. A Canadian crossover study of eight weeks duration showed a significant decrease in 24-hour ambulatory systolic blood pressure in nocturnal HHD patients versus ICHD, without any difference in post dialysis weights. This was theorized to be connected to decreases in plasma norepinephrine levels, rather than optimized extravascular fluid control[44].

A meta-analysis of observational data collected from 23 studies between 1996-2011 of patients on frequent or extended HHD showed an overall favourable reduction in left ventricular mass on two-dimensional cardiac echocardiogram. There was a mean reduction in left ventricular mass index of 31.2g/m^2, 95% CI (22.5, 39.8)[45]. There is evidence of benefits in optimizing bone and mineral metabolism, specifically serum phosphate levels, a metric which is often difficult to manage in ICHD patients. The Frequent Hemodialysis Network trial showed a mean reduction in serum phosphate concentration of 1.24mg/dl, 95% CI (0.68-1.79) in nocturnal HHD compared to ICHD. At the end of the trial, 73% of patients on nocturnal HHD did not require phosphate binder medications, compared to 8% of ICHD patients[43]. Finally, quality of sleep has been shown to improve on HHD. Restless leg

syndrome is a common issue for patients with ESKD, especially affecting these patients' ability to sleep. The FREEDOM trial, which is a prospective cohort study, found that after 12 months on HHD, patients' restless leg syndrome severity decreased from 18 to 11 on the International Restless Leg Syndrome scale, and restless leg syndrome prevalence decreased from 35% to 26%[46]. Additionally, in a small Canadian cohort study examining dialysis patients with obstructive sleep apnea, where polysomnography of 14 patients was completed during ICHD and then again 6-15 months after switching to nocturnal HHD, mean apnea hypopnea index rates decreased from 25 to 8 overall, and from 46 to 9 in the severe obstructive sleep apnea group[47]. In summary, clinical benefits in HHD patients include improved blood pressure control, better left ventricular geometry, optimized bone and mineral metabolism, and improved quality of sleep.

It should be noted that there is a selection bias in the populations used to study physical health advantages in home dialysis patients. Often, since performing dialysis at home requires a certain level of cognition, strength, and dexterity, patients who are selected to train and practice home dialysis, are younger, healthier, and carry less comorbidities. This may confound the results of the mainly observational studies, used here.

There are other advantages to home dialysis besides physical health. The current ICHD system is crowded and pressured in Newfoundland and Labrador. There are currently 10 satellite hemodialysis sites across the province, some of which operate at full capacity and have waitlisted patients. While waiting to transfer to the satellite hemodialysis site, new dialysis start patients must be dialyzed in acute care sites including St. John's, Grand Falls-

Windsor, and Corner Brook, where on-call nursing is available for dialysis units beyond normal capacity. Often these patients must relocate for weeks to months before being transferred to the satellite site nearest their home. These strains have become exacerbated by recent nursing shortages and the COVID-19 pandemic, where isolation and distancing were more often required. By increasing the number of dialysis patients performing dialysis at home, the system is less strained and crowding in units is decreased, increasing flexibility for patient transfers. This has a downstream effect for patients, who for a variety of reasons, must stay on ICHD and are not able to do dialysis at home. By allowing patients to do dialysis in the most geographically convenient site, QOL is improved. In addition, by taking the crowding strain off the system by increasing home dialysis uptake, there is a benefit for ICHD nurses and physicians by redistributing care. The coastal geography of Newfoundland and Labrador carries a unique challenge. Often patients are isolated with long driving times between remote communities and main centres or satellite units. This confers a significant burden which is lifted for patients on home dialysis.

There are also financial benefits for stakeholders who provide dialysis. In 2013, the base cost per year of treating a patient with ESKD on ICHD was $95,000-107,000. The expense of the increased complications associated with ICHD further increases the average cost per patient. Comparatively, HHD costs were $71,000-90,000 per year, and for PD, were $56,000 per year[48]. When looking at trends of developed nations, 85% of the 20 countries analyzed had a 1.25-2.35 times higher cost comparing hemodialysis to PD[49]. Comparing PD patients to ICHD patients, Wang et al., (2020) showed an average savings of $28,000 CAD saved per year[50]. In Alberta, Canada, where dialysis patients make up 0.15% of the total population

but use 4% (26.7 times) health expenditure costs, it was estimated that a PD patient costs $39,000-57,000 CAD per year, compared to the more expensive ICHD patient of approximately $100,000 per year[51]. These data should be interpreted in the context that this represents direct savings, such as nursing hours and infrastructure expenses, which can be measured, but not indirect unmeasurable costs on patients.

1.7 Field Analysis of Home Dialysis Units in North America

Several dialysis groups in North America have similarly worked to increase home dialysis prevalence and published their successful methods. The Ontario Renal Network in Canada revealed the beneficial interventions they trialed in their endeavours: pre-dialysis education and clinics, financial support for staffing, patient support, financial incentives for providers, addressing barriers to PD access, providing assisted PD and HHD, providing peritoneal dialysis in long-term care homes, creating a transitional care unit, and promoting urgent PD starts[52]. In California, United States, a group published a list of their successful interventions: increased education for nephrologists, patients, general practitioners, emergency room physicians, and surgeons involved in access creation, increased urgent PD start access, increased PD catheter placement, the engagement of a PD champion and supportive leadership, use of financial incentives, and increased pre-dialysis care[52]. The START trial in Alberta, Canada, created three intervention phases with focuses on high-quality data collection with standardized documentation and regular meetings, structured review of all new dialysis patients with detailed reporting of metrics involved in modality selection, and a collaborative quality improvement process to implement change.

They identified their successful interventions as home dialysis first policies, audit and feedback, methods to manage unplanned dialysis starts, pre-dialysis education, assisted PD, and nephrologist PD catheter placement[51]. In British Columbia, Canada, a program attributed their success to the development of three multidisciplinary working groups. The pathway-working group was tasked to document the current pathway through the dialysis program, identify key issues, and develop a future pathway, the outreach-working group incorporated early referrals, early and repeated education, and promoted early awareness and decision making, and the hybrid-self-care working group worked with satellite patients to assist and develop individualized treatment for patients previously determined to be "unstable" for home dialysis[53].

A Canadian study, with a 55-clinic cluster trial design, set out to standardize a one-size-fits-all protocol that programs can use to increase home dialysis prevalence. The process included developing a summary of current practices, reviewing guidelines, auditing, and providing feedback on clinic performance, offering educational materials to providers (including a standardized assessment tool) and patients (including posters, handouts, videos), identifying a local champion, and providing follow-up calls and recurrent education. The primary outcome, the percentage of patients on home dialysis 180 days after dialysis initiation, showed no significant difference (ARR 4%, 95% CI [-2%, 9%]) before or after the intervention[52]. As demonstrated throughout the studies in Canada and United States, there are multiple sets of interventions that have led to success in different locations, with some degree of variability among programs. There is no one recipe for

success, and it is more important to focus on unique local cultural considerations. For this reason, it is important to identify a current state map of the program in St. John's, NL.

1.8 Part 2 – Purpose

The purpose of the second part of the study is to review recently started dialysis patients to determine the current state of the dialysis start pathway and identify if there are local barriers to uptake, and therefore prevalence of home dialysis.

Two potential inefficiencies in the local dialysis program have been identified: the use of inaccurate urea distribution volume equations to determine dialysis dose, and barriers in the dialysis start pathway toward home dialysis. With direction from the Health Accord for Newfoundland and Labrador, I set out to form the basis of learning health system (LHS) cycles, the collection of high-quality data in this area, with the hope to one day transform these data into LHS cycles within the nephrology department.

Chapter 2: Methods

2.1 Methods Part 1 – Urea Distribution Volume Comparison

The first part of the project involved ICHD patients. The population targeted was adult patients, greater than 18 years old, with ESKD receiving outpatient hemodialysis three times per week at the main dialysis unit, at that time the Waterford Hospital, in St. John's, Newfoundland and Labrador. Each patient acted as their own control, comparing the calculated urea distribution volume on the same patient. The only exclusion criterion was if patients were admitted to hospital. The primary outcome was to evaluate if the Watson Formula estimates higher urea distribution volumes, and therefore, lower dialysis doses, compared to the urea kinetic model used in the equilibrated Kt/V equation in patients on hemodialysis. The secondary outcome was to evaluate if the Watson Formula calculates lower urea distribution volumes, and therefore, higher dialysis doses, compared to the urea kinetic model used in the equilibrated Kt/V equation in subpopulations with disproportionate adipose tissue and muscle mass.

Ethics approval (file number: 20170322) was granted through Health Research Ethics Authority (HREA). All data was anonymized. Permission was granted from the Research Proposals Approval Committee of Eastern health.

Consent was initially obtained prior to collection of blood with information regarding the procedures available upon request. This was performed in conjunction with a nephrologist

and hemodialysis nurses. All blood urea concentrations were resulted in Eastern Health's secure electronic patient information system, Meditech. Only members of the research team had access to these results. All data were securely collected and stored.

The procedure involved collecting blood thirty minutes prior and immediately after the first dialysis session of the week, and thirty minutes prior to the second dialysis session of the week. A dialysis nurse collected blood from the dialysis access site currently in place for each patient. This involved an AVF, AVG, or CVC. Because of this, no new peripheral access points were required. The blood was collected in a heparainized vacutainer as per standard blood draw technique. It was analyzed in the lab to determine the serum urea concentrations. Additionally, pre-dialysis and post-dialysis weights, ultrafiltration volume, and access information were noted for each patient, all using previously collected data as per standard dialysis protocol. Finally, clearance and effective dialysis time were extracted from the hemodialysis delivery system software as channeled through a dialysis specific electronic medical record, Nephrocare, to Meditech. These numbers were plotted in known urea kinetic model equations to calculate urea distribution volume, and therefore dialysis dose.

