Clinical Outcomes of a Novel Multidisciplinary Care Program in Advanced Kidney Disease (PEAK)

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Introduction: Multidisciplinary care (MDC) for late-stage chronic kidney disease (CKD) has been associated with improved patient outcomes compared with traditional nephrology care; however, the optimal MDC model is unknown. In 2015, we implemented a novel MDC model for patients with late-stage CKD informed by the Chronic Care Model conceptual framework, including an expanded MDC team, care plan meetings, clinical risk prediction, and a patient dashboard.

Methods: We conducted a single-center, retrospective cohort study of adults with late-stage CKD (estimated glomerular filtration rate [eGFR] < 30 ml/min per 1.73 m^2) enrolled from May 2015 to February 2020 in the Program for Education in Advanced Kidney Disease (PEAK). Our primary composite outcome was an optimal transition to end-stage kidney disease (ESKD) defined as starting in-center hemodialysis (ICHD) as an outpatient with an arteriovenous fistula (AVF) or graft (AVG), or receiving home dialysis, or a preemptive kidney transplant. Secondary outcomes included home dialysis initiation, preemptive transplantation, vascular access at dialysis initiation, and location of ICHD initiation. We used logistic regression to examine trends in outcomes. Results were stratified by race, ethnicity, and insurance payor, and compared with national and regional averages from the United States Renal Data System (USRDS) averaged from 2015 to 2019.

Results: Among 489 patients in the PEAK program, 37 (8%) died prior to ESKD and 151 (31%) never progressed to ESKD. Of the 301 patients (62%) who progressed to ESKD, 175 (58%) achieved an optimal transition to ESKD, including 54 (18%) on peritoneal dialysis, 16 (5%) on home hemodialysis, and 36 (12%) to preemptive transplant. Of the 195 patients (65%) starting ICHD, 51% started with an AVF or AVG and 52% started as an outpatient. The likelihood of starting home dialysis increased by 1.34 times per year from 2015 to 2020 (95% confidence interval [CI]: 1.05–1.71, $P = 0.018$) in multivariable adjusted results. Optimal transitions to ESKD and home dialysis rates were higher than the national USRDS data (58% vs. 30%; 23% vs. 11%) across patient race, ethnicity, and payor.

Conclusion: Patients enrolled in a novel comprehensive MDC model coupled with risk prediction and health information technology were nearly twice as likely to achieve an optimal transition to ESKD and start dialysis at home, compared with national averages.

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KEYWORDS: chronic care model; health information technology; home dialysis; late-stage chronic kidney disease; multidisciplinary care; optimal starts

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CKD is of both global and national concern and impacts 37 million people in the United States. Approximately 1.1 to 1.3 million individuals have late-stage CKD G4 and G5.[1] Advanced CKD confers a substantially elevated risk of adverse outcomes, including hospitalizations, cardiovascular events, progression to

ESKD, and death. In addition, late-stage CKD imposes a large financial burden on the health care system, both through costs of care at the current stage and future costs if patients progress to ESKD.

To improve the care for Medicare beneficiaries with kidney disease, the Center for Medicare and Medicaid Innovation (CMMI) has tested new models of care delivery.[2] In 2015, The Rogosin Institute, a New York City-based nonprofit nephrology organization, joined as a pioneer participant in the Comprehensive ESRD Care model. We recognized the need to focus on the period of transition from late-stage CKD to ESKD to improve patient-centered outcomes and reduce costs of care. Nationally, this period is marked by low rates of preemptive kidney transplantation (3.1% in 2021); high rates of patients starting hemodialysis with catheters (85.4%); low rates of maturing AVFs and AVGs (11.4%) among those starting with catheters; and low, albeit improving, rates of patients receiving home dialysis at dialysis initiation (13.1%).[1] Unplanned dialysis initiation is associated with increased financial costs, high morbidity and mortality, and poorer psychological outcomes.[3,4]

MDC clinics for CKD are associated with improved patient outcomes when compared to traditional nephrology care.[5-7] However, there remain several key knowledge gaps. First, most MDC clinics (∼80%) in systematic reviews were located outside of the US where different payment models may impact the efficacy and feasibility of MDC.[5] Reports of MDC CKD clinics are limited in diverse urban patient populations in the US. Second, the optimal team composition of MDC clinics is unknown and very few clinics incorporate behavioral health professionals or peer mentors within MDC teams. Third, evidence is still emerging on the use of clinical risk prediction tools (such as the Kidney Failure Risk Equation) within MDC clinics to guide clinical decision making.[8,9] Fourth, the use of clinical information systems and patient registries within MDC clinics is under characterized, despite being a key component of the Chronic Care Model which is a widely accepted framework shown to improve chronic disease management.[10-12]

The PEAK program was established in 2015 to provide a novel MDC program for patients with late-stage CKD. In this manuscript, we describe the implementation and clinical outcomes of the PEAK program. We hypothesized that an MDC approach provided by a nephrologist, nurse practitioner, nurse educator, dietician, social worker, psychologist, and peer mentors coupled with clinical risk prediction and health information technology interventions could achieve improved transitions to ESKD in a diverse, urban population as compared with national and regional averages.

