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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Abstract

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Background: Hospital readmissions among patients receiving dialysis are associated with inadequate coordination of care, which is at least partially due to the substantial lack of electronic health record interoperability between U.S. dialysis facilities and hospitals. To address this gap, a web-based communications platform, DialysisConnect, was developed and piloted. Here, we examined whether this intervention had a differential effect on health outcomes between high utilizers (patients who account for a significant proportion of dialysis-related health care costs and hospital readmissions) and other patients.

Methods: DialysisConnect was tested in a pre-post pilot study conducted at Emory University Hospital Midtown (EUHM) and four Emory-affiliated dialysis clinics in Atlanta. Characteristics of all hospital admissions (n=1046) during the study period were compared by high utilizer status at admission (at least three hospital admissions or observation stays in the prior year) and by pilot (11/1/20-5/31/21) vs. pre-pilot (1/1/19-10/31/20) period. Interrupted time series, difference-in-difference (DID) analyses, and index admission-level linear regression, with adjustment for age, sex, race, and Charlson comorbidity index, were performed for primary (30-day hospital readmission) and secondary (30-day observation stay, 30-day emergency department (ED) visit, hospital length of stay, 30-day mortality) outcomes.

Results: The adjusted 30-day readmission rate among high utilizer admissions was higher in the pilot period after DialysisConnect was introduced vs. the pre-pilot (35.9% vs. 27.0%). In contrast, 30-day readmissions after non-high utilizer admissions were lower in the pilot vs. pre-pilot period among non-high utilizer admissions (14.0% vs. 20.2%). The primary outcome in 30-day readmission rates by high utilizer status was associated with a statistically significant DID value of 14.2%. We found opposite and statistically significant trends for 30-day observation stays/ED visits and 30-day observation stays alone, with lower rates among high utilizer admissions and higher rates among non-high utilizer admissions after the pilot period.

Conclusion: DialysisConnect was associated with lower 30-day readmission among non-high utilizers and higher 30-day readmission among high utilizers. Future studies should examine the effectiveness of such platforms embedded within multi-component, patient-centered interventions and also address who could most effectively serve as care coordinators for dialysis, particularly those who are high utilizers of the healthcare system.

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Background

Chronic Kidney Disease

Chronic kidney disease (CKD) affects more than 1 in 7 U.S. adults, an estimated 37 million Americans.[1] According to current estimates, CKD is more common in individuals aged 65 years or older (38%) than those who are aged 45-64 years (12%) or 18-44 years (6%).[1] Additionally, CKD is slightly more prevalent in women (12%) than men (10%), and the disease is more common in non-Hispanic Black adults (16%) compared to non-Hispanic White adults (13%) or non-Hispanic Asian adults (13%).[1] Chronic kidney disease occurs through kidney damage and the gradual loss of kidney function, such that the kidneys cannot filter the appropriate wastes and excess fluids from the blood into the urine. It is usually diagnosed through decreased estimated glomerular filtration rate (GFR) from the body's creatinine levels and/or increased protein urine level (proteinuria), which are indicators of reduced kidney function and kidney damage, respectively.[2] Staging of CKD is based on both estimated GFR level and presence of proteinuria. In all stages, patient quality of life and physical functioning are low relative to the general population.[3,4] While the two most common causes of kidney disease are diabetes and high blood pressure, other risk factors include cardiovascular disease, drug abuse, blockages in the urinary tract, inflammation, and family history of kidney failure.[5] People with early-stage CKD usually do not have symptoms, and 9 in 10 people with CKD are not aware they have the disease, often delaying diagnosis.[1] However, as CKD progresses, patients may experience a wide variety of often non-specific symptoms: fatigue, swelling, changes in urination, dry and itchy skin, shortness of breath, and/or nail changes.[6] The last stage of CKD is end-stage renal disease (ESRD), which is defined as the final and permanent stage of CKD, in which kidneys can no longer function on their own, and patients with ESRD must receive renal replacement therapy (dialysis or a kidney transplantation) to survive[7]; although patients can also choose to forego these treatments for conservative management (or palliative care) to manage symptoms and maintain quality of life. As CKD patients approach ESRD, mortality risk increases, and patients are more likely to die than to reach ESRD and receive renal replacement therapy.[8]

End Stage Renal Disease and Dialysis

The prevalent count of patients living with ESRD reached 783,000 in December 31, 2019, which was up 40% from 2009.[9] However, the annual incidence of ESRD has stabilized at 370 cases per million people from 2017 to 2019.[9] Increasing ESRD prevalence despite stable incidence reflects advances in long-term survival of ESRD patients. ESRD incidence is higher in older individuals and is far higher (>3-fold) in Black individuals than in white non-Hispanic individuals; additionally, males have higher ESRD incidence than females.[9] Among prevalent treated U.S. ESRD patients in 2019, 29% had a functioning kidney transplant and 71% were on dialysis; however, the average wait time for a kidney transplant was 49.2 months and 98% of treated ESRD patients start treatment on dialysis.[9] Thus, most ESRD patients require dialysis at some point.

There are two types of dialysis that can perform the normal functions of the kidney, which are to filter waste and remove excess fluid from the blood. In hemodialysis, blood is pumped out of the body into an artificial kidney machine, where filtration occurs, and the cleaned blood is then returned to the body through tubes that connect patients to the machine. For adults with ESRD, this process typically takes 3 to 5 hours and takes place in an outpatient dialysis clinic at least three times a week, although home hemodialysis is rarely but increasingly used: from 2009 to 2019, there was an increase from 0.9% to 1.4% of dialysis patients receiving home hemodialysis.[9] In peritoneal dialysis, the more common home dialysis option, the inside lining and tiny blood vessels of the patient's abdomen act as a natural filter. A cleaning fluid, called dialysate, filters the blood through washing in and out of the abdomen in cycles. Peritoneal dialysis usually occurs 5-7 days of the week at the patient's residence for a duration ranging from 4 to 10 hours. The utilization of peritoneal dialysis expanded from 9.6% in 2009 to 16.9% in 2019.[9] While common side effects of hemodialysis consist of fatigue, low blood pressure, sepsis, muscle cramps, and itchy skin, side effects of peritoneal dialysis can include fatigue, peritonitis (a bacterial infection of the peritoneum), hernia, and weight gain.[10] Additionally, dialysis patients experience multiple concurrent symptoms, which can be clustered together. Multiple symptom clusters were identified among dialysis patients, which included uremic, gastrointestinal, musculoskeletal, and emotional symptoms, negatively effecting and impacting various aspects of patients' well-being.[11]

Delivery of Dialysis Care in the U.S.