Age, sex, height, and weight were collected as variables included in the Watson Formula. These were tabulated to verify the Watson Formula produced Kt/V and back-calculated urea distribution volumes automatically reported by the current dialysis machines. Patients were classified by 20-kilogram ranges and standardized body mass index (BMI)

categories. BMI was calculated by: (weight (kg)/height (m))^2. In addition, data were collected regarding the presence or absence of lower limb amputations.

All blood samples were labeled with standard identification. Laboratory personnel, as per Eastern Health protocol, analyzed the serum to determine the concentration of urea, and then disposed of the blood. Urea concentrations were recorded in Meditech. These results, along with the previously mentioned demographic information were recorded on a secure, password-protected computer on the Memorial University server. All analysis was completed on the SPSS version 19 software, accessed through Memorial University Library. A paired sample t-test was used. In this case, two population means were determined for the same patient using two different methods to calculate urea distribution volume. One population mean is the Kt/V calculated using the urea kinetic model and the other is that calculated by the Watson Formula. Additionally, linear regression models were used to determine the coefficient of determination between the BMI data and mean Kt/V difference between the two methods.

Sample size, based on the paired sample t-test, was calculated using a standard formula and an alpha value of 0.05 and a power of 80%. The mean volume difference was estimated at two liters and a standard deviation sigma estimated at four liters. The sample size was then calculated to be 33 using this equation, accounting for paired samples. There were approximately 160 patients receiving dialysis at the specified site, so this sample size was attainable. As the objective is to specifically elicit subpopulations with differences in volumes, the aim for sample size was set higher at 50-100. Data were initially collected

from 47 patients in 2017 and an additional 42 patients in 2018, targeting the subpopulations previously mentioned.

All funding was covered by the Nephrology Department and Memorial University of Newfoundland.

2.2 Methods Part 2 – Review of Incident Dialysis Starts

The second part of the project involved a chart review of incident dialysis patients. Canadian Organ Replacement Register (CORR) is a Canadian Information System managed by the Canadian Institute of Health Information (CIHI). Each Dialysis and Transplant Program in Canada submits data to track patients from first treatment to death[54]. I aggregated CORR data of new dialysis starts between January 1st, 2019, and December 31st, 2021. All new dialysis starts occurred at either the two acute care sites in the Eastern Health Authority, Health Science Centre (HSC), and St. Clare's Hospital (STC), or the outpatient hemodialysis site, the Kidney Care Centre (KCC) which included ICHD, PD, and HHD starts. CORR data excluded patients if they died within three months of starting dialysis or if they recovered from dialysis within three months of starting dialysis. In addition, patients who subsequently moved away from the Health Authority were excluded as records were not available for review.

This CORR data provided full name, Medical Care Plan number, dialysis start date, and date of first nephrologist visit, if this occurred. The remainder of the data were collected

through Meditech and through paper charts retained by progressive renal insufficiency (PRI) nurses and home dialysis nurses. This included sex, date of birth, dialysis initiation site (HSC, STC, KCC), access type (CVC, AVF, AVG, or PD catheter), and initial dialysis modality (ICHD, PD, or HHD). Data on current disposition were collected, including access type (AVF, AVG, CVC, or PD catheter), modality (ICHD, PD, HHD, or transplant), and current dialysis site if on ICHD (HSC, STC, KCC, Carbonear Hospital, Clareville Dialysis Unit, Bonavista Hospital, Burin Hospital, Gander Hospital, St. Anthony Hospital, Labrador City Hospital, or Happy Valley Goose Bay Hospital).

Data were collected on the entry point into the dialysis pathway, including acute kidney injury (AKI), entry through PRI clinic, or through failed transplant or failed other dialysis modality. If patients entered through the PRI clinic, information was collected including the serum creatinine and estimated glomerular filtration rate using the CKD-EPI equation at first visit. Also, data were collected on the number of visits from the multidisciplinary team during the monitoring period between enrollment into the clinic and dialysis initiation, including nurses, pharmacists, social workers, and dieticians.

Data were collected on whether a renal replacement discussion occurred during this monitoring period, and if so, the date this happened. Further to this, if a discussion regarding RRT occurred and was documented, it was determined if it included home dialysis modality options, and if so, the date this occurred. For all patients, data were collected on whether a dialysis access referral was made, and if so, the date this occurred. In those patients who started ICHD, data were collected on whether a discussion about

home dialysis options was subsequently documented, and if so, the date this occurred. If home dialysis eligibility was determined, data were collected on whether the patient received education and a demonstration in the home dialysis unit, and if the patient transitioned to home dialysis, the date this occurred.

This information was collected from physician dictation letters describing encounters and discussions with patients during clinic visits. There were eight nephrologists who saw patients during this time with multiple dictation styles resulting in multiple locations of file storage within Meditech. Some were dictated using Fusion voice recognition software, appearing immediately as an electronic file. Others used Fusion back-end software, transcribed by Eastern Health clerks, appearing within one month as an electronic file. Others used personal tape recorder dictation, transcribed in different ways by administrative assistants, printed and usually scanned into multiple locations as medical records, not as an electronic file. Locations of all dictation storage sites changed over time with updates to the electronic medical record. All reasonable efforts were made to uncover and review these notes.

Attempts were made to review electronic and paper records for nursing, pharmacy, social work, and dietician encounters. Home dialysis nursing records, both electronic and paper copy, were reviewed. Objective information like access modality, site of RRT, entry point origin, and CKD-Epi-derived estimated glomerular filtration rate (eGFR) during nephrologist visits were attainable via Meditech.

Data analysis first looked at those who entered RRT via the PRI pathway. I determined the number and percentage of patients who started on ICHD, PD, and HHD, the number and percentage of patients who were male, and the mean age in years. I calculated the CKD-Epi-derived mean eGFR and the mean number of multidisciplinary visits for each group. For documentation of RRT discussion between the nephrologist and patient, home dialysis discussion between the nephrologist and patient, and vascular access referrals, the number, percentage, and mean number of months it occurred prior to starting RRT was calculated.

Data analysis of patients who started on ICHD via the PRI and AKI pathways occurred, comparing those who transitioned to home dialysis at any time prior to January 1st, 2024 (even if the patient did not remain on a home dialysis modality until the cut-off date), to those who stayed on ICHD until January 1st, 2024. The number and percentage of patients in each category was determined, along with the number and percentage of patients who were male and mean age in years of each group. In addition, the number and percentage of patients who had a home dialysis discussion after starting ICHD was determined.

Finally, the likelihood of transitioning to a home-based modality based on whether the patient had a home dialysis discussion prior to starting RRT, after starting RRT, or in total, as well as the likelihood of transitioning home if the patient had a general RRT discussion, was calculated.

Data were stored on a secure Microsoft Excel database, that was password protected through Eastern Health's Microsoft Outlook Account.

Chapter 3: Results

3.1 Results Part 1– Mean Kt/V differences comparing Watson Formula and Equilibrated Equation

In part 1, there were 89 patients analyzed. The mean Kt/V for all participants using the Watson Formula was 1.33 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.48, a mean Kt/V difference of 0.15 ($p < 0.001$), shown in Table 1.

Table 1: Mean Kt/V difference between Watson Formula and Equilibrated Equation for the overall population

Population	Watson	Equilibrated	Kt/V Difference
Overall	1.33	1.48	0.15
	p<0.001, n=89		

Next, in Table 2, analysis was based on BMI groups using the international classification of overweight individuals by the World Health Organization[55]. For those with normal BMI (BMI 18.5-25), the mean Kt/V using the Watson Formula was 1.50 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.63, a mean Kt/V difference of 0.13 ($p < 0.001$). For obese individuals (BMI >30), the mean Kt/V difference using the Watson Formula was 1.17 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.33, a mean Kt/V difference of 0.16 ($p < 0.001$). The mean Kt/V using the equilibrated

Kt/V equation was significantly greater than the mean Kt/V using the Watson Formula. As described, this was seen in the normal weight and obese groups. The Kt/V difference was greater in the obese BMI group compared to the normal BMI group.

Table 2: Mean Kt/V difference between Watson Formula and Equilibrated Equation comparing normal BMI to obese BMI

Population	Watson	Equilibrated	Kt/V Difference
Normal BMI (18.5-25.0)	1.50	1.63	0.13
	P <0.001, n=34		
Obese BMI (>30.0)	1.17	1.33	0.16
	P <0.001, n=34		

Through further subgroup analysis, non-normal BMI participants were divided into four groups: pre-obese (BMI 25-29.9), obesity class I (BMI 30-34.9), obesity class II, (BMI 35-39.9), and obesity class III (BMI ≥40). As noted in table 3, the pre-obese group had a group size of 24. For this group, the mean Kt/V using the Watson Formula was 1.34 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.47, a mean Kt/V difference of 0.13 (p <0.001). The obesity class I group had a group size of 15. For this group, the mean Kt/V using the Watson Formula was 1.19 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.36, a mean Kt/V difference of 0.17 (p = 0.005). The obesity class II group had a group size of 10. For this group, the mean Kt/V using the Watson Formula was 1.21 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.37, a mean Kt/V difference of 0.16 (p = 0.03). The obesity

class III group had a group size of 9. For this group, the mean Kt/V using the Watson Formula was 1.07 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.24, a mean Kt/V difference of 0.17 (p = 0.005).