METHODS

PEAK Program Description

The PEAK program was initiated in April 2015 to provide MDC for patients with CKD stage G4 or G5 in an urban nephrology practice based in New York City. Patients with an eGFR < 30 ml/min per 1.73 m^2 were referred into the PEAK program by their primary nephrologist or an inpatient nephrology team following a hospitalization. Not all patients with an eGFR < 30 ml/min per 1.73 m^2 were referred to PEAK and referral was at the discretion of the primary nephrologist or inpatient nephrology team. The PEAK care team included 1 to 3 nurse practitioners, 1 nurse educator, 1 social worker, 1 dietitian, 1 to 2 nephrologists, 1 clinical psychologist, 1 licensed mental health counselor, multiple PhD-level data scientists and health informaticians, and a group of 5 to 7 trained peer mentors called wellness ambassadors. All patients enrolled in PEAK were longitudinally tracked in a registry.

The PEAK initial visit consisted of 2 appointments, each lasting 40 to 60 minutes, with a nurse practitioner and a social worker. Appointments with the other disciplines were then scheduled based on the patients' needs. Follow-up appointments with the nurse practitioner and social worker were scheduled every 2 weeks to 3 months, and usually alternated with visits with the primary nephrologist. Education was provided using both printed and web-based kidney care resources including the Medical Education Institute, Inc.'s Kidney School, Home Dialysis Central, and My Kidney Life Plan.[13-15] Dieticians billed insurance payors for their services, whereas social workers and nurse educators did not submit billing (e.g., the Kidney Disease Education benefit was not billed). Wellness ambassadors were paid an hourly rate supported by grant funding. The PEAK program was supported by institutional funds from a nonprofit nephrology organization (The Rogosin Institute). In Figure 1, we depict a process map of the PEAK program.

In addition to patient visits, weekly care plan meetings involving all disciplines (except for the wellness ambassadors) were held using a proactive, population health–based approach. Patients with upcoming PEAK appointments were discussed by the MDC team to modify care plans, review psychosocial assessments, and highlight gaps in care. The appropriate team member was then assigned to address these gaps, including contacting the patient or family member to schedule appointments with care team members.

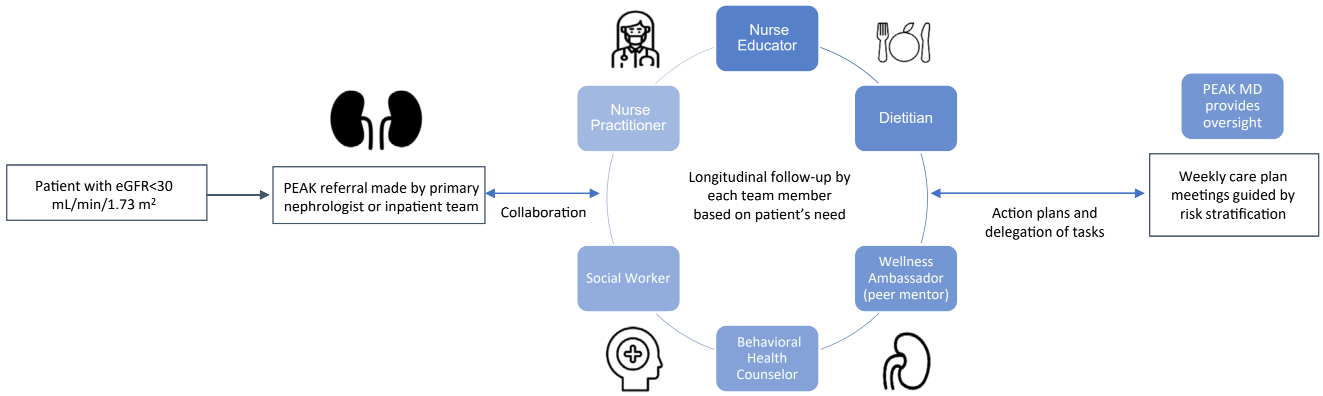

Figure 1. Process map of the Program for Education in Advanced Kidney disease (PEAK) program.

Primary nephrologists, transplant coordinators, and dialysis access surgeons or interventionalists were frequently messaged to coordinate care. Family members and care partners were actively engaged during visits and via telephone calls to facilitate discussions about transplantation and ensure viable support systems for patients choosing home modalities.