The global dialysis population is growing rapidly, and the costs of dialysis are high, estimating to continuously rise due to annual increases in life expectancy.[12] In the United States, all Social Security-eligible individuals with ESRD are eligible for Medicare insurance coverage, regardless of age or disability, and Medicare Part A covers the costs of dialysis treatment as well as inpatient admissions. Dialysis patients can also opt into Parts B and D to cover outpatient services and medications, respectively. Medicare-related spending for U.S. beneficiaries with ESRD was $51.0 billion in 2019, representing 7.1% of all Medicare spending in that year.[9]

Furthermore, annual average per-person spending was $94,608, $81,091, and $38,863 for ESRD patients treated with hemodialysis, peritoneal dialysis, and transplant, respectively.

Due to the high medical costs for treating ESRD patients and covering dialysis care, the Centers for Medicare & Medicaid Services (CMS) implemented the ESRD Quality Incentive Program (QIP) in 2008, in an attempt to simultaneously reduce costs and improve quality of care. The ESRD QIP is a pay-for-performance program that uses four domains to evaluate the facilities' performances: clinical care measures, care coordination measures (including hospital readmissions, due to evidence that, with the exception of history of 30-day readmissions, ESRD is the strongest risk factor for 30-day readmissions[16]), safety measures, and patient and family engagement measures.[13] The ESRD QIP program includes financial penalties: when ESRD clinics do not meet or exceed certain performance standards, Medicare payments could be reduced as much as 2%.

Hospital Readmissions

Among the 550,000 U.S. patients receiving Medicare-covered dialysis treatment in 2019, there was an average of 1.60 hospital admissions per year.[9] The major reasons for hospitalization in dialysis patients are dialysis access problems, sepsis and other infections, surgery, serious bleeding, gastrointestinal complications, and cardiac complications.[14,15] Additionally, approximately one-third of dialysis patients' hospitalizations were followed by a readmission within 30 days.[9] Among U.S. patients receiving hemodialysis, 23.1% of patients had a readmission within 30 days; from these patients, 40.2%, 23.9%, and 35.9% had readmissions within 15-30, 8-14, and 0-7 days, respectively.[17] Furthermore, it was found in an additional study that 22% of the index admissions in the dialysis population were followed by a 30-day unplanned readmission.[18] Comparing the primary diagnoses between the initial hospitalization and rehospitalization, 80% of the admission diagnoses were different, and they discovered that depression, leaving against medical advice, and substance use were associated with readmissions.[18] Other risk factors for hospital readmissions include a younger age at dialysis initiation, the inability to ambulate, higher number of previous hospitalizations, and longer duration on dialysis.[19]

In 2019, CMS added the standardized readmissions ratio to the ESRD QIP to further improve patient outcomes and reduce costs through specifically prioritizing reduction of hospital readmissions in dialysis patients via payment incentives for dialysis facilities, which they were already doing for hospital.[13,20] Given these incentives, there is great interest to reduce readmission rates through interventions targeting dialysis patient risk factors. In a systematic review, the most common categories of interventions were patient education, discharge planning, follow-up telephone calls, patient-centered discharge instructions, and discharge coaches/nurses.[21] However, no single intervention alone was associated with a reduced risk of 30-day readmission.[21]

Challenges in Dialysis Care Coordination

Care coordination for dialysis patients who are admitted to the hospital and then discharged back to the dialysis clinic remains a challenge. One reason is that, despite the national emphasis on readmission reduction among dialysis patients, there is a substantial lack of interoperability between U.S. dialysis facilities and hospitals, which generally use different electronic health records (EHRs).[22] As U.S. dialysis facilities and hospitals use different systems, important elements of successful care transitions for dialysis patients, such as reasons for hospitalization, discharge summaries, updated problem/medication lists, and weight changes, are often not transmitted to outpatient dialysis facilities at discharge, or the transmission is not timely.[23–26] Medication errors are common in dialysis patients when they are hospitalized due to weak transitions of care from hospital to dialysis facilities.[27] Chronic medications are often changed when patients are hospitalized, and inadequate reconciliation may result in medicine duplication, therapeutic deletions, or dosing error after discharge, which increases the risk of hospital readmissions.[27] Additionally, hospitals may not receive pertinent medical information about their patients, such as continuation of antibiotics and labs, from dialysis facilities in a timely manner to provide high-quality, patient-centered care during hospitalization.[28] Since there is not a direct communication system between providers in the different settings, the lack of formalized care coordination and essential medical information flow between the hospitals and dialysis clinics increases the risk of preventable readmissions. Adequate care coordination between dialysis facilities and hospitals, which is key to reducing readmission rates in dialysis patients, is not possible in the current fragmented healthcare system without a means of communication outside of the EHR. Existing research to improve care transitions and reduce hospital readmissions among dialysis patients are few and not generalizable, illustrating a clear gap.

DialysisConnect

To address this gap, Dr. Plantinga's research team developed a secure web-based platform, called DialysisConnect, to provide a means of direct communication between dialysis facilities and hospitals at admission as well as during and after hospitalizations of dialysis patients. DialysisConnect was piloted at Emory University Hospital Midtown (EUHM) and four Emory-associated dialysis centers. Since EUHM and the affiliated dialysis facilities have separate EHRs and do not share a healthcare management system, DialysisConnect provided a two-way communication system between clinicians so that they can exchange essential patient information, beyond what is found on typical discharge summaries, such as the reasons for hospitalization, dialysis schedules, discharge summaries, updated problem/medication lists, dry weight changes, and follow-up appointments.[29] The system allows hospitalists and dialysis providers to request specific medical information from each other to increase patient awareness about their medical plan.[29] Discharge information is efficiently submitted to the system to allow dialysis providers to be aware of any changes to the patients' usual care before their next scheduled dialysis session.[29] The ultimate goal of DialysisConnect is to improve care coordination among dialysis patients with the primary aim of reducing hospital readmissions in this population.