Comparable to the overall group, the mean Kt/V consistently was greater when calculated using the equilibrated Kt/V equation compared to the standard Watson Formula. This was statistically significant across all four overweight BMI classification analyzed. The mean Kt/V difference was greater across the obesity classes compared to the normal BMI class.

Table 3: Mean Kt/V difference between Watson Formula and Equilibrated Equation by BMI obesity class

Population	Watson	Equilibrated	Kt/V Difference
Normal BMI (18.5-25.0)	1.50	1.63	0.13
	P <0.001, n=34		
Overweight (BMI 25.1-30.0)	1.34	1.47	0.13
	P <0.001, n=24		
Obesity Class I (BMI 30.1-35.0)	1.19	1.36	0.17
	P =0.005, n=15		
Obesity Class II (BMI 35.1-40.0)	1.21	1.37	0.16
	P =0.03, n=10		
Obesity Class III (BMI >40.0)	1.07	1.24	0.17
	P=0.005, n=9		

Linear regression analysis was completed using mean difference in Kt/V between the Watson Formula and the equilibrated Kt/V equations as the dependent variable and BMI as the independent variable. The regression analysis showed a correlation coefficient (R) of 0.263 (p=0.015). The linear equation relating Kt/V difference and BMI was found to be Kt/V difference = (0.00528)*(BMI) – (0.0206). Figure 1 shows a scatterplot and fit line for the data Kt/V difference and BMI.

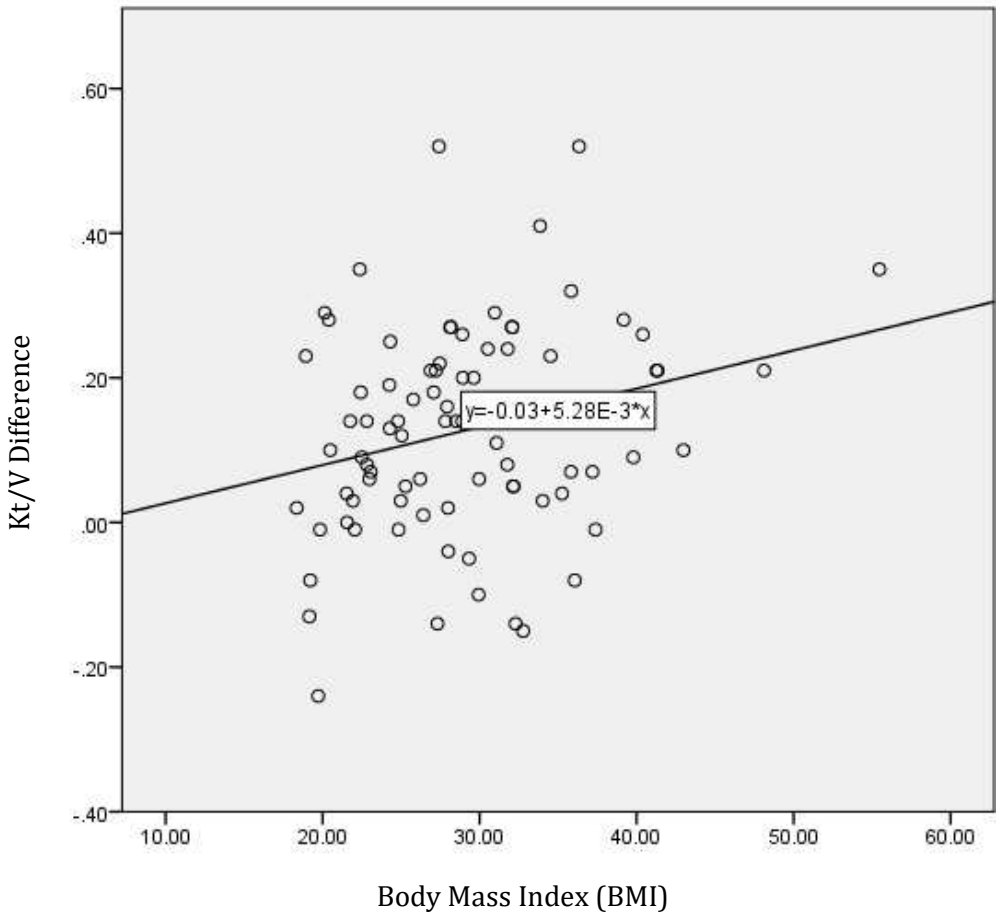

Figure 1: Scatterplot of Kt/V difference and Body Mass Index (BMI)

When participants were broken down into categories based on weight alone, a similar trend was seen (Table 4). For each weight group, the mean Kt/V calculated using the

equilibrated Kt/V equation was greater than that estimated using the Watson Formula. As seen in Table 4, the <60kg group had a group size of 17. For this group, the mean Kt/V using the Watson Formula was 1.58 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.67, a mean Kt/V difference of 0.09 (p <0.04). The 60-80kg group had a group size of 27. For this group, the mean Kt/V using the Watson Formula was 1.45 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.62, a mean Kt/V difference of 0.17 (p < 0.001). The 80-100kg group had a group size of 27. For this group, the mean Kt/V using the Watson Formula was 1.22 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.36, a mean Kt/V difference of 0.14 (p = 0.002). The >100kg group had a group size of 19. For this group, the mean Kt/V using the Watson Formula was 1.05 and the mean Kt/V for participants using the equilibrated Kt/V equation was 1.26, a mean Kt/V difference of 0.21 (p < 0.001).

The greatest Kt/V difference occurred in the largest weight group (>100kg) compared to the other lower weight groups. The trend appears clearer across weight classes than across standardized BMI classes suggesting height is less relevant than weight in Kt/V differences.

Table 4: Mean Kt/V difference between Watson Formula and Equilibrated Equation compared across weight classes

Weight	Watson	Equilibrated	Kt/V Difference
<60kg	1.58	1.67	0.09
	P=0.04, n=17		
60.1-80.0kg	1.45	1.62	0.17

	P<0.001, n=27		
80.1-100.0kg	1.22	1.36	0.14
	P=0.002, n=27		
>100kg	1.05	1.26	0.21
	P<0.001, n=19		

The secondary objective discussed patients with amputations as well. As seen in Table 5, in the groups containing patients with lower limb amputations, the mean Kt/V using the Watson Formula was 1.07 while the mean Kt/V for participants using the equilibrated Kt/V equation was 1.43, a mean Kt/V difference of 0.36 (p =0.05). In the groups containing patients without lower limb amputations, the mean Kt/V using the Watson Formula was 1.33 while the mean Kt/V for participants using the equilibrated Kt/V equation was 1.48, a mean Kt/V difference of 0.15 (p <0.001). The Kt/V difference was substantially larger in the amputation group compared to the group without amputations.

Table 5: Mean Kt/V difference between Watson Formula and Equilibrated Equation in patients with lower limb amputations

	Watson	**Equilibrated**	**Kt/V Difference**
Patients with lower limb amputations	1.07	1.43	0.36
	P=0.05, n=3		
Patients without lower limb amputations	1.33	1.48	0.15
	P<0.001, n=86		

3.2 Results Part 2 – Review of Incident Dialysis Starts

Part two of this study analyzed CORR Data for incident dialysis starts for patients in St. John's, Newfoundland and Labrador, between January 1st, 2019, and December 31st, 2021. The initial data set included 244 patients. There were 232 patients who stayed on dialysis for at least three months after starting dialysis, excluding those who died within three months of starting, or recovered some renal function to allow discontinuation of dialysis within three months of starting. Of those, 8 patients were excluded as they left the Health Authority and medical records were not available, leaving 224 patients remaining. As seen in Figure 2, 183 (81.7%) started dialysis after being followed by the nephrology team in the PRI clinic, and 41 (18.3%) started dialysis entering through the AKI pathway, having not seen the nephrology team prior to starting dialysis.

Of the group that entered through the PRI pathway, 171 (93.4%) started on ICHD, 12 (6.6%) started on PD, and 0 (0%) started on HHD. Of the group that entered through the AKI pathway, 41 (100%) started on ICHD, and 0 (0%) started on PD or HHD. Combining both pathways, as of January 1, 2024, 89 (39.7%) patients died, 111 (49.6%) were on ICHD, 14 (6.3%) were on PD, 2 (0.9%) were on HHD, and 8 (3.6%) received a kidney transplant and have discontinued dialysis.