In October 2018, we transitioned to a web-based dashboard to guide care plan meetings, which was codeveloped by a health technology company and the PEAK program.[16,17] The dashboard imported patient demographics, diagnoses, medications, and laboratory values from the electronic health record (EHR) and used structured data fields to track patient milestones (Supplementary Figure S1). These milestones included transplant referrals and visits, transplant waitlist status, living donor availability, visits to home dialysis units, surgical referrals and visits, vascular and peritoneal access placement, and access maturity. The dashboard also displayed a graph of longitudinal eGFR trends, highlighting episodes of acute kidney injury and changes in CKD stage.

As previously described, the dashboard deployed a proprietary machine learning algorithm to predict the risk of ESKD or eGFR <10 ml/min per 1.73 m^2 at 6 months.[18,19] Features in the model included patient demographics, vital signs, comorbidities, laboratory values, and medications. Patients with a high risk score were prioritized during care plan meetings, monitored more closely by the PEAK team, and often were scheduled for more frequent appointments.

Study Population and Covariates

We conducted a retrospective cohort study of patients who were seen at least once in the PEAK program. Our study was approved by the Weill Cornell Medicine Institutional Review Board (Protocol #: 21-0102311). We included patients aged ≥ 18 years enrolled in PEAK from May 1, 2015, until February 29, 2020, prior to the first New York City wave of the COVID-19 pandemic. The patients were followed-up with until they progressed to ESKD, died, or until September 30, 2020. Participants who transferred care or were lost to follow-up were excluded from the analysis if we were unable to ascertain their clinical outcomes.

Baseline characteristics at the time of the first PEAK visit were obtained from the Jupiter Epic Clarity database using SQL server management studio v18.10. Demographics, including age, sex, race, and ethnicity were collected. Race and ethnicity were entered in the EHR via patient self-report or as assigned by clinical staff. Insurance status was classified as commercial (private insurance), Medicare fee-for-service (public insurance for individuals aged ≥65 years), Medicare Advantage (private insurers administer Medicare benefits), Medicaid (public insurance for low-income individuals), and Managed Medicaid (private insurers administer Medicaid benefits). Marital status was obtained from an EHR structured data field.

Comorbidities at PEAK enrollment were identified using Problem list and Encounter diagnoses (list of ICD-10 Codes in Supplementary Table S1). Creatinine values were ascertained within 3 months before or after PEAK enrollment and converted to eGFR using the 2012 CKD-EPI creatinine equation, which was recommended by Kidney Disease Improving Global Outcomes guidelines during our study period.[20,21] Urine albumin-to-creatinine ratio values were measured from spot urine samples. Missing data were only present for urine albumin-to-creatinine ratio values (53% missing), and multiple imputation was not employed because these data were not thought to be missing at random.

Outcomes

Our primary outcome was an optimal transition to ESKD, a composite outcome defined as follows: (i) starting ICHD in the outpatient setting with a functional AVF or AVG, (ii) home dialysis, including peritoneal dialysis or home hemodialysis, or (iii) preemptive transplant. Optimal starts are a well-accepted measure of the quality of nephrology care, and is currently used in CMMI's Kidney Care Choices Model. We used a more stringent definition than CMMI and the National Quality Forum–endorsed Optimal Starts measure stewarded by the Permanent Federation, which considers either inpatient and outpatient initiation of hemodialysis as optimal, as long as an AVF or AVG is used during the first outpatient session.[4]

Secondary outcomes included the following: (i) home dialysis initiation (peritoneal dialysis or home hemodialysis), (ii) preemptive transplantation, (iii) permanent vascular access (AVF or AVG) at dialysis initiation among patients receiving ICHD, and (iv) location of dialysis initiation (inpatient or outpatient) among patients receiving ICHD. Outcomes were collected from the PEAK registry and structured data fields from the web-based dashboard. Missing outcomes were ascertained by at least 2 investigators (DS, SLT, SD, SW, and AB) through manual chart review of NewYork-Presbyterian/Weill Cornell Epic EHR data and CareEverywhere using a standardized template.

Statistical Analysis

Characteristics of the participants at the time of PEAK enrollment were reported using percentages and mean (SD). Among patients with incident ESKD, optimal transitions were tabulated as a binary variable. Characteristics of PEAK patients with an optimal versus nonoptimal transition to ESKD were compared in unadjusted analyses using chi-square tests and t tests. Secondary outcomes, including dialysis modality, access, and location at dialysis initiation were tabulated as categorical variables.

Because optimal transitions and home dialysis are a major focus of current CMMI payment models, we compared these outcomes with unadjusted national data from the USRDS averaged from 2015 to 2019 (pre-COVID). We stratified these data by race, ethnicity, and insurance payor to assess variation by sociodemographic characteristics. Optimal starts among patients with incident ESKD were estimated using USRDS data by calculating the sum of home dialysis, preemptive transplantation, and ICHD initiation with an AVF or AVG. We also compared PEAK results to unadjusted regional averages in New York State and New York City using USRDS's Data Extraction System for Kidney Related Information and Basic Epidemiology tool.[22] Regional data were available for home dialysis and preemptive transplantation, but not other outcomes.