High Utilizers

In most patient populations, there is a small group of patients who could be considered high utilizers. These patients impose a disproportionately high burden on the healthcare system due to their elevated resource use. Based on a national estimate, a group of high utilizers on hemodialysis constituted 2% of the population and was responsible for 20% of all readmissions.[18] This group of patients consist of the sickest and most complex patients, and their high utilization of the healthcare system is primarily explained by their multiple chronic conditions, mental illness, and social determinants of health including homelessness and history of recreational drug use.[30] However, there is no consensus on the definition for patients who are high utilizers, and the choice of metric to define utilization differs depending on the healthcare context.[31] Thus, researchers may characterize this group through different methods, such as patients' type of hospital utilization (the number of emergency department (ED) visits or hospital admissions), healthcare costs, and number of chronic conditions.[32,33] High utilizers are more likely to be over the age of 65, female, non-Hispanic White, less educated, and publicly insured; the majority of patients in this group also have low socioeconomic status and self-report poor or fair heath.[32] Although high utilizers represent a small proportion of the patient population, they account for a significant proportion of hospital readmissions and health care costs.[34] Therefore, healthcare systems strive to accomplish two goal for these high-need, high-cost patients: reduce their healthcare use through preventable or modifiable interventions, typically in the ED or hospital inpatient settings,[35–39] and to increase their quality of care.[37–39] There have been multiple attempts to lower the costs and admissions for these patients. Some of the designs and delivery of these interventions targeted case management, intensive primary care, social determinants of health, and alerts in the ED.[30]

However, there has not been a clear system for the most effective intervention for this population,[30] so more research is needed to address the needs and understand practical interventions for high utilizers. While the primary aim of DialysisConnect was to improve care coordination and reduce hospital readmission among all dialysis patients, here we aimed to analyze whether the two-way communication system would have a differential effect in health outcomes between high utilizers and non-high utilizers.

Study Aims

Aim 1: Assess and compare the effectiveness of DialysisConnect in reducing 30-day hospital readmission rates for admissions to EUHM among Emory Dialysis patients classified as high utilizers and non-high utilizers at admission, before and after implementation of DialysisConnect

Aim 2: Examine the differential effect of DialysisConnect among high vs. non-high utilizer admissions on other secondary outcomes pre- and post- implementation, including post-discharge 30-day observation stays, 30-day ED visits, 30-day mortality rates, and hospital length of stay

Hypotheses

1. The rates of 30-day readmission will decrease in both high utilizer and non-high utilizer admissions after implementation, with a larger decline for admissions among non-high utilizers.

2. The rates of 30-day observation stays, ED visits, and mortality, and hospital length of stay, will decrease in both patient populations, with a larger decline for admissions among non-high utilizers.

Methods

Study Design and Data Sources

DialysisConnect was a pre-post pilot study conducted at Emory University Hospital Midtown (EUHM) and four Emory affiliated dialysis clinics in metropolitan Atlanta. All admissions at EUHM among Emory Dialysis patients on or after 1/1/19 and discharged before or on 5/31/21 (end of pilot) were included. EUHM electronic health record (EHR) data were used to identify all admissions and outcomes, except for post-discharge mortality, which was identified using Emory Dialysis EHR data. Patients receiving dialysis were identified in the EUHM EHR using ICD-10 diagnosis codes related to dialysis (any of: N18.6, Z99.2, Z91.1, V45.11, V45.12); in a preliminary sensitivity analysis using pre-pilot data, this method was shown to capture 99% of admissions for Emory Dialysis patients. We identified a total of 1046 index admissions among 396 individuals in the period 1/1/19-5/31/21, excluding events with discharge status of expired, left against medical advice, and planned readmissions. The study protocol and waiver of patient consent were approved by the Emory University Institutional Review Board.

Variables

Study period. DialysisConnect was initially rolled out on 10/12/20 and its first use was on 10/28/20. For simplicity, the pre-pilot period was defined as 1/1/19-10/31/20, and the pilot period was defined as 11/1/20-5/31/21. The pilot ran for a total of 7 months.

High utilizer admission. A high utilizer admission was defined by whether the patient had at least three admissions or observation stays in the year prior to the admission date. Specifically, for each index admission from the start to end of the comparison study (1/19-5/21), it was considered a high utilizer admission if the patient had 3+ admissions or observation stays in the past 365 days prior to the start of the index admission. An observation stay allows physicians to place patients in an acute care setting to monitor symptoms that can be resolved within 48 hours or when the need for an inpatient admission is unclear. Events that did not match this definition were considered non-high utilizer admissions. Patients could have both high utilizer and non-high utilizer admissions, depending on the number of admissions and observation stays prior to their index admission, during the study period.

Primary outcome: hospital readmissions. Hospital readmissions were defined for each inpatient event by whether the patient was admitted at EUHM within 30 days of the discharge date of the index admission.

Secondary outcomes. Observation stays and ED visits within 30 days of discharge from the index admission were examined, alone and combined with hospital readmissions as well as with one another (readmission, observation stay, or ED visit combined; readmission or observation stay combined; 30-day observation stay or ED visit combined; 30-day observation stay alone; 30-day ED visit alone). Length of stay in days was calculated for all admissions by subtracting the discharge date from admission date. Mortality within 30 days of discharge was also assessed using dialysis facility data.

Other variables. At the time of admission, age, sex, and race were obtained from the EMR data. Comorbidity was estimated using the Charlson comorbidity index, based on inpatient ICD-10 codes per Quan et al.,[40,41] using all available codes in the year prior to the first admission in our sample; all patients were coded to have renal disease regardless of whether the codes were present. Cardiovascular and infectious causes of index admission were defined using primary ICD-9 codes, based on the classifications used by the United States Renal Data System.[9]

Statistical Analysis

Characteristics of hospital admissions during the study period were summarized overall and compared by high utilizer status (high utilizer vs. non-high utilizer) and also by pre-pilot vs. pilot period (within each dialysis affiliation group). The dataset was collapsed by month for interrupted time series analysis stratified by high utilizer status at the admissions level. The interruption was defined at the start of the pilot, on 11/1/20. Readmission rates were calculated as (number of index admissions in month followed by a 30-day readmission)/(number of index admissions in month). Interrupted time series pre-post analysis was performed for the Emory population, combining both high utilizers and non-high utilizers. Single-group pre-post analyses within high utilizers and within non-high utilizers were also performed. Multiple-group difference-in-difference (DID) analyses between the two populations with readmissions among non-high utilizers as the control group were performed, using Newey-West standard errors for ordinary least-squares regression coefficients. We also performed index admission-level linear regression (not collapsed at the monthly level) for readmissions and secondary outcomes. In sensitivity analyses, we used generalized estimating equations (GEE) to take into account that same individuals have multiple readmissions during the study period. DID analyses were performed, adjusted for age, race, sex, and Charlson comorbidity index, comparing differences between the pre-post pilot outcomes. DID values were obtained through an interaction term: group (high utilizer vs. non-high utilizer) x period (pre-post). The DID value represents the difference between the pre-post difference in the high-utilizers and the pre-post difference in the non-high utilizers.