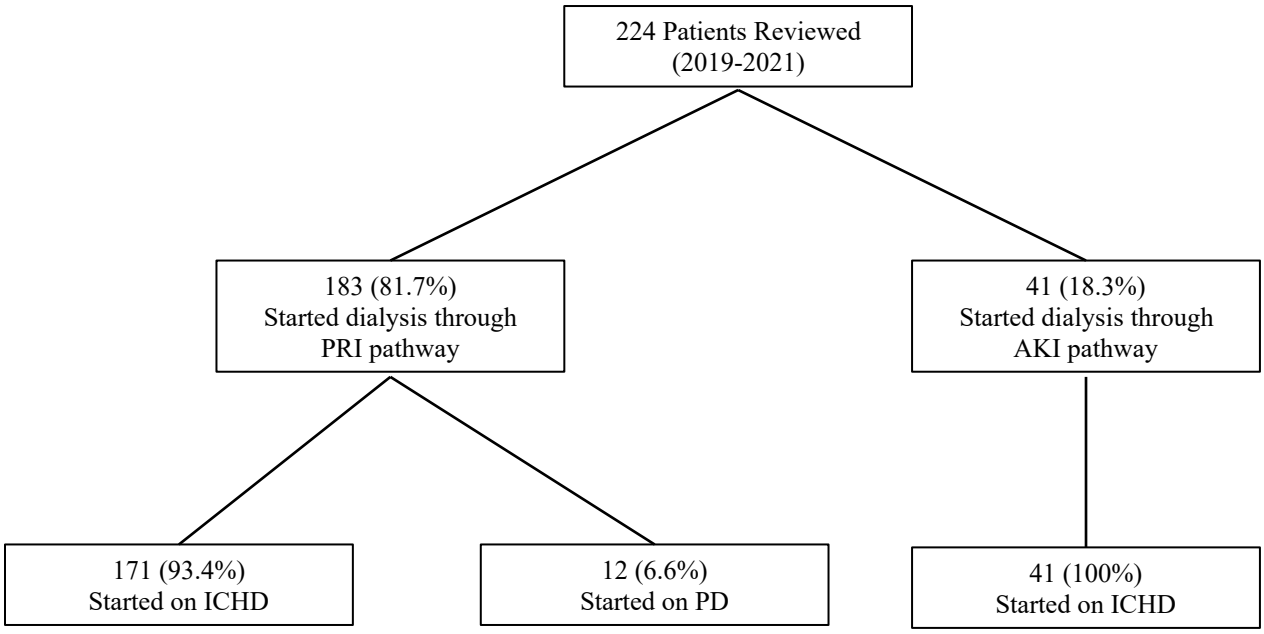

Figure 2: The Initial Dialysis Disposition of Incident Dialysis Starts for Patients with Care Managed from St. John's, Newfoundland and Labrador between 2019-2021

Data analysis started with patients being followed in the PRI clinic (Table 6). Patients were grouped as to whether they started on ICHD or PD. No patients started on HHD. There were 171 (93.4%) patients who started on ICHD. Of those 115 (66.7%) were male with a mean age of 69. The eGFR of this group when the original nephrologist consult was received was 31ml/min/m^2. The mean number of nursing visits documented in the visit registration section of Meditech was 2.4. There were no PRI nursing patient care notes identified in the electronic medical records for these patients, which began transitioning from paper to electronic in 2019. Prior to this, paper records were inconsistently kept and there was no consistent filing or storage for PRI clinic patients. These records were unable to be obtained. In addition, there was no visit registration information or paper, or electronic

medical records obtained for patient visits with pharmacists, social workers, or dieticians, due to similar issues with recording, filing, and storage. There were 12 (6.6%) patients who started on PD. Of those, 7 (58.3%) were male with a mean age of 61. The eGFR of this group when the original nephrologist consult was received was 40ml/min/m^2. The mean number of nursing visits documented in the visit registration section of Meditech was 3.5. The same issues with inconsistent keeping and difficulty obtaining medical records of encounters with PRI nurses, pharmacists, social workers, and dieticians were noted in this group.

Table 6: Demographic Information for Incident Dialysis Patients Entering through the Progressive Renal Insufficiency Pathway

Start Modality	In-Centre Hemodialysis	Peritoneal Dialysis
Number Started	171 (93.4%)	12 (6.6%)
Male Sex	115 (66.7%)	7 (58.3%)
Age (years)	69	61
eGFR (ml/min/m^2) on Referral	31	40
Number PRI Nursing Visits	2.4	3.5

As seen in Table 7, in the ICHD group, of the 171 patients who started, 111 (64.9%) had a documented discussion referencing RRT prior to starting dialysis. Of the 12 patients in the PD group, 12 (100%) had a documented discussion. The average timing of the RRT

discussion prior to the ICHD group starting dialysis was 9.4 months, and the average timing of the RRT discussion prior to the PD group starting dialysis was 13.1 months, 3.7 months before the average ICHD discussion. Of the 171 patients who started dialysis as ICHD, 31 (18.1%) had a documented discussion referencing home-based dialysis modality options, while 12 (100%) patients who started on PD had documentation of a previous discussion referencing home-based modalities. The timing of the home dialysis discussion was on average 10.7 months prior to starting in the ICHD group, and 12.4 months prior to starting in the PD group, 1.7 months earlier than their ICHD counterparts. These results show that the patients who started ICHD has a lower documented discussion rate of both general RRT options and home dialysis options, a possible factor in these patients not starting on home-based modalities. These discussions, if they occurred, were on average 1.7-3.7 months earlier in the group that started on PD.

Of the 183 patients in the PRI pathway entering dialysis, 129 (70.5%) had a referral to the respective surgeon required to create the dialysis access. For ICHD, this is a general or vascular surgeon, assessing for placement of an AVF or AVG, and for PD this is a general surgeon for placement of a PD catheter. When broken down, 117 (68.4%) patients from the ICHD group had a surgical referral and 12 (100%) patients from the PD group had a surgical referral, 31.6% lower in the ICHD compared to the PD group. Without a surgical access referral and subsequent assessment by the appropriate surgeon, patients are limited in their ability to transition to home dialysis, as the placement of a PD catheter is an essential step to doing PD.

Table 7: Timing of Dialysis Discussions for Incident Dialysis Patients Entering through the Progressive Renal Insufficiency Pathway

Start Modality	In-Centre Hemodialysis (171)	Peritoneal Dialysis (12)
Documented discussion referencing renal replacement therapy (RRT)	111 (64.9%)	12 (100%)
Timing of RRT Discussion (months prior to starting)	9.4	13.1
Documented discussion referencing home modalities	31 (18.1%)	12 (100%)
Timing of home modality discussion (months prior to starting)	10.7	12.4
Surgical access referral prior to starting RRT	117 (68.4%)	12 (100%)

The next group analyzed were those patients who started on ICHD, shown in Table 8. This included patients who started on ICHD through the PRI pathway (N=171), and those who started on ICHD through the AKI pathway (N=41), totalling 212 patients for analysis. 33 (15.6%) transitioned home for some period, 20 (60.1%) of which were male with an average age of 62 years. Of this group, 33 (100%) had a documented discussion on home dialysis modalities after starting ICHD. Of the 179 (84.4%) patients who stayed on ICHD, 111 (65.4%) were male with an average age of 63 years. This group had a documented home dialysis discussion in 25 (14%) of patients.

Again, patients who did not transition to home dialysis had a much lower proportion of documented home dialysis discussion than those who did transition to home dialysis. An attempt was made to ascertain records regarding the number of patients who received formal home dialysis education, the number of patients who received a home dialysis demonstration from home dialysis nurses in the home dialysis unit, and documentation of reasons for declining home dialysis, for those who received discussions, educations, and demonstrations. There was no apparent system for documenting or filing this information, and there was no identified paper or electronic notes from which to pull these records.

Table 8: Comparison of Patients who Started and Remained on ICHD with those who Transitioned to Home Dialysis

	Transitioned Home	Stayed on ICHD
Number	33 (15.6%)	179 (84.4%)
Male (Sex)	20 (60.1%)	111 (65.4%)
Age (Years)	62	63
Documented home dialysis discussion	33 (100%)	25 (14%)

As seen in Table 9, following the patients who started in the PRI clinic group, 43 discussed home dialysis prior to starting RRT, and when followed to January 1st, 2024, 20 (46.5%) of

those eventually tried home dialysis for some period. After starting RRT, 27 patients had a documented home dialysis discussion of which another 25 eventually transitioned to home dialysis (92.6%). When taken altogether, of the 224 patients who started dialysis between January 1st, 2019 and December 31st, 2021, 70 patients had a documented home dialysis discussion, of which 45 patients tried home dialysis at some point during their renal replacement journey, demonstrating a 64.9% transition rate to home dialysis with a documented home dialysis discussion. There are likely some inconsistent records kept, especially for those who discussed home dialysis but did not transition. However, these data support the fact that a large proportion of those who become aware and educated on the benefits of home dialysis attempt to transition to home dialysis. When looking at the overall group, 139 patients had a general RRT discussion prior to starting dialysis, 45 (32.3%) of which eventually tried home dialysis. Finally, of the 224 patients in the total sample, 70 (31.3%) patients had a documented discussion of home dialysis.

Table 9: Proportion of Patients who Tried Home Dialysis Based on Discussing Dialysis Options

Timing	Had Discussion	Tried Home Dialysis	Proportion
Home Discussion Before Starting RRT	43	20	46.5%
Home Discussion After Starting RRT	27	25	92.6%
Home Discussion in Total	70	45	64.9%
RRT Discussion in Total	139	45	32.3%

Chapter 4: Discussion

4.1 Part 1 – Discussion

In part 1 of the study, I found that using the direct measurement of the urea reduction ratio to calculate dialysis dose as part of the equilibrated Kt/V equation showed a significantly higher Kt/V than the mean Kt/V estimated using the Watson Formula. When this group was broken into a normal BMI group and an obese BMI group, the Kt/V difference was greater in the obese cohort. A significant correlation was shown between Kt/V difference and BMI. Similarly, when height was removed from the equation, weight alone affected the Kt/V difference, with the largest Kt/V difference in the highest weight cohort. I have also shown Kt/V difference is greater in patients with amputations compared to patients without amputations.

These results show that the current methods for calculating dialysis dose are underestimated due to the inaccuracy in predicting urea distribution volume, compared with methods for individualized, direct calculations. They are particularly inaccurate in subpopulations with disproportionate adipose tissue and muscle mass. I have shown this in the obese population and the population with lower limb amputations.