Trends in yearly optimal transitions, modalities, access, and location at dialysis initiation were graphed and evaluated using unadjusted logistic regression and multivariable logistic regression adjusting for all sociodemographics and comorbidities in Table 1. Trends were assessed using the year of incident ESKD as the predictor, modeled as a continuous variable. Data analyses were performed using Stata/IC, version 15.1 (StataCorp) and P <0.05 was considered statistically significant.

Table 1. Characteristics of participants at Program for Education in Advanced Kidney disease (PEAK) enrollment (n = 489)

Characteristics	PEAK Participants (n = 489)
Sociodemographic	
Age, yr	
19–44	71 (15%)
45–59	136 (28%)
60–69	134 (27%)
70–79	98 (20%)
≥80	50 (10%)
Sex	
Male	273 (56%)
Female	216 (44%)
Race and ethnicity	
Non-Hispanic White	168 (34%)
Non-Hispanic Black/African American	136 (28%)
Hispanic	74 (15%)
Asian	38 (8%)
American Indian or Alaska Native	1 (0.2%)
Other or Mixed Race	33 (7%)
Declined	39 (8%)
Insurance	
Commercial	110 (21%)
Medicare fee-for-service	244 (50%)
Medicare Advantage	74 (15%)
Medicaid	8 (2%)
Managed Medicaid	47 (10%)
Self-pay, other, or missing	15 (3%)
Marital status	
Single	204 (42%)
Married or domestic partner	214 (44%)
Divorced	35 (7%)
Widowed	36 (7%)
Clinical and laboratory variables	
BMI (kg/m^2)	27.9 (6.8)
Hypertension	433 (89%)
Diabetes	216 (44%)
Coronary artery disease	172 (35%)
Congestive heart failure	134 (27%)
eGFR at enrollment (ml/min per 1.73 m^2)	16.9 (8.3)
UACR at enrollment (mg/g)	1,530 (1,906)

BMI, body mass index; eGFR, estimated glomerular filtration rate; UACR, urine albumin-to-creatinine-ratio.
eGFR and UACR were +/− 3 months from enrollment.
Percentages may not add up to 100% due to rounding.
Continuous variables expressed as mean (SD).

RESULTS

Patient Characteristics

Among 519 patients enrolled in PEAK from May 2015 to February 2020, 30 (5.8%) transferred care or were lost to follow-up (Supplementary Table S2), yielding 489 patients in our final analytic sample. The patients had a mean age of 61 years (SD: 15), and 273 (56%) of them were male; 168 (34%) were Non-Hispanic White, 136 (28%) were Non-Hispanic Black, 74 (15%) were Hispanic, 38 (8%) were Asian, and 72 (15%) were other, mixed race, or declined (Table 1). Patients most often had Medicare fee-for-service insurance (244 [50%]) followed by commercial insurance (110 [21%]), Medicare Advantage (74 [15%]), and managed Medicaid (47 ([10%]). A total of 433 (89%) had hypertension and 216 (44%) had diabetes. Mean eGFR at PEAK enrollment was 16.9 (SD: 8.3) and patients were followed-up with for an average of 1.4 years (SD: 1.3 years).

Optimal Transitions to ESKD

Among the 489 patients in our study cohort, 301 patients (62%) progressed to ESKD, 37 (8%) died prior to ESKD, and 151 (31%) never progressed to ESKD. Among the 301 patients who progressed to ESKD, 195 (65%) started ICHD, 54 (18%) were on peritoneal dialysis, 16 (5%) were on home hemodialysis, and 36 (12%) received a preemptive transplant. A total of 175 (58%) patients had an optimal transition to ESKD. Patients experiencing an optimal transition to ESKD were more likely to be Non-Hispanic White (35% vs. 22%, $P = 0.105$), have hypertension (95% vs. 86%, $P = 0.006$), have higher eGFR at PEAK enrollment (15.1 vs. 13.2, $P = 0.067$), and lower urine albumin-to-creatinine ratio (1,609 vs. 2,339, $P = 0.051$) than those with nonoptimal transitions to ESKD in unadjusted analyses (Table 2, Supplementary Table S3). In unadjusted logistic regression, there was a 1.15 times higher odds (95% CI: 0.97–1.36, $P = 0.115$) of an optimal transition to ESKD per chronological year (Figure 1, Supplementary Table S4). In multivariable adjusted results, there was no statistically significant increase in optimal transitions to ESKD over time (adjusted odds ratio 1.16/yr [95% CI: 0.95–1.41], $P = 0.140$).