Results

Characteristics of Index Inpatient Admissions

We identified a total of 1046 inpatient index admissions, representing 396 unique patients **(Table 1)**, during our study period. Among these, 466 admissions were among patients who were high utilizers at the time of admission (n=151), and 580 admissions were among patients who were non-high utilizers at the time of admission (n=360). Note the total number of high utilizers and non-high utilizers exceeds the total number of individuals because patients could be in different categories for different index admission events. Among high utilizer admissions, 361 index admissions (77.5%) were during the pre-pilot period and 105 (22.5%) were during the pilot period. Among non-high utilizer admissions, 434 admissions (74.8%) were during the pre-pilot period and 146 (25.2%) were during the pilot period **(Table 1)**. The average age at index admission was 59.1; average ages at admission were 58.2 vs. 59.9 for high utilizer vs. non-high utilizer admissions **(Table 1).** More than half of index admissions were among females (54.9% for high utilizer admissions and 53.6% for non-high utilizer admissions). Most index admissions were among Black patients: 98.9% and 93.0% of high utilizer and non-high utilizer admissions, respectively ($P<0.001$). Higher Charlson comorbidity indices (4.6 vs. 4.1; $P=0.008$) were seen in high utilizer vs. non-high utilizer admissions. Congestive heart failure (61.4% vs. 48.1%; $P<0.001$) and chronic obstructive pulmonary disease (36.5% vs. 23.8%; $P<0.001$) were more likely to be present in high utilizer vs. non-high utilizer admissions. Among high utilizer admissions, more diabetes (62.0% vs. 57.6%) and cardiovascular related admissions (63.5% vs. 59.5%) were observed, but the difference was not statistically significant **(Table 1)**.

Additionally, high utilizer index admissions were less likely to be related to infectious causes (25.1% vs. 37.9%; P<0.001).

Readmissions Before and After DialysisConnect Rollout at the Monthly Level

As the dataset was collapsed at the monthly level, the baseline monthly readmission rate among all patients during the pre-pilot phase was 24.2% **(Figure 1)**. The slope of the pre-pilot period was -0.13 (P=0.60); there was a non-statistically significant negative trend in readmission rates within the first 22 months of the study. When DialysisConnect was introduced at month 23, there was an average jump of 3.6% (P=0.76) from the pre-pilot to pilot period. Also, the slope for the pilot period was -0.60 (P=0.81); the negative trend in readmission rates continued. The difference between the pre-pilot and pilot periods was -0.47 (P=0.85). Like the pilot and pre-pilot negative trends, the pilot vs pre-pilot difference in trends was also not statistically significant **(Figure 1)**.

Comparing the high utilizers vs. non-high utilizer admissions, the slopes in the pre-pilot period were -0.40 (P=0.34) vs. 0.10 (P=0.69), and the difference between these slopes was -0.50 (P=0.31) **(Figure 2)**. From the pre-pilot period, the average jump at the start of the pilot was -1.7% (P=0.89) and 11.11 (P=0.50) for the non-high utilizer and high utilizer admissions, respectively. In the pilot period, the slopes were 1.01 (P=0.69) vs. -1.16 (P=0.66) for high utilizers vs. non-high utilizer admissions, and the difference between these slopes were 2.2% (P=0.55). Compared to the non-high utilizer admissions, the high utilizer readmission rates were generally higher with a positive trend in the pilot period **(Figure 2)**. In the non-high utilizer admissions, the pilot vs. pre-pilot difference in slopes was -1.27 (*P*=0.63); in the high utilizer admissions, the difference was 1.41 (*P*=0.59). The DID estimate, which represents the difference between the pre-post difference in the high-utilizers and the pre-post difference in the non-high utilizers, was 2.7% (P=0.47).

Readmissions Before and After DialysisConnect Rollout at the Admissions Level

After adjustment for age, sex, race (Black vs. other), and Charlson comorbidity index, the admissions-level 30-day readmission rates among the high utilizer admissions in the pilot and pre-pilot period were 35.9% and 27.0%, respectively; the absolute difference between these rates was 9.0% **(Table 2)**. Among the non-high utilizers, the rates in the pilot and pre-pilot period were 14.9% and 20.2%, respectively; the difference was -5.3%. The primary outcome in 30-day readmission rates by high utilizer status showed a statistically significant DID value of 14.2%. In the secondary outcome, 30-day observation stay or ED visit rates among the high utilizers in the pilot and pre-pilot period were 12.8% and 27.5%, respectively; the difference between these rates was -14.6% **(Table 2)**. Among the non-high utilizers, the rates in the pilot and pre-pilot period were 17.9% and 12.7%, respectively; the difference was -19.8%. The DID value of -19.8% for this comparison was statistically significant **(Table 2)**. Rates for 30-day observation stays among the high utilizers in the pilot and pre-pilot period were 5.4% and 15.4%, respectively; the difference between these rates was -10.0%. Also, the percentages among the non-high utilizers for the pilot and pre-pilot period were 8.9% and 5.5%, respectively, with a difference of 3.3%. For this comparison, the DID estimate of -13.3% was statistically significant **(Table 2)**. While the other adjusted secondary analyses showed null results, there was a statistically significant effect for readmissions, observation stays or ED visits, and observation stays only at the admission level. After running the sensitivity analysis into taking account intra-individual correlation due to multiple index admissions during the study period, the magnitude, direction, or statistical significance in the DID values were similar to those in the primary analyses **(Table 3)**. The DID values for % followed by 30-day readmission, % followed by 30-day observation stay or ED visit, and % followed by 30-day observation stay remained statistically significant; the other secondary outcomes' DID values also remained non-statistically significant in these sensitivity analyses.

Discussion

We found that 30-day readmissions after high utilizer admissions were higher in 7-month pilot period after our web-based platform, DialysisConnect, was introduced vs. the pre-pilot period (36% vs. 27% of admissions followed by 30-day readmission). In contrast, 30-day readmissions after non-high utilizer admissions were lower in the pilot vs. pre-pilot period among non-high utilizer admissions (15% vs. 20% of admissions). Pre-post differences in the two groups had similar, although non-statistically significant, trends when data were collapsed at the monthly level, and there was also no statistically significant change in readmissions when all admissions were combined. We found opposite, but statistically significant, trends for 30-day observation stays or ED visits, with pilot vs pre-pilot rates of 13% vs 28% after high utilizer admissions and 18% vs. 13% after non-high utilizer admissions. Similarly, there was a statistically significant pilot vs pre-pilot change in 30-day observation stays alone (5% vs. 15% after high utilizer admissions and 9% vs 5% after non-high utilizer admissions). Pilot vs pre-pilot differences in hospital length of stay and 30-day mortality did not differ between high utilizer and non-high utilizer admissions.