These data can be interpreted differently for different groups. The normal and overweight BMI groups have average Kt/V values much greater than 1.2 at baseline. Presumably, their prescribed time is required for other functions of dialysis such as fluid removal or

electrolyte balance. My study is less applicable to these groups, as any reduction in time would likely already have occurred if possible. However, there are two other groups for which these results are clinically significant. The first group is those who narrowly achieve an adequate Kt/V (BMI 30-40), representing 28% of the study population. This group may have had previously added time to achieve this dosing which is unnecessary based on alternate calculating methods. In terms of practice change, this group could decrease dialysis time by 30 minutes and still maintain an adequate Kt/V of 1.2. Secondly, there is a group who currently is not meeting the desired Kt/V value of 1.2 (BMI >40, and patients with amputations), representing 13% of the study population. Based on Kt/V alone, a practitioner may be inclined to lengthen time on dialysis by 28 minutes, on average, to achieve adequate dosing. However, I have shown that on average these groups do indeed meet the desired dialysis dosing based on alternate methods of calculating urea distribution volume. These data can be used by nephrologists to not increase time based on Kt/V alone in this population, and to consider other factors, such as blood pressure, fluid control, and patient symptoms, if prescribing longer dialysis.

This is the first step of creating an LHS cycle – converting data to knowledge. These data show that the current methods for calculating urea distribution volume are not precise and required dialysis time may be therefore affected to maintain a desired Kt/V. The next step is converting knowledge to performance. Using my subgroup analysis, I can apply this information individually to patients currently on dialysis. By identifying patients in the obese BMI classes, or those with amputations, and using already collected monthly serum urea concentrations as part of standard monitoring procedures in the dialysis units, direct

calculations of urea reduction ratio, and Kt/V can be determined. Alternatively, lower Kt/V targets can be used when monitoring dialysis dose efficacy. By applying this data clinically, a nephrologist can use clinical judgement when assessing a patient with obesity or an amputation, and accept a lower Kt/V value as sufficient dialysis dosing.

I am the first to show a significant difference in Kt/V values between anthropometric calculations and direct calculations when analyzed by weight category differences. This has changed practice in St. John's, where nephrologists have applied these results to ICHD patients when interpreting Kt/V. As a result, I have seen individual quality of life benefits in patients who have seen decreases in prescribed time. Given the burden of time required of these patients to receive ICHD, small changes have a large impact.

The creation and routinization of data infrastructure is key to this part of the cycle. It is important to incorporate easy-to-use systems by the regular users in the program where this information is continuously collected and easily analyzed. Much of these data are already collected automatically during dialysis sessions through Nephrocare and Meditech and using data systems like that used in this study, the alternative Kt/V measure can be quickly produced. By organizing these patients by subgroups, and reviewing other factors contributing to dialysis dosing decisions, like electrolyte and fluid balance, I can adjust times accordingly. It would be important to include the dialysis multidisciplinary team, specifically nurses, pharmacists, and patients, as they all play a role in this decision making. As serum urea concentrations are collected monthly, this initial performance change could

be implemented and monitored in the short-term. My goal is to identify the patients who fit this cohort and implement the change over the next three months.

Once this performance change occurs, it is important to measure value added through the quintuple aim of healthcare improvement. This will continue the LHS cycle of documenting performance changes to generate new data. In doing so I can determine if the data I collected implemented meaningful change. In this case, I would look at multiple parts of the aim. First, I could monitor patient care experience through qualitative feedback and quantitative surveys. As one of the main goals is decreasing time, patient quality of life should be followed to ensure it has improved. Secondly, by involving managers I can determine if administrative changes, such as the accommodation of more patients, are possible by comparing capacity before and after these changes in time occurred. Thirdly, population health can be assessed to ensure it is maintained with shorter times. Over the next 6-12 months, per standard practice, I will continue to collect bloodwork to monitor clearance, ultrafiltration data to monitor fluid balance, and patient feedback to monitor clinical status. In this way, I can determine if changes in time affects the health of patients on dialysis. Finally, through qualitative and quantitative feedback, I can ensure provider experience doesn't change.

4.2 Part 1 – Limitations

There are limitations in interpreting these data. This is observational data and therefore there was no randomization and inferences on causation cannot be made. There were only

three patients in the cohort with amputations. While the data was significant, a larger cohort would be required to draw firm conclusions. In addition, while a correlation exists between Kt/V difference and BMI, the strength is weak. Additional confounders, other than those identified in my data, may exist, and should be explored to strengthen the correlation. The ongoing collection of data from patients, building a larger cohort going forward, will allow me to continue to monitor to see if my data is correct in driving the performance changes in the right patient at the right time. This sample was representative of the population in St. John's, as patients were selected from the single outpatient dialysis centre in the city. However, the population is homogenous with most of the patients being white. It lacks external validity in other cities, where breakdown of race and ethnicity differs. While I can use this data to drive LHS cycles locally, caution should be used when driving change in other centres, where local data should be collected and analyzed.

4.3 Part 2 – Discussion

Part two of this project looked at the efficiency of the nephrology unit at transitioning patients onto home dialysis. I showed that only one in fifteen patients from the clinic pathway started dialysis at home, while the others started in centre on hemodialysis. The home dialysis group tended to be younger. This likely reflects younger patients' confidence with performing dialysis at home, their retained cognitive ability to comprehend the training period and troubleshoot issues at home, and their increased desire to maximize time with younger families with an increased likelihood of retaining a job. The home dialysis group were referred to the nephrologist at a higher kidney function on average,

allowing for an increased number of nursing visits with PRI nurses. This indicates that increased encounters with PRI nurses increases the likelihood that patients will achieve home dialysis through awareness and education surrounding home dialysis logistics and benefits, and increased opportunities for patients to process and question information. This first barrier showed that an increase in pre-dialysis awareness and education would help all patients feel confident during training and performing dialysis at home, in the form of educational aids, increased time in training, and community health dialysis support outside the home dialysis unit. I was unable to compare patient encounters with other members of the multi-disciplinary team such as pharmacists, dieticians, and social workers, as there were incomplete and missing documentation. This reflects the second barrier. The PRI team lacks robustness and organization and is unable to uphold standards set in centres with high home dialysis prevalence through lack of nursing and multidisciplinary capacity and no system to manage and document encounters.

Subsequent analysis comparing the groups of patients who started on home dialysis and in-centre dialysis showed the patients who started in-centre had a lower proportion of documented discussions about RRT, specifically home dialysis, prior to starting. In addition, patients who had these discussions documented, experienced them 2-4 months earlier in the group that started on home dialysis. As previously mentioned, these data demonstrate that awareness and education is critical to transitioning to home dialysis. In addition, a third barrier was identified: the lack of a consistent, early, and standardized approach to dialysis initiation. The current approach is not systematic and is individualized to the nephrologist and nephrology nurse having the discussion. There are also minimal

and inconsistent written or media tools, and there is no standardized checklist to document and navigate patients through the system leading to inconsistent and inequitable care.

I found that for patients who started on ICHD, only one in six eventually transitioned home. All those patients who transitioned home had a documented home dialysis discussion. However, for those who stayed on ICHD and did not transition home, only 14% had the same discussion documented. Again, this demonstrates the lack of standardized, consistent conversations about modality options with all patients, possibly due to the lack of a nephrology pathway with checklists and readily available materials. I have shown that two thirds of patients who had a home dialysis discussion eventually tried home dialysis for some period, indicating the importance of awareness.

Encounters with home dialysis nurses, including educational sessions and demonstrations of equipment and materials in the unit were not systematically recorded in data sets and were inconsistently documented. For those who received this information, the reason patients declined home dialysis was not collected. Because of this, I were unable to determine the frequency and effectiveness of this use of nursing hours. Similarly, the keeping of records surrounding referrals to general surgeons for peritoneal catheter placement, the assessing and booking of peritoneal catheter placement procedures, and the complications and revisions following the procedure are unclear and inconsistently documented. As part of a local study in 2019, data for PD patients in St. John's, NL was collected looking at predictors of PD catheter failure. It showed lack of home support, poorly controlled diabetes, concurrent abdominal surgery, and poor perioperative catheter

flow tests correlated with failure of PD. They also showed differences based on surgeon and surgical technique, and that on review, data was missing on training descriptions. This lack of routinized PD catheter placement review was a fourth barrier, preventing me from making inferences about its effectiveness and the impact of any delays along the pathway. Taken altogether, a global, fifth barrier was identified as inconsistent or missing datasets.

Several centres across North America have identified similar barriers and published their success rates. The Ontario Renal Network in Canada saw an increase of home dialysis prevalence from 22% to 27% from 2012 to 2017[52]. They identified and implemented changes surrounding nine barriers pertinent to their program, some of which I have also identified: pre-dialysis education and clinics, patient support, and addressing barriers to PD access. In California, United States, a group increased the home dialysis prevalence from 15% in 2008 to 34% in 2018, also identifying and correcting some crossover barriers, such as increased education, increased effective PD catheter placement, and increased pre-dialysis care[52]. The START trial in Alberta, Canada, showed an increase in PD prevalence from 25% in 2015 to 32% in 2018, with an even more significant increase in Calgary, Canada, where prevalence increased from 27% to 43% in the same time frame. Their approach mirrored my approach and involved three intervention phases. The first focused on high-quality data collection and standardized documentation, the second was a structured review of all new dialysis patients, and the third was a collaborative quality improvement process[51]. In British Columbia, Canada, a similar endeavour increased home dialysis prevalence from 14.8% in 2011 to 30% in 2013, and subsequently has maintained home dialysis prevalence at 35% for eight years. There they created a pathway-working

group that documented the current pathway through the dialysis program, identified barriers, and helped develop a future pathway[51]. These encouraging results indicate that my process, of identifying local barriers is the first step to reach my goal of increasing home dialysis prevalence in this program to meet the average of large programs, at 25-30%.