Trends in Secondary Outcomes

Among patients who started ICHD, 93 (49%) started with an AVF, 5 (2.6%) with AVG, 93 (49%) with a central venous catheter, and 4 had missing access types. Among ICHD patients, 15 were missing information on inpatient versus outpatient dialysis start. Of the remaining, 94 (52%) started as an outpatient. The odds of starting home dialysis increased by 1.34 times per chronological year (95% CI: 1.08–1.66, $P = 0.007$) in unadjusted logistic regression and 1.34 (95% CI 1.05–1.71, $P = 0.018$) in multivariable adjusted results (Figure 2). There were no statistically significant changes over time in preemptive transplantation, AVF or AVG usage at ICHD initiation, or outpatient dialysis starts (Supplementary Table S4).

Table 2. Characteristics of PEAK patients with an optimal versus non-optimal transition to ESKD

Characteristics	Optimal transition to ESKD[a] ($n = 175$)	Nonoptimal transition to ESKD ($n = 126$)	P-value
Sociodemographics			
Age, yr			
19–44	36 (21%)	16 (13%)	0.103
45–59	46 (26%)	42 (33%)	
60–69	53 (30%)	34 (27%)	
70–79	31 (18%)	20 (16%)	
≥80	9 (5%)	14 (11%)	
Sex			
Male	100 (57%)	71 (56%)	0.891
Female	75 (43%)	55 (44%)	
Race and ethnicity			
Non-Hispanic White	61 (35%)	28 (22%)	0.105
Non-Hispanic Black/African American	50 (29%)	49 (39%)	
Hispanic	20 (11%)	20 (16%)	
Asian	12 (7%)	10 (8%)	
American Indian or Alaska Native	0 (0%)	1 (1%)	
Other or Mixed Race	17 (10%)	7 (6%)	
Declined	15 (9%)	11 (9%)	
Insurance			
Commercial	36 (21%)	18 (14%)	0.148
Medicare fee-for-service	92 (53%)	66 (52%)	
Medicare Advantage	18 (10%)	25 (20%)	
Medicaid	2 (1%)	2 (2%)	
Managed Medicaid	22 (13%)	10 (8%)	
Self-pay, other, or missing	5 (3%)	5 (4%)	
Marital status			
Single	68 (39%)	52 (41%)	0.058
Married or domestic partner	84 (48%)	53 (42%)	
Divorced	16 (9%)	7 (6%)	
Widowed	6 (3%)	14 (11%)	
Clinical and laboratory variables			
BMI (kg/m2)	28.0 (7.2)	28.1 (6.9)	0.901
Hypertension	166 (95%)	108 (86%)	0.006
Diabetes	76 (43%)	64 (51%)	0.206
Coronary artery disease	60 (34%)	55 (44%)	0.099
Congestive heart failure	40 (23%)	36 (29%)	0.260
eGFR at enrollment (ml/min per 1.73 m^2)	15.1 (8.8)	13.2 (5.6)	0.067
UACR at enrollment (mg/g)	1609 (1682)	2339 (2608)	0.051

BMI, body mass index; eGFR, estimated glomerular filtration rate; ESKD, end-stage kidney disease; UACR, urine albumin-to-creatinine-ratio.
[a]Optimal transition to ESKD defined as: (i) starting in-center hemodialysis in the outpatient setting with a functional arteriovenous fistula or graft, (ii) home dialysis, including peritoneal dialysis or home hemodialysis, or (iii) preemptive transplant.
eGFR and UACR were +/- 3 months from enrollment.
Percentages may not add to 100% due to rounding.
Continuous variables expressed as mean (standard deviation).
Categorical and continuous variables compared using chi-square tests and 2-sided *t* tests, respectively.

PEAK Outcomes Versus National and Regional Outcomes

Compared with national data, there was a significantly higher percentage of patients in the PEAK program achieving an optimal transition to ESKD (58%, 95% CI: 53%–64%) than in USRDS data (30.1%) (Figure 2). This finding was consistent across all racial and ethnic