While we did not expect the readmission rates among high utilizer admissions to increase after the introduction of DialysisConnect, our results do suggest that DialysisConnect may have had a differential positive effect on the non-high utilizer admissions. It is unlikely that DialysisConnect is the primary reason for increased readmissions after high utilizer admissions, but these results do suggest that these patients may need a more targeted approach to address the specific needs and issues of individuals who are high utilizers at admission. Since DialysisConnect is primarily a provider intervention to address the gap in communication across settings, our intervention did not fundamentally attend to high utilizers' complex social and medical needs. Since many high utilizers have social issues, such as poverty, homelessness, food insecurity, transportation challenges, and drug addiction,[42] this patient population may need a more patient-centered approach to have a significant effect on their risk of readmission. Additionally, high utilizers may also have multiple complex chronic conditions and mental illnesses,[43] not all of which would be mentioned or addressed by providers at admission or discharge. Thus, many high utilizers may be admitted with a social need or condition that our intervention did not intend to target. Therefore, the primary results suggest that DialysisConnect and other similar interventions may need to take into account high utilizers' social barriers and challenging health needs in order to effectively reduce hospital readmissions among this population.

In our primary effectiveness analysis of our pilot study (manuscript submitted) with the intervention group defined as admissions among patients treated at Emory Dialysis at the time of admission, we found that the introduction of DialysisConnect was not associated with decreased readmission rates, accounting for secular trends by the inclusion of a control group of patients from other dialysis facilities. Comparing these results to our study, it may be suggested that the increased readmissions among the high utilizer admissions were counterbalanced by non-high utilizer readmissions, considering the disproportionate influence high utilizers, who are common in ESRD,[34,44] have on overall readmission rates.[18] Thus, in future studies of interventions to decrease readmissions in this population, it will be important to examine effects stratified by high utilizer status to ensure a full understanding of the intervention's effect.

Furthermore, in existing studies, researchers found there were no consistent data that showed a single component intervention to significantly reduce hospital readmission rates.[21,45] Instead, many successful interventions to reduce 30-day readmissions consisted of multiple domains to address the different stages in care. Some predischarge domains included patient education, discharge planning, medication reconciliation, and scheduling of a follow-up appointment before discharge. Post discharge components included follow-up telephone calls, follow-up with ambulatory providers, and post-discharge home visits. There were also bridging interventions that included transition coaches and physician continuity across inpatient and outpatient settings.[21] The only significant predictor of success to reduce readmissions was the number of domains included in the intervention, so the strength of successful transition depended on the number of components within a multi-faceted intervention.[45] For example, interventions, such as Care Transitions[46] and Project Reengineering Discharge,[47] used a multifaceted approach to reduce 30-day readmissions. Both interventions were successful and aimed to improve cross-site communication in addition to using transition and discharge coaches, who educated and met with patients throughout the hospital admission.

Given that we found the introduction of DialysisConnect was associated with decreased readmissions among non-high utilizer admissions but increased readmissions among the high utilizer admissions, it may be that this single-component approach is not sufficient to change readmission risk in high utilizers. Thus, it may be important to tailor and target the necessary resources to high utilizers' specific needs to observe a significant change overall in dialysis patients' risk of readmission. With the use of providers like nurse coaches, who can schedule follow-up appointments, review test results, encourage a patient-active role, and organize post-discharge services,[46] patients can receive more individualized care for their needs. Furthermore, high utilizer patients may need extra assistance with personal care through the guidance of social workers, who can provide the necessary community resources, such as housing, meals, and transportation, while connecting patients with existing programs and social services for their unmet needs. In 2008, CMS mandated the presence of nephrology social workers in ESRD facilities to support dialysis patients. It was found that the presence of social workers, who worked closely with ESRD patients suffering from psychosocial stressors, lowered patient depression scores, hospitalizations, and ED visits.[48] The positive differential role of social workers, in addition to improving communication between hospitals and dialysis clinics, can inform a targeted approach to improve certain health outcomes and reduce hospital readmissions among the high utilizer dialysis patients.

However, there may be challenges in incorporating additional providers to work closely with the high utilizer population. There is the complex decision to choose who would act as the primary care coordinators for these patients, because many healthcare providers, such as social workers and nurses in both the dialysis clinic and hospital settings, already have many responsibilities and may not have sufficient time to additionally attend to hospital transitions. For instance, many dialysis clinic social workers reported having insufficient time to provide psychosocial services.[49] During our pilot study, none of the dialysis clinic social workers used DialysisConnect (manuscript submitted), despite initial enthusiasm. Additionally, more than half of the dialysis clinic social worker population reported to be dissatisfied with their current job tasks,[49] which may lower their motivation to work closely with the high utilizer population. Although dialysis clinics can also hire a separate healthcare role to primarily serve as a care coordinator for high utilizers throughout their hospitalizations, there would be substantial costs and hesitancy for supporting these positions due to the current climate in dialysis facilities, the majority of which are for-profit. Additionally, it is important to note that many hospital readmissions in this population occur in 1-2 days, meaning that they would be readmitted prior to returning to the dialysis clinic, giving little opportunity for social workers, or even dialysis clinic staff hired specifically to coordinate care, to intervene.[17]

Interestingly, in our secondary analyses, we observed opposite trends examining 30-day observation stays/ED visits combined and 30-day observation stays alone: in the pilot vs. pre-pilot periods, observation stays/ED visits increased in non-high utilizer admissions and decreased in high utilizer admissions. Observation stays are utilized when patients are not well enough to be discharged and not sick enough to require a prolonged inpatient admission, and these patients are not expected to require prolonged monitored care due to the nature of their condition.[50] Providers may be less likely to assign an observation stay or ED visit to these high utilizer patients, due to the complexity and unpredictability of their needs and conditions, and instead assign an inpatient admission to more closely monitor the patient. In contrast, providers may be able to control and manage non-high utilizers' symptoms and condition on an outpatient basis, so providers may be more likely to order an observation stay to non-high utilizers. Since ED providers, who were not participating in our study, would typically make these patient status decisions, these secondary results are not likely directly explained by our intervention.