There is significant data demonstrating specific barriers to the uptake of home dialysis among patients. Each data set should be the basis of knowledge translation and the creation of small LHS cycles all contributing to one goal to increase home dialysis prevalence. By converting the data surrounding each barrier to knowledge and implementing this in performance change cycles, I can generate new data, and through its collection, measure value gained in the quintuple aim. This will help ensure I am making the right change at the right time, and adjust accordingly, ultimately moving toward my goal of increased home dialysis prevalence.

There were five specific barriers identified impacting the uptake of home dialysis. These included: (1) lack of dialysis awareness and education that is early and repetitive in a robust clinical scenario, (2) the lack of a standardized pre-dialysis team and home dialysis support network, (3) the lack of an efficient dialysis navigating pathway for all stakeholders, with standardized documentation and a centralized home dialysis first policy, (4) the lack of data surrounding the efficient placement and regular review of PD catheters, and (5) the poor collection of high-quality data with quality improvement initiatives.

The first two barriers, the lack of pre-dialysis awareness and education that is early and repetitive in a robust clinical scenario, and the lack of a standardized pre-dialysis team and home dialysis support network, are connected. I need to expand the multi-disciplinary team to support education prior to starting dialysis. To drive change in this area, hospital management must be involved. By providing the field analysis showing success in other provincial programs, and now having pre-implementation data showing the scarcity of home dialysis uptake, I have demonstrated the necessity of acting on this. By calculating time and money saved going forward, hopefully I can show that increasing the robustness of the nephrology clinic team will be beneficial to patients and provide time and financial benefits for the system. The current management in the Nephrology Department has been receptive to this with the recent hiring of a second PRI nurse and two new home dialysis nurses, as well as the creation of a new home dialysis unit space and the reorganization of the unit with a new Patient Care Coordinator. I also plan to create multiple formats of standardized education tools by comparing resources received from other centres and integrating identified research for our culture and language. Pamphlets are being produced for those who learn best through reading, and a video is being created for those who learn best through media, to provide precise details on the benefits and logistics of home dialysis. Education can be provided to clinic and ICHD nurses to ensure their knowledge is current, to elaborate on options and answer questions appropriately. Additionally, involving personnel in pharmacy, social work, and dietetics would add the necessary multi-disciplinary focus required to fully manage and transition through CKD to dialysis. These multidisciplinary groups have started meeting with administrators to present this data and start the process of redefining roles and responsibilities within the unit. Finally, I plan to

create an organized checklist and pathway to ensure all patients in the PRI clinic receive consistent and equitably distributed care. Patient support needs to extend through the PRI clinic pathway and into the home dialysis program, beyond the nursing capacity available in the unit, in the form of community health support and long-term care PD. I showed that older patients tend to do less home dialysis, and this support would help some of these patients. These first two barriers require multiple solutions to solve, many of which are underway. My goal is to continue putting in place, the necessary changes over the coming year and re-evaluate data over a three-year period to assess changes.

The third barrier identified was the lack of an efficient dialysis navigating pathway for all stakeholders, with standardized documentation and a centralized home dialysis-first policy. This pathway involves a repetitive, systematic approach in a straightforward written or media tool, with ample time for questions and follow-up at subsequent clinical visits. As well, a checklist filed for each patient can be the starting point of a nephrology-unit pathway that adds consistency to each patient's journey. By creating standardized material, personal biases and rushed conversations are taken away, and I ensure that patients receive appropriate information. I am in the planning stages of creating an automated pathway to streamline nephrology processes. A new electronic medical record is being implemented in Newfoundland and Labrador called Epic Systems, and I have started talks with the Digital Health Team, as well as the team responsible one of the current systems, HEALTHeNL, about options for incorporating this pathway into their systems as I enter the transition period. Two nephrology nurses, with over 20 years of dialysis experience between them, have recently joined the Digital Health Team as

permanent members and are helping with this project. As it proceeds over the next two years, the vision is to have a pathway filed for each patient, including a clinic and dialysis portion of the pathway with the ability to document any step within the file, and mandatory checklists that automatically appear during encounters, triggered by time or current kidney function. This would incorporate assessment in clinic by nephrologists, nurses, pharmacists, social workers, and dieticians in the appropriate stages of CKD to lay the foundation of care and discuss and educate around dialysis modalities. As eGFR falls, this will initially trigger, as appropriate, consults to the home dialysis team, palliative care team, and vascular access team for assessments, and eventually trigger final decisions on modality along with unit education and demonstrations, assessment by the appropriate surgeon for access creation, and assessment by the kidney transplant coordinator. Mandatory checklists for discussions involving RRT options and education, and reasoning behind modality, access, and transplant decisions would be required. Based on these answers, prompting of questions, investigations, referrals, and orders could occur. Finally, the RRT would have a timeline of modalities chosen with labeled changes and decisions along the way, for a readily available, full view of the patient's journey through their nephrology experience. This ensures patients make informed choices and receive equitable care regarding their health.

The fourth barrier was the lack of data surrounding the efficient placement and regular review of PD catheters. Unfortunately, there were little to no data on the timing of referrals, results of clinical assessments, or the proficiency or complications of PD catheter placements. The separate local study indicates this is an area where high-quality data

collection is necessary, but it is currently not standardized or routinized. Therefore, I have started collecting the necessary data to implement performance changes in an LHS cycle here. Over the past 12 months, I have implemented data infrastructure and directed nursing capacity hours in the home dialysis unit to begin collecting this data going forward. I have also started quarterly checkpoints to review the data and a comprehensive annual assessment, and through this process have already made small changes to increase the efficiency of the PD catheter pathway. Once I have enough data, I can evaluate value added through the quintuple aim.

The final barrier identified was poor collection of high-quality data with quality improvement initiatives. This is mainly because there is no standardized system in place to collect these data, and it falls on individual users to maintain current data collection. The data I was able to collect, including initial and subsequent dialysis modalities, access type, current disposition, eGFR, nursing visits, and discussions of dialysis options, were inconsistently recorded with over a dozen possible locations of data storage within the electronic medical record. Other data like clinic visits with multi-disciplinary team members, timing and success of home dialysis education sessions and demonstrations, reasons for declining home dialysis, and PD catheter placement efficiency, were unable to be located, making inferences about barriers impossible. Due to these results, I have started and expanded on data sets in most of these areas with plans to initiate datasets in all areas over the next year. For now, they are being stored manually by members of the nephrology team, with future goals to incorporate all these pieces in the nephrology pathway. I have requested to administrators to incorporate increased nursing capacity

hours to maintain and routinize the upkeep of data for future analysis. Going forward, these data sets will prove crucial for the LHS cycles to continue. As the program grows, I make changes based on barriers identified for success and continue to collect data in this area. As my goal is to increase patients on home dialysis in a method that is efficient for the system, I can see if these changes make significant differences and adjust accordingly. This will also help identify any new barriers which arise through this process.

For example, in 2023, after collecting six months of data on PD catheter efficiency, it was determined that due to lack of operating room time for PD catheter placement by general surgeons, there were few patients to train, and a waitlist of over 20 patients awaiting PD catheters had developed. The rate-limiting step was no longer recruitment to the program from the PRI clinic, rather the PD catheter placement itself. After meetings with appropriate administrators, operating room time for PD catheter placement was adjusted with an average of three catheters placed per month for the last nine months, significantly decreasing the waitlist. During a recent staff quarterly review, we identified that we now have 10 patients waiting to be trained this month with PD catheters in place but are now limited by our home dialysis nursing capacity, and anticipate this list will continue to expand throughout the year. After discussing our report with nephrology administrators, we are seeking the addition of two more home dialysis nurse positions to help with training to decrease this waitlist to maintain our growth in home dialysis prevalence. Without continuing to collect and analyze data, we may not become aware of the rate-limiting steps in our pathway, and not make the correct adjustments (or make incorrect

adjustments). We plan to continue doing this in real time as the program grows and faces new challenges.

These data have identified several problems in our current system that limit our growth, including the lack of standardized educational systems, and the lack of data storage systems and electronic pathways to monitor patient progress throughout the network, and assess SMART (specific, measurable, achievable, relevant, and time-bound) goals at both the patient and population level. By identifying these barriers and using data to start the cycles involved in a learning health system, there is an opportunity for sustainable and meaningful growth. As discussed, the data plays a pivotal role in implementing the cycle. It also allows for regular, ongoing measurements to ensure we are meeting the goals we set out to achieve. This will require stakeholder uptake at all levels of the system. It is important to engage patients in the process, not only because of our patient-centred approach to care, but also to receive feedback from them as part of our learning cycles. They can provide useful qualitative feedback through informal discussions, standardized questionnaires, and focus groups, to measure the impact these changes have on the patients and combine this information with quantitative metrics to determine a wholistic picture of change. The success of the learning health system cycles also depends on other stakeholders, like staff and administration. Changes to current practice will affect the physicians, nurses, and multi-disciplinary team members. Implementing new educational resources and pathway processes require new learning from our team members and motivated participation will be critical for success. This will also require adaptable, creative, and reliable team members who are interested in making the change.

Additionally, the importance of maintaining and routinizing data collecting systems is pivotal, and staff members will need to be proactive in their practice. Finally, administrators are key players in the success of these cycles. Often changes are required on a managerial level, such as budget or staffing changes, identified as the cycle develops. It will be important to engage these members of the team and educate them on the goals of this process, and the necessity of their involvement. Success will depend on the buy-in of members at all levels of the team.