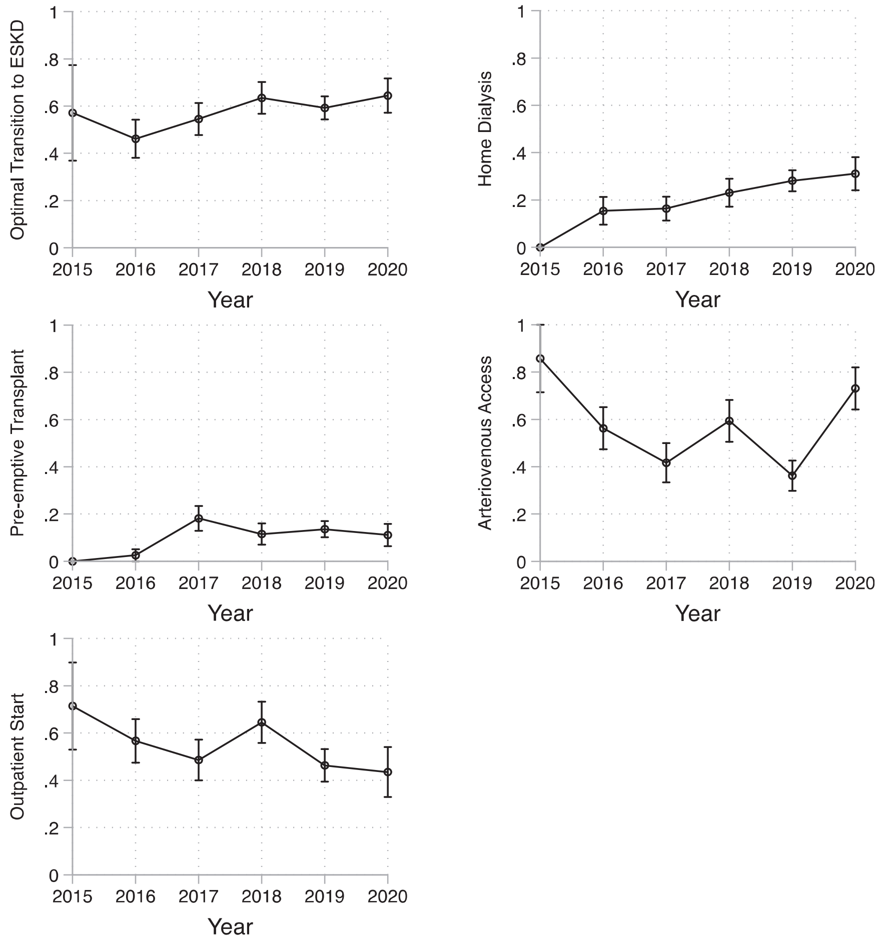

Figure 2. Trends in optimal transitions to ESKD and secondary outcomes within the Program for Education in Advanced Kidney disease (PEAK). ESKD, end-stage kidney disease. Graphs depict the proportion of optimal transitions to ESKD and secondary outcomes. Error bars depict standard errors.

categories, and across all payor categories (Figure 3 and Supplementary Table S5). Similarly, there was a significantly higher percentage of patients in the PEAK program transitioning to home dialysis (23%, 95% CI :19–28%) compared to national data (10.6%), and this finding was consistent across all racial and ethnic categories and across all payor categories. Compared with regional data, PEAK had a higher percentage of patients initiating home dialysis (23%) than in New York State (5.7%) and New York City (3.5%) (Supplementary Table S6). Similarly, the percentage of patients with a preemptive transplant was higher in PEAK (12.0%) than in New York State (3.4%) and New York City (3.0%).

DISCUSSION

In this urban, diverse cohort of patients with late-stage CKD seen in a novel and comprehensive MDC program incorporating an expanded MDC team, clinical risk prediction, and an electronic patient care dashboard, we achieved 58% optimal transitions to ESKD, approximately double the national average (30.1%). The percentage of patients initiating home dialysis (23%) or receiving a preemptive transplant (12%) were higher than national averages by approximately 2-fold and 4-fold, respectively, and higher than regional averages by 4-to-7-fold for home dialysis. Over half of patients starting ICHD started as an outpatient with an AVF or AVG. Importantly, our findings were reproduced across all racial and ethnic categories, as well as across all insurance payors, including low-income Medicaid patients, highlighting how MDC interventions can be used to promote health equity. Our data find that a comprehensive MDC model coupled with health information technology achieves patient-centered, equitable outcomes that far exceed national and regional averages.

Our results add to the previous literature showing that MDC clinics and nurse care management were associated with a higher likelihood of AVFs, home dialysis, and optimal transitions to ESKD than usual care.[23,24] Other studies have suggested that MDC is associated with reduced eGFR decline, incident ESKD,