Importantly, our intervention was piloted during the COVID-19 pandemic, which may have influenced provider's decisions to assign specific patients to observation stays or inpatient admissions, increasing the secondary outcome rates after our intervention was introduced. ED visits and hospitalizations related to COVID-19 in Georgia exponentially increased in December 2020-February 2021. This pattern may have been due to the generally large patient volumes in the ED, making providers more likely to place or transfer high utilizers with complex needs to an inpatient admission during these pilot months to allow for more beds available in the ED for other patients' needs. This may have explained the decreased 30-day ED visit rates among the high utilizers when our intervention was introduced, although this result was not statistically significant. Since Medicare patients originating from the ED with comorbidities are more likely to have an unsuccessful observation stay in general,[50] high utilizers with multiple comorbidities, who were initially in the ED or observation stay, may also have been more likely to be transferred to an inpatient admission due to their complexity during the peak months of the pandemic during our pilot period. Another study also found that about 50% of the patients with congestive heart failure as their observation stay diagnosis were transferred to an inpatient admission.[50] For example, our high utilizer population admissions more likely to be among patients with a congestive heart failure diagnosis compared to non-high utilizer admissions; many of these patients may have initially been placed in an observation stay that eventually required an admission or were directly admitted as an inpatient hospitalization. Additionally, it may be more likely that high utilizers, who may have various underlying medical conditions and social factors, were hospitalized with COVID-19 more frequently, rather than receiving treatment from the ED/observation stay during the pilot period, contributing to the increased 30-day readmissions rate among high utilizers.

This study has several limitations not mentioned above. In addition to the COVID-19 pandemic affecting outcomes during our pilot period, the pandemic may have had a profound effect during the pre-pilot period. Due to the fear of contracting the virus in the hospital or dialysis setting, patients' admission and readmission levels may have been affected, particularly during the first months of the pandemic. In fact, the pandemic was generally associated with major changes in the utilization of healthcare services: for patient with milder or less severe illnesses, there was a larger reduction in healthcare utilization during the pandemic compared to those with severe illnesses.[51] Furthermore, high utilizers, who are already challenged with medical conditions and social needs, may have been more severely affected by the pandemic. This may have resulted in more utilization of healthcare resources, affecting the readmission rates. Additionally, since EUHM is a tertiary referral care hospital with specialized services and COVID-19 expertise, EUHM experienced a larger number of admissions during the pandemic, which may have affected hospitalization patterns among dialysis patients. Thus, the monthly patterns observed may have been a result of factors outside of DialysisConnect's influence. For example, increased systolic blood pressure, interdialytic weight gain, and risk of mortality during the months in winter compared to those in summer have been shown in ESRD.[52] These seasonal factors may have influenced the patterns in readmission rates, regardless of the effect of DialysisConnect, and these effects may have been differential by high utilizer status. While there was an increase in readmissions during the annual winter months for each population, there was a greater increase in readmissions among the high utilizers, as shown in the monthly level analysis. Additionally, our intervention was introduced during the winter months, which may have contributed to the increased readmission rates observed among the high utilizers during the 7-month pilot period.

Another limitation in this study of a web-based intervention aimed at providers was that patients were not directly involved in our study. Future studies could gather qualitative data for the high utilizer population to better understand their unique health and social needs because it is crucial to understand the target population's characteristics, qualities, and priorities. When we are more aware of these patient factors, it can allow us to better understand the complexity of care these patients may need and adjust interventions accordingly. Another potential limitation of the study could be that many of the hospital readmissions consist of the same high utilizer patients. However, we were able to perform sensitivity analyses to show that results were not significantly changed when we recognized the intra-individual correlation. Lack of power was likely an issue in the monthly level analyses, given that our pilot period was only 7 months. Extending the pilot period and gathering more collapsed data points at the monthly level may have provided statistically significant results at the monthly level. Finally, these results may not be generalizable to other U.S. hospitals or dialysis facilities, given substantial variations in practice and resources across settings.

In conclusion, the introduction of the web-based communications platform, DialysisConnect, was associated with decreased 30-day readmission among non-high utilizers and increased 30-day readmission among high utilizers. The results of this study suggest that this and similar interventions may need to target the specific health and social needs of the high utilizers to effectively reduce hospital readmissions and improve other hospital outcomes, both among these individuals and overall. Futures studies should examine the effectiveness of such platforms embedded within multi-component, patient-centered interventions and also address who could most effectively serve as care coordinators for patients receiving dialysis, particularly those who are high utilizers of the healthcare system.

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Tables and Figures

Table 1. Characteristics of index inpatient admissions to Emory University Midtown Hospital among Emory Dialysis patients, overall and by high utilizer status at index admission, from 1/1/19 to 5/31/21

Characteristic	**Overall**	**High Utilizer**	**Non-High Utilizer**	***P*[a]**
No. of patients	396	151[b]	360[b]	---
No. of admissions	1046	466	580	---
Period				
Pre-pilot	795 (76.0%)	361 (77.5%)	434 (74.8%)	*0.3*
Pilot	251 (24.0%)	105 (22.5%)	146 (25.2%)	
Patient age, mean (SD)	59.1 (15.0)	58.2 (14.8)	59.9 (15.2)	*0.07*
Sex, *n* (%)				*0.7*
Female	567 (54.2%)	256 (54.9%)	311 (53.6%)	
Male	479 (45.8%)	210 (45.1%)	269 (46.4%)	
Race,[c] *n* (%)				*<0.001*
Black	990 (95.7%)	458 (98.9%)	532 (93.0%)	
Other	45 (4.4%)	5 (1.1%)	40 (7.0%)	
Charlson comorbidity index,[d] median (IQR)	4.4 (2.8)	4.6 (3.0)	4.1 (2.6)	*0.008*
Diabetes,[d] *n* (%)				*0.15*
Yes	623 (59.6%)	289 (62.0%)	334 (57.6%)	
No	423 (40.4%)	177 (38.0%)	246 (42.4%)	
Congestive heart failure,[d] *n* (%)				*<0.001*
Yes	565 (54.0%)	286 (61.4%)	279 (48.1%)	
No	481 (46.0%)	180 (38.6%)	301 (51.9%)	
COPD,[d] *n* (%)				*<0.001*
Yes	308 (29.5%)	170 (36.5%)	138 (23.8%)	
No	738 (70.6%)	296 (63.5%)	442 (76.2%)	
Cardiovascular admission[e]				*0.18*
Yes	641 (61.3%)	296 (63.5%)	345 (59.5%)	
No	405 (38.7%)	170 (36.5%)	235 (40.5%)	
Infectious admission[e]				*<0.001*
Yes	337 (32.2%)	117 (25.1%)	220 (37.9%)	
No	709 (67.8%)	349 (74.9%)	360 (62.1%)	

COPD, chronic obstructive pulmonary disease; IQR, interquartile range.