This project targets multiple parts of the quintuple aims for health care improvement[49]. I anticipate that getting patients onto a home dialysis modality satisfies the original triple aim, improves population health with multiple medical benefits to PD and HHD, enhances the care experience of patients by improving QOL, and reduces costs on the system. I plan to assess this through ongoing clinical monitoring, patient feedback, and program audits. The fourth aim is improved provider satisfaction. As a nephrologist who works in home dialysis, there is a great deal of satisfaction derived from seeing patients successfully transition to home dialysis, and gain increased autonomy of their care, independence, and physical health benefits. Finally, the most recent aim for health care improvement, advancing health equity, may also be satisfied. The lack of standardization showed inconsistent care across patients in the nephrology department which can be optimized with a standardized checklist and pathway.

4.4 Part 2 – Limitations

There are limitations to this part of the project. Evidently, the inconsistent and missing data only tells part of the story. It is likely that some of these metrics are occurring informally without proper documentation which can skew the results. The lack of standardization in documentation and data storage made it very difficult to access even what information was maintained, leading to possible human error in accurately retrieving it. While all attempts were made to be thorough and precise, the absence of a collated system risked bias in collection of data. Again, this is data collected with the aim of quality improvement methods, and no cause and effect can be determined. While I chose metrics that I believe affect the targets, long term data collection and LHS cycle management is required to determine if altering performance based on the data creates meaningful change. Again, this data is collected in a homogenous population in a single centre, where it will be used in change cycles. I recommend locally collected data in other centres where similar endeavours are occurring. However, its use in quality improvement and learning health initiatives in this centre is helpful. With cycles of collecting, analyzing, making changes, and studying, I can make small, fast, and incremental changes in real-time to move towards my goal.

4.5 Recommendations

4.5.1 Part 1 Recommendations

1. In patients with obesity and/or amputations, recognize that current methods for estimating Kt/V are inaccurate; based on clinical judgment, consider time reductions if prescribed time is solely based on Kt/V target achievement.
2. Implement and maintain a learning health system cycle and collect data on patient and provider experience, dialysis unit capacity, and patient health metrics, to assess outcomes based on the quintuple aim for healthcare improvement.

4.5.2 Part 2 Recommendations

1. Create a standardized multi-disciplinary pre-dialysis team to provide equitable home dialysis education to patients in the nephrology clinic and in-centre hemodialysis population.
2. Create and maintain an electronic dialysis navigating pathway for patients with chronic kidney disease, with standardized documentation for all interactions between the patient and healthcare workers.
3. Create data storage systems for information surrounding the placement and health of peritoneal dialysis catheters; ensure healthcare worker capacity to collect and maintain these data.

4. Implement and maintain a learning health system cycle and collect data on patient and provider experience, dialysis unit capacity, and patient health metrics, to assess outcomes based on the quintuple aim for healthcare improvement.

4.6 Conclusion

In conclusion, the Health Accord for Newfoundland and Labrador recommended implementation of learning health system, the basis of which are change implementation cycles focused on value-oriented outcomes in the quintuple aim for healthcare improvement. I have collected data in two aspects of the nephrology program to initiate these cycles. In individuals on ICHD, the data shows alternative methods for calculating urea reduction volume and Kt/V, which can be implemented to adjust time in certain patients. In addition, I have identified five barriers in our process of initiating patients on home dialysis, for which change cycles have started being created with plans to implement all over the next year. By addressing these barriers with change cycles, I will continue to monitor outcomes and my goal of increasing home dialysis prevalence in our program.

This process has laid the foundation of responding to the Health Accord's call to implement local learning health systems in my corner of healthcare. In doing so, I have started to create a culture and system where I focus on high-quality data collection and quality improvement methods to deliver ongoing value-based health care to the people of my province.

References

1. KDIGO 2012 clinical practice guideline for the Evaluation and management of chronic kidney disease. *Nephrology and Dialysis*. 2017;19(1):22-206. doi:10.28996/1680-4422-2017-1-22-206.

2. Bello AK, Ronksley PE, Tangri N et al. Prevalence and demographics of CKD in Canadian primary care practices. *Kidney Int Reports*. 2019;4(4):561-570. doi:10.1016/j.ekir.2019.010.05.

3. What is dialysis? National Kidney Foundation. Published 2023. Accessed 27 January 2024. https://www.kidney.org/atoz/content/dialysisinfo.

4. Schmidt, RJ. Overview of the hemodialysis apparatus. In: *UpToDate.* UpToDate; 2024. Accessed February 6, 2016. www.uptodate.com.

5. Kim J. Annual statistics on organ replacement in Canada, 2012 to 2021. CIHI. Accessed 27 January 2024. https://www.cihi.ca/en/annual-statistics-on-organ-replacement-in-canada-2012-to-2021.

6. Mendu ML, Divino-Filho JC, Vanholder R et al. Expanding utilization of home dialysis: An action agenda from the first international home dialysis roundtable. *Kidney Med*. 2021;3(4):635-643. doi:10.1016/j.xkme.2021.04.004.

7. Ito Y, Ryuzaki M, Sugiyama H, et al. Peritoneal dialysis guidelines 2019 part 1 (Position paper of the Japanese Society for dialysis therapy. *Ren Replace Ther.* 2021;7(1). doi:10.1186/s41100-021-00348-6.

8. Sachdeva B, Zulfiqar H, Aeddula NR. Peritoneal Dialysis. In: *Statpearls.* Treasure Island (FL): StatPearls Publishing; October 3, 2022.

9. Ibrahim A, Chan CT. Managing kidney failure with home hemodialysis. *Clin J Am Soc Nephrol*. 2019;14(8):1268-1273. doi:10.2215/cjn.13931118.

10. Match-D. Home Dialysis Central. Accessed 27 January 2024. https://homedialysis.org/match-d.

11. Kimmel PL. Psychosocial factors in dialysis patients. *Kidney Int*. 2001;59(4):1599-1613. doi:10.1046/j.1523-1755.2001.0590041599.

12. Palmer S, Vecchio M, Craig JC, et al. Prevalence of depression in chronic kidney disease: Systematic review and meta-analysis of observational studies. *Kidney Int*. 2013;84(1):179-91. doi:10.1038/ki2013.77.

13. Mousa I, Ataba R, Al-ali K, Alkaiyat A, Sa'ed HZ. Dialysis-related factors affecting self-efficacy and quality of life in patients on haemodialysis: A cross-sectional study from Palestine. *Ren Replace Ther*. 2018;4(1). Doi:10.1186/s41100-018-0162-y.

14. Parfrey P, Davis E. Health Accord NL. Published 2022. Accessed 5 March 2024. https://www.healthaccordnl.ca/final-reports/.

15. Menear M, Blanchette MA, Demers-Payette O, Roy D. A framework for value-creating learning health systems. *Health Res Policy Sys*. 2019;17(1). doi:10.1186/s12961-019-0477-3.

16. Nundy S, Cooper LA, Mate KS. The Quintuple Aim for Health Care Improvement: A New Imperative to Advance Health Equity. *JAMA*. 2022;327(6):521-522. doi:10.1001/jama.2021.25181.

17. Home. Quality Of Care. Accessed 5 March 2024. https://qualityofcarenl.ca/.

18. What is dialysis? National Kidney Foundation. Published 2023. Accessed 27 January 2024. https://www.kidney.org/atoz/content/dialysisinfo.

19. Tobias A, Ballard BD, Mohiuddin SS. Physiology, Water Balance. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; October 3, 2022.

20. Gotch FA, Sargent JA. A mechanistic analysis of the National Cooperative Dialysis Study (NCDS). *Kidney Int*. 1985;28(3):526-534. doi:10.1038/ki.1985.160.

21. Eknoyan G, Beck GJ, Cheung AK, et al. Effect of dialysis dose and membrane flux in maintenance hemodialysis. *N Eng J Med.* 2003;347(25):1491-1494. doi:10.1056/nejm200304103481514.

22. Watson PE, Watson ID, Batt RD. Total body water volumes for adult males and females estimated from simple anthropometric measurements. *Am J Clin Nutr.* 1980;33(1):27-39. doi:10.1093/ajcn/33.1.27.

23. Meigs, JB. The metabolic syndrome (insulin resistance syndrome or syndrome X). In: *UpToDate.* UpToDate;2024. Accessed March 16, 2016. www.uptodate.com.

24. Depner TA, Cheer A. Modeling urea kinetics with two vs. three bun measurements. A critical comparison. *ASAIO Trans*. 1989;35(3):499-502. doi:10.1097/00002480-198907000-00105.

25. Arora P, Vasa P, Brenner D, et al. Prevalence estimates of chronic kidney disease in Canada: Results of a nationally representative survey. *Can Med Assoc J.* 2013;185(9). doi:10.1503/cmaj.120833.

26. Quinibi, WY. Prescribing and assessing adequate hemodialysis. In: *UpToDate*. UpToDate;2024. Accessed February 6, 2016. www.uptodate.com.

27. Noori N, Wald R, Sharma Parpia A, Goldstein MB. Volume Estimates in Chronic Hemodialysis Patients by the Watson Equation and Bioimpedance Spectroscopy and the Impact on the Kt/V_{urea} calculation. *Can J Kidney Health Dis*. 2018;5 doi:10.1177/2054358117750156.

28. Chuasuwan A, Pooripussarakul S, Thakkinstian A, Ingsathit A, Pattanaprateep O. Comparisons of quality of life between patients underwent peritoneal dialysis and hemodialysis: A systematic review and meta-analysis. *Health Qual Life Outcomes*. 2020;18(1). doi:10.1186/s12955-020-01449-2.