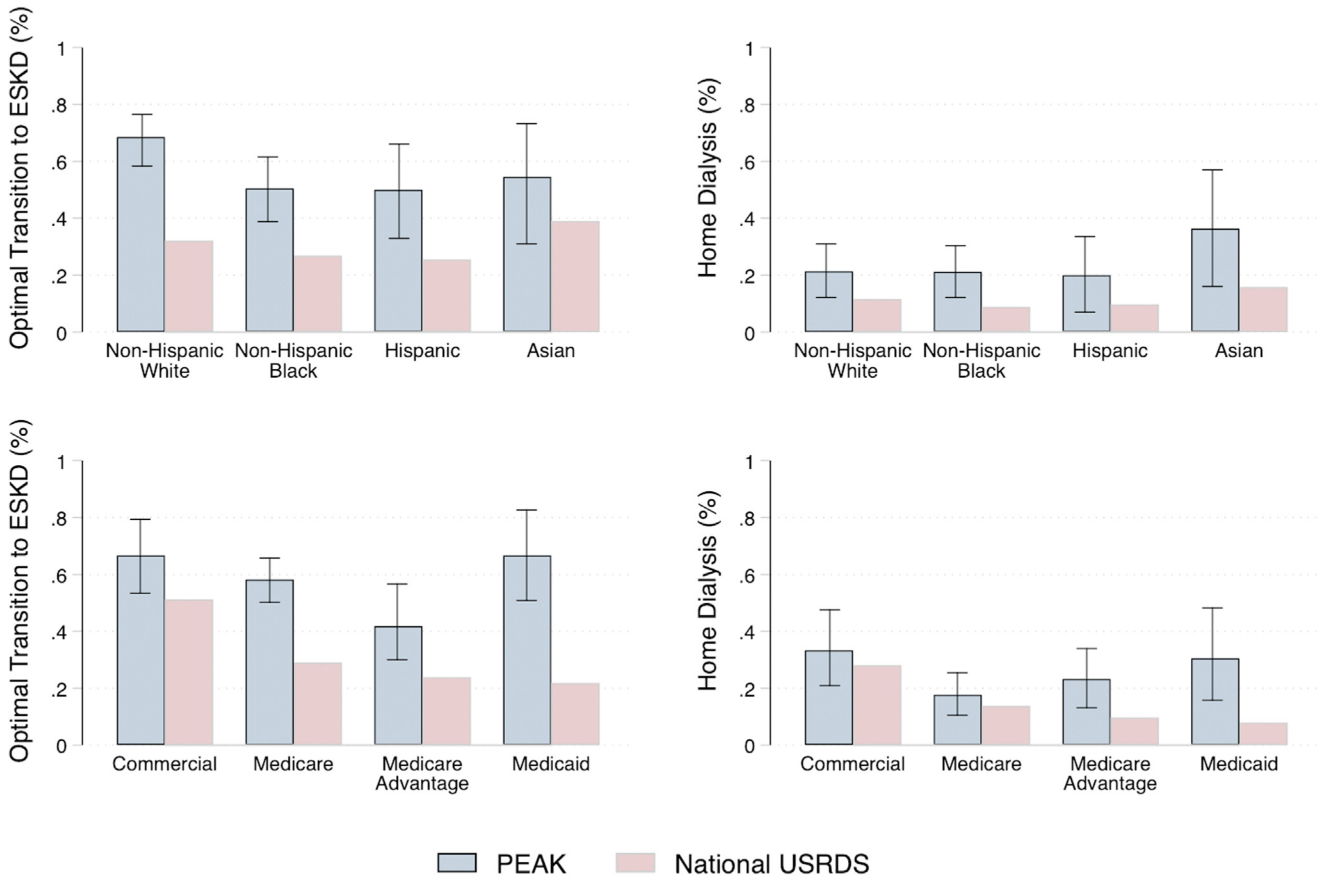

Figure 3. Percentage of optimal transitions to ESKD and home dialysis stratified by race and ethnicity and insurance coverage, versus national estimates from the United States Renal Data System. ESKD, end-stage kidney disease. Error bars depict 95% confidence intervals.

hospitalizations, and mortality, although were largely limited by nonrandomized, observational study designs.[6,7,25-27] Although the MASTERPLAN trial found that nurse practitioner care decreased the risk of death, ESKD, or 50% increase in serum creatinine by 20%,[28] other randomized studies have largely failed to show a benefit of MDC clinics on eGFR decline, cardiovascular outcomes, or mortality.[29-32] Given these results, we chose to focus our analysis on optimal transitions to ESKD, which are associated with reduced hospitalizations, improved survival, and lower health care costs, and being emphasized in the Kidney Care Choices value-based payment model through CMMI.[33,34] Our year-over-year data showed a sustained high level of optimal transitions to ESKD, and further analyses are needed to assess whether our optimal transitions led to reductions in hospitalizations, mortality, and health care costs.

Although we found a significant increase in home dialysis and increases in unadjusted optimal starts over time, other outcomes such as preemptive transplantation and AVF or AVG use remained stable, suggesting a potential ceiling effect. It is also important to note that by definition, everyone in our study had predialysis nephrology care, whereas about 30% of patients with incident ESKD in USRDS had no or unknown predialysis nephrology care.[35] When comparing PEAK patients to USRDS patients with >12 months of predialysis nephrology care, who may more closely resemble PEAK patients, our percentage of AVF or AVG use still exceeds USRDS (51% vs. 34%).[1] Data on other outcomes stratified by predialysis nephrology care were not available in the USRDS annual data report.

Our study extends the previous literature on MDC clinics for CKD in several aspects. First, the PEAK program uses a novel MDC team composition, including behavioral health specialists and peer mentors. Over 20% and 30% of patients with CKD experience depressive and anxiety symptoms, respectively.[36-38] Our introduction of behavioral health specialists is part of a growing awareness of how mental readiness and overall coping, and acceptance can positively impact long-term CKD outcomes. Similarly, peer mentoring through our wellness ambassadors is a promising strategy to allow patients and caregivers to learn from others who may have gone through similar life experiences,[39,40] but to our knowledge, its use in late-stage CKD MDC clinics has not been previously reported.

Second, PEAK used a risk prediction algorithm to identify the patients most likely to advance to ESKD within 6 months. Studies on the use of risk prediction tools within nephrology clinical practice are limited and are mostly used to prioritize patients for nephrology referral or MDC care.[41] One study used a similar approach to ours using a kidney failure risk equation threshold of >15% to engage in population health rounding.[42] To the best of our knowledge, ours is the first report of using machine learning algorithms within MDC clinics to drive improvements in optimal transitions to ESKD.

Third, PEAK exemplifies the 6 components of the Chronic Care Model (Table 3), which is a population health approach to improve chronic disease management.[10,12,44–47] The PEAK program aims to support patient self-management by reorganizing the delivery of CKD care through the use of care plan meetings and clinical information systems. The PEAK program is designed to improve care of patients with advanced CKD using measurable outcomes, promotes teamwork among multidisciplinary experts devoted to this select group of patients, encourages team members to consider aspects outside their area of expertise ("No-Silo" approach), and uses health information technology to ensure that high-risk patients do not fall through the cracks, thus practicing a philosophy of "No Patient Left Behind."

The strengths of this study include the racial and socioeconomic diversity of the patient population and limited loss to follow-up. The PEAK program's longevity for over 7 years also speaks to its ongoing sustainability. There are several limitations of the study, which include the single-center, nonrandomized, and retrospective study design. We lacked data from the EHR about visit frequency and missed appointments. This study was conducted in an urban setting, and it is unclear whether our findings are generalizable to different geographic areas. We were unable to adjust for patient characteristics and other potential confounders in our comparisons between PEAK results and national or regional data. In our analyses of trends in primary and secondary outcomes over time, we may have been underpowered to detect an effect. These points highlight the need for large-scale, multicentered, randomized controlled studies of MDC care to determine its efficacy and cost-effectiveness.

In summary, we have found that the PEAK program for late-stage CKD had high rates of optimal transitions to ESKD. Our novel MDC model demonstrated increased home dialysis and preemptive kidney transplantation, reduced inpatient hemodialysis initiation, and earlier AVF or AVG creation when compared with national and regional data. For nephrology practices to achieve goals stated in the Advancing American Kidney Health Initiative, it will be necessary to develop new and innovative ways to provide integrated, high-quality care for patients with late-stage CKD. The outcomes achieved by the PEAK program could be replicated by participants in CMMI's Kidney Care Choices Model, Medicare Advantage plans, and other health systems and payors seeking to improve late-stage CKD care and lower health care costs. It is important for Centers for Medicare and Medicaid Services and other payors to identify sustainable payment models that reimburse MDC programs to allow for their continued success. The PEAK program can serve as a

Table 3. Components of the chronic care model in program for education in advanced kidney disease (PEAK)

Components of Chronic Care Model[10,11]		PEAK Multidisciplinary Care Program
Health system organization of health care	Program planning that includes measurable goals for better care of chronic illness	• Provides focused care for CKD G4 and CKD G5 patients within a large nephrology practice • Periodic assessment of whether patients were achieving care milestones and optimal transitions to ESKD
Self-management support	Emphasis on the importance of the central role that patients have in managing their own care	• 1-on-1 NP and RN education so that patients and families can make informed decisions about CKD-ESKD transitions • Structured support for those who historically have had decreased access to healthcare
Decision support	Integration of evidence-based guidelines into daily clinical practice	• Guidelines created by KDOQI and KDIGO are used to achieve optimal outcomes[43]
Delivery system design	Focus on teamwork and an expanded scope of practice for team members to support chronic care	• Weekly care plan meetings emphasize interdisciplinary collaboration and a "No-Silo" approach • Processes for reaching out to patients who have been lost to follow up ("No Patient Left Behind")
Clinical information systems	Developing information systems based on patient population to provide relevant client data	• Creation of a tailored PEAK web-based dashboard to stratify patients with CKD who are at the greatest and most immediate risk for advancing to ESKD • Patients longitudinally followed in the PEAK registry
Community resources and policies	Developing partnerships with community organizations that support and meet patients' needs	• PEAK program incorporates social workers, behavioral health counselors, and wellness ambassadors who connect patients to resources in the broader community

CKD, chronic kidney disease; ESKD, end-stage kidney disease; NP, nurse practitioner; RN, registered nurse; KDOQI, Kidney Disease Outcomes Quality Initiative; KDIGO, Kidney Disease Improving Global Outcomes.

model for nephrology practices and thus add to the national conversation on the best ways to provide late-stage CKD care