[a]High utilizer admission vs. non-high utilizer admission, by *t*, Wilcoxon rank sum, or chi-square test, as appropriate.

[b]Number of patients adds up to more than the total, due to *n*=115 patients who were dialyzing as a high utilizer at the start of some index admissions but dialyzing as a non-high utilizer at the start of other index admissions during the pilot period.

[c]*N*=1035. Other race is primarily white (3.09% overall) but also includes Asian (0.58%), American Indian/Alaskan Native (0.1%), Hawaiian/Pacific Islander (0.1%), and multiple races (0.48%).

[d]*N*=1046.

[e]*N*=1046. Diagnostic codes for cardiovascular and infectious causes can occur in the same admission

Table 2. Adjusted[a] difference-in-difference results comparing differences between pre-pilot and pilot outcomes, by high utilizer status

	Mean[b] (95% CI)		
Outcome	**Pilot period**	**Pre-pilot period**	**Difference**
Primary:			
% followed by 30-day readmission			
High utilizer	35.9 (27.8,44.1)	27.0 (22.5, 31.4)	9.0 (-0.3,18.2)
Non-high utilizer	14.9 (7.9, 21.9)	20.2 (16.2,24.2)	-5.3 (-13.3,2.8)
Difference	21.0 (10.3,31.8)	6.8 (0.8,12.8)	**14.2 (2.0,26.5)**
Secondary:			
% followed by 30-day readmission, observation stay, or ED visit			
High utilizer	44.4 (35.1,53.6)	47.3 (42.3,52.3)	-2.9 (-13.4,7.6)
Non-high utilizer	30.3 (22.4,38.2)	29.8 (25.3,34.4)	0.5 (-8.6,9.6)
Difference	14.1 (1.9,26.3)	17.5 (10.6,24.3)	**-3.4 (-17.3,10.6)**
% followed by 30-day readmission or observation stay			
High utilizer	39.0 (30.2,47.9)	39.3 (34.5,44.1)	-0.3(-10,9.8)
Non-high utilizer	24.0 (16.5,31.6)	24.5 (20.1,28.8)	-0.4 (-9.2,8.3)
Difference	15.0 (3.3,26.7)	14.8 (8.3,21.4)	**0.1 (-13.2,13.5)**
% followed by 30-day observation stay or ED visit			
High utilizer	12.8 (5.4,20.2)	27.5 (23.5,31.5)	-14.6 (-23.1,-6.2)
Non-high utilizer	17.9 (11.5,24.2)	12.7 (9.1,16.4)	5.1 (-2.2,12.4)
Difference	-5.0 (-14.8,4.7)	14.7 (9.3,20.2)	**-19.8 (-31.0,-8.6)**
% followed by 30-day observation stay			
High utilizer	5.4 (-0.2,10.9)	15.4 (12.3,18.4)	-10.0 (-16.3,-3.7)
Non-high utilizer	8.9 (4.1,13.6)	5.5 (2.8,8.3)	3.3 (-2.2,8.8)
Difference	-3.5 (-10.9,3.9)	9.9 (5.7,13.9)	**-13.3 (-21.7,-4.9)**
% followed by 30-day ED visit			
High utilizer	7.5 (1.9,13.0)	12.1 (9.1,15.1)	-4.6 (-11.0,1.7)
Non-high utilizer	9.0 (4.2,13.8)	7.2 (4.5,9.9)	1.8 (-3.7,7.3)
Difference	-1.5 (-8.9,5.8)	4.9 (0.8,9.0)	**-6.4 (-14.9,2.0)**
Hospital length of stay, days			
High utilizer	6.5 (4.9,8.0)	5.8 (4.9,6.6)	0.7 (-1.0,2.5)
Non-high utilizer	6.4 (5.1,7.8)	6.5 (5.7,7.3)	-0.07 (-1.6,1.5)
Difference	0.1 (-2.0,2.1)	-0.8 (-1.9,0.4)	**0.8 (-1.6,3.2)**
% followed by 30-day mortality			
High utilizer	5.3 (1.3,9.2)	5.5 (3.3,7.7)	-0.2 (-4.8,4.3)
Non-high utilizer	4.4 (1.0,7.8)	3.4 (1.4,5.3)	1.0 (-2.9,5.0)
Difference	0.9 (-4.4,6.1)	2.1 (-0.8,5.1)	**-1.3 (-7.3,4.7)**

ED, emergency department.
[a]Adjusted for age, sex, race (black vs. other), and Charlson comorbidity index.
[b]In some cases, difference estimates do not reflect the difference of the estimated means displayed, due to rounding error.

Table 3. Sensitivity analyses: adjusted[a] difference-in-difference results comparing differences between pre-pilot and pilot outcomes, by high utilizer status, accounting for intra-individual correlation