29. Heidenheim AP, Muirhead N, Moist L, Lindsay RM. Patient quality of life on quotidian hemodialysis. *Am J Kidney Dis.* 2003;42:36-41. doi:10.1016/s0272-6386(03)00536-5.

30. Jaber BL, Lee Y, Collins AJ, et al. Effect of daily hemodialysis on depressive symptoms and postdialysis recovery time: Interim report from the freedom (following rehabilitation, economics and everyday-dialysis outcomes measurements) study. *Am J Kidney Dis*. 2010;56(3):531-539. doi:10.1053/j.ajkd.2010.04.019.

31. Yeates K, Zhu N, Vonesh E, Trpeski L, Blake P, Fenton S. Hemodialysis and peritoneal dialysis are associated with similar outcomes for end-stage renal disease treatment in Canada. *Nephrol Dial Transplant*. 2012;27(9):3568-3575. doi:10.1093/ndt/gfr674.

32. McDonald SP, Marshall MR, Johnson DW, Polkinghorne KR. Relationship between dialysis modality and mortality. *J Am Soc Nephrol*. 2009;20(1):155-163. doi:10.1681/asn.2007111188.

33. Snyder JJ, Kasiske BL, Gilbertson DT, Collins AJ. A comparison of transplant outcomes in peritoneal and hemodialysis patients. *Kidney Int.* 2003;63(5):1956-1957. doi:10.1046/j.1523-1755.2002.00563.

34. Perl J, Dong J, Rose C, Jassal SV, Gill JS. Is dialysis modality a factor in the survival of patients initiating dialysis after kidney transplant failure? *Perit Dial Int*. 2013;33(6):618-628. doi:10.3747/pdi.2012.00280.

35. Lysaght MJ, Vonesh EF, Gotch F, et al. The influence of dialysis treatment modality on the decline of remaining renal function. *ASAIO Trans*. 1991;37(4):598-604.

36. Bargman JM, Thorpe KE, Churchill DN. Relative contribution of residual renal function and peritoneal clearance to adequacy of dialysis: a reanalysis of the CANUSA study. *J Am Soc Nephrol*. 2001;12(10):2158-2162. doi:10.1681/ASN.V12102158.

37. Oliver MJ, Verrelli M, Zacharias JM, et al. Choosing peritoneal dialysis reduces the risk of invasive access interventions. *Nephrol Dial Transplant*. 2012;27(2):810-816. doi:10.1093/ndt/gfr289.

38. Ishani A, Collins AJ, Herzog CA, Foley RN. Septicemia, access and cardiovascular disease in dialysis patients: the USRDS Wave 2 study. *Kidney Int*. 2005;68(1):311-318. doi:10.1111/j.1523-1755.2005.00414.

39. Foley RN, Gilbertson DT, Murray T, Collins AJ. Long interdialytic interval and mortality among patients receiving hemodialysis. *N Engl J Med*. 2011;365(12):1099-1107. doi:10.1056/NEJMoa1103313.

40. Perl J, Wald R, Na Y, Bell CM, Harel Z. Continuous mortality risk among peritoneal dialysis patients. *Arch Intern Med*. 2012;172(7):589-590. doi:10.1001/archinternmed.2012.215.

41. Marshall MR, Hawley CM, Kerr PG, et al. Home hemodialysis and mortality risk in Australian and New Zealand populations. *Am J Kidney Dis*. 2011;58(5):782-793. doi:10.1053/j.ajkd.2011.04.027.

42. Pauly RP, Maximova K, Coppens J, et al. Patient and technique survival among a Canadian multicenter nocturnal home hemodialysis cohort. *Clin J Am Soc Nephrol*. 2010;5(10):1815-1820. doi:10.2215/CJN.00300110.

43. Rocco MV, Lockridge RS Jr, Beck GJ, et al. The effects of frequent nocturnal home hemodialysis: the Frequent Hemodialysis Network Nocturnal Trial. *Kidney Int*. 2011;80(10):1080-1091. doi:10.1038/ki.2011.213.

44. Chan CT, Harvey PJ, Picton P, Pierratos A, Miller JA, Floras JS. Short-term blood pressure, noradrenergic, and vascular effects of nocturnal home hemodialysis. *Hypertension*. 2003;42(5):925-931. doi:10.1161/01.HYP.0000097605.35343.64.

45. Susantitaphong P, Koulouridis I, Balk EM, Madias NE, Jaber BL. Effect of frequent or extended hemodialysis on cardiovascular parameters: a meta-analysis. *Am J Kidney Dis*. 2012;59(5):689-699. doi:10.1053/j.ajkd.2011.12.020.

46. Jaber BL, Schiller B, Burkart JM, et al. Impact of short daily hemodialysis on restless legs symptoms and sleep disturbances. *Clin J Am Soc Nephrol*. 2011;6(5):1049-1056. doi:10.2215/CJN.10451110.

47. Hanly PJ, Pierratos A. Improvement of sleep apnea in patients with chronic renal failure who undergo nocturnal hemodialysis. *N Engl J Med*. 2001;344(2):102-107. doi:10.1056/NEJM200101113440204.

48. Klarenbach SW, Tonelli M, Chui B, Manns BJ. Economic evaluation of dialysis therapies. *Nat Rev Nephrol*. 2014;10(11):644-52. doi: 10.1038/nrneph.2014.145.

49. Karopadi AN, Mason G, Rettore E, Ronco C. Cost of peritoneal dialysis and haemodialysis across the world. *Nephrol Dial Transplant*. 2013;28(10):2553-2569. doi:10.1093/ndt/gft214.

50. Wang A, Turnbull L, Williams J, et al. Systematic Evaluation of a Provincial Initiative to Improve Transition to Home Dialysis Therapies. *Can J Kidney Health Dis*. 2020;7:2054358120949811. Published 2020 Aug 28. doi:10.1177/2054358120949811.

51. Quinn RR, Mohamed F, Pauly R, et al. Starting Dialysis on Time, At Home on the Right Therapy (START): Description of an Intervention to Increase the Safe and Effective Use of Peritoneal Dialysis. *Can J Kidney Health Dis*. 2021;8. doi:10.1177/20543581211003764.

52. Shen JI, Perl J. Is There an Ideal Recipe to Increase Home Dialysis Use? Is It Enough?. *Clin J Am Soc Nephrol*. 2022;17(4):484-486. doi:10.2215/CJN.02150222.

53. Tombocon O, Tregaskis P, Reid C, et al. Home before Hospital: a whole of system re-design project to improve rates of home-based dialysis therapy: Experience and outcomes over 8 years. *Int J Qual Health Care*. 2021;33(3):108. doi:10.1093/intqhc/mzab108.

54. Canadian Organ Replacement Register (CORR). CIHI. Accessed 5 March 2024. https://www.cihi.ca/en/canadian-organ-replacement-register-corr.

55. World Health Organization. A health lifestyle – WHO recommendations. World Health Organization. Published 6 May 2010. Accessed 5 March 2024. https://www.who.int/europe/news-room/fact-sheets/item/a-healthy-lifestyle---who-recommendations.

Appendix – Ethics Approval

NEWFOUNDLAND AND LABRADOR
HREB
HEALTH RESEARCH ETHICS BOARD

Ethics Office
Suite 200, Eastern Trust Building
95 Bonaventure Avenue
St. John's, NL
A1B 2X5

June 22, 2016

13 Tigress St.
St. John's, NL
A1B 0L6

Dear Dr. Davis:

Researcher Portal File # 20170322
Reference # 2016.160

RE: "Assessing the Validity of Measuring Dialysis Dose using Body Water estimating formulae versus the Urea Kinetic Model: A Cross-Sectional Observational Study"

Your application received an expedited review by a sub-committee of the Health Research Ethics Board (HREB). ***Full approval*** of this research study is granted for one year effective **June 21, 2016**.

This is your ethics approval only. Organizational approval may also be required. It is your responsibility to seek the necessary organizational approval from the Regional Health Authority (RHA) or other organization as appropriate. You can refer to the HREA website for further guidance on organizational approvals.

This is to confirm that the HREB reviewed and approved or acknowledged the following documents (as indicated):

- Application, approved
- Revised consent form, approved
- Patient information sheet, approved

MARK THE DATE

This approval will lapse on June 21, 2017 . It is your responsibility to ensure that the Ethics Renewal form is submitted prior to the renewal date; you may not receive a reminder. The Ethics Renewal form can be found on the Researcher Portal as an Event form.

If you do not return the completed Ethics Renewal form prior to date of renewal:

- ***You will no longer have ethics approval***
- *You will be required to stop research activity immediately*
- *You may not be permitted to restart the study until you reapply for and receive approval to undertake the study again*
- *Lapse in ethics approval* ***may result in interruption or termination of funding***

You are solely responsible for providing a copy of this letter, along with your approved HREB application

form; **to Research Grant and Contract Services** should your research depend on funding administered through that office.

Modifications of the protocol/consent are not permitted without prior approval from the HREB. **Implementing changes without HREB approval may result in your ethics approval being revoked, meaning your research must stop**. Request for modification to the protocol/consent must be outlined on an amendment form (available on the Researcher Portal website as an Event form) and submitted to the HREB for review.

The HREB operates according to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2), the Health Research Ethics Authority Act (HREA Act) and applicable laws and regulations.

You are responsible for the ethical conduct of this research, notwithstanding the approval of the HREB.

We wish you every success with your study.

Sincerely,

Dr Fern Brunger (Chair, Non-Clinical Trials Health Research Ethics Board)
Ms. Patricia Grainger (Vice-Chair, Non-Clinical Trials Health Research Ethics Board)

CC: B. Barrett