	Mean[b] (95% CI)		
Outcome	**Pilot period**	**Pre-pilot period**	**Difference**
Primary:			
% followed by 30-day readmission			
High utilizer	7.0 (0.6,13.2)	-4.5 (-9.8,0.9)	11.4 (6.6,16.3)
Non-high utilizer	16.7 (10.7, 22.8)	19.6 (14.9,24.4)	-2.9 (-8.1,2.3)
Difference	-9.8 (-16.2,-3.3)	-24.1(-27.8,-20.4)	**14.3 (7.4,21.3)**
Secondary:			
% followed by 30-day readmission, observation stay, or ED visit			
High utilizer	19.6 (10.8,28.3)	21.3 (14.9,27.8)	-1.7 (-10.1,6.6)
Non-high utilizer	32.6 (24.8,40.4)	30.6 (25.3,35.8)	2.0 (-6.1,10.1)
Difference	-13.0 (-23.5,-2.5)	-9.3 (-15.4,-3.1)	**-3.7 (-15.1,7.6)**
% followed by 30-day readmission or observation stay			
High utilizer	8.3 (1.2,15.4)	5.7 (-0.2,11.5)	2.6 (-3.0,8.2)
Non-high utilizer	30.0 (23.2,36.7)	24.3 (19.1,29.5)	5.6 (-0.4,11.6)
Difference	-21.7 (-29.1,-14.2)	-18.6 (-22.9,-14.4)	**-3.0 (-11.0,5.0)**
% followed by 30-day observation stay or ED visit			
High utilizer	10.0 (2.3,17.8)	24.7 (20.0,29.5)	-14.7 (-23.1,-6.2)
Non-high utilizer	18.5 (12.0,24.9)	13.5 (9.6,17.3)	5.0 (-2.3,12.3)
Difference	-8.4 (-18.3,1.5)	11.3 (5.5,17.0)	**-19.7 (-30.8,-8.6)**
% followed by 30-day observation stay			
High utilizer	3.9 (-1.9,9.7)	13.9 (10.4,17.4)	-10.0 (-16.4,-3.7)
Non-high utilizer	9.8 (5.0,14.6)	5.8 (3.0,8.7)	4.0 (-1.5,9.5)
Difference	-5.9 (-13.4,1.5)	8.1 (3.8,12.4)	**-14.0 (-22.4,-5.6)**
% followed by 30-day ED visit			
High utilizer	7.1 (1.5,12.8)	11.8 (8.6,15.0)	-4.7 (-11.0,1.7)
Non-high utilizer	9.0 (4.1,13.7)	7.3 (4.5,10.1)	1.6 (-3.9,7.1)
Difference	-1.7 (-9.2,5.7)	4.9 (0.3,8.7)	**-6.2 (-14.7,2.2)**
Hospital length of stay, days			
High utilizer	6.8 (5.1,8.4)	6.0 (5.0,7.0)	0.8 (-1.0,2.6)
Non-high utilizer	6.5 (5.2,7.9)	6.4 (5.6,7.2)	0.2 (-1.4,1.7)
Difference	0.3 (-1.9,2.4)	-0.4 (-1.6,0.9)	**0.6 (-1.8,3.0)**
% followed by 30-day mortality			
High utilizer	7.2 (3.0,11.3)	6.6 (4.1,9.0)	0.6 (-4.0,5.2)
Non-high utilizer	4.8 (1.4,8.3)	3.3 (1.3,5.4)	1.5 (-2.5,5.4)
Difference	2.4 (-3.0,7.7)	3.2 (0.2,6.3)	**-0.9 (-6.9,5.2)**

[a]Adjusted for age, sex, race (black vs. other), and Charlson comorbidity index.
[b]In some cases, difference estimates do not reflect the difference of the estimated means displayed, due to rounding error.

Figure 1 Interrupted time series for readmission rates for all index admissions among Emory Dialysis patients from 1/1/19 to 5/31/21, with introduction of DialysisConnect on 11/1/20.

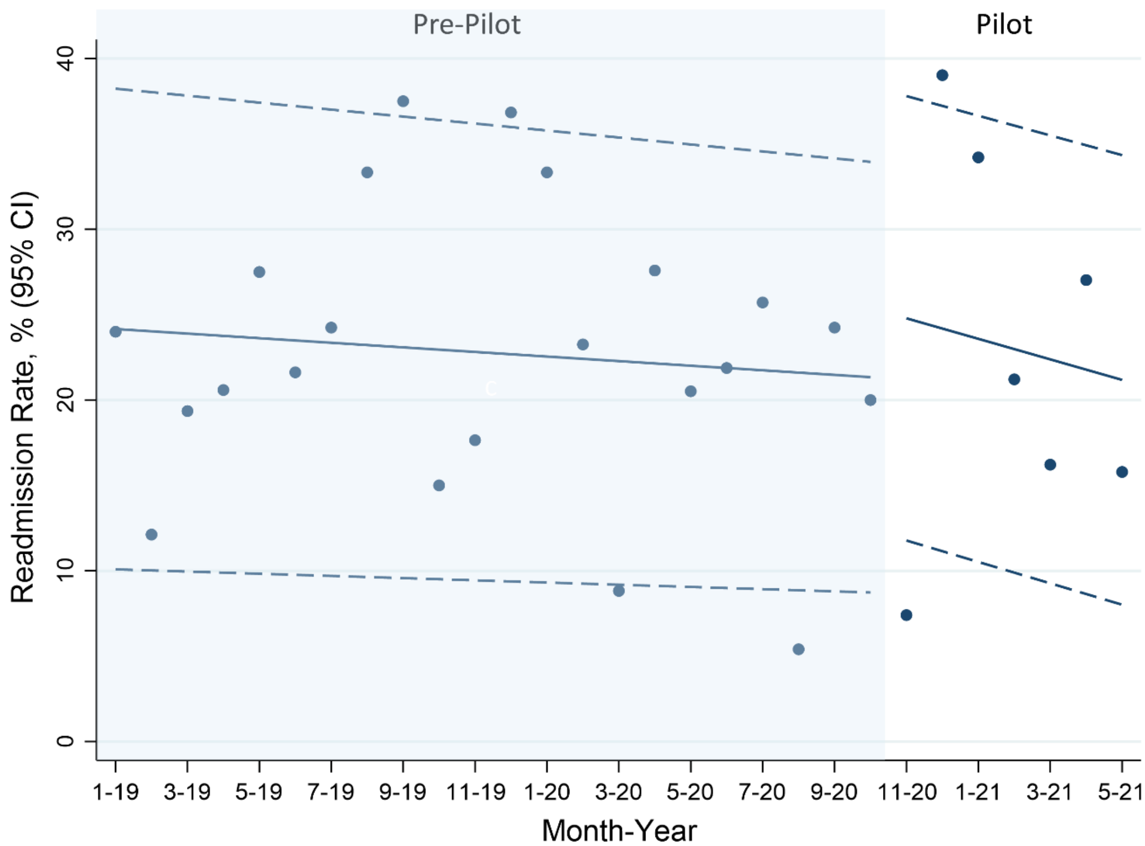

Figure 2 Interrupted time series of crude monthly readmission rates for index admissions occurring 1/1/19 to 5/31/21, comparing admissions among high utilizers and non-high utilizers, with introduction of DialysisConnect on 11/1/20.

	Slope/Trend		
Group/Period:	**Pilot**	**Pre-pilot**	**Difference**
High utilizers	1.01 (*P*=0.69)	-0.40 (*P*=0.34)	1.41 (*P*=0.59)
Non-high utilizers	-1.16 (*P*=0.66)	0.10 (*P*=0.69)	-1.27 (*P*=0.63)
Difference	2.18 (*P*=0.55)	-0.50 (*P*=0.31)	**2.68 (*P*=0.47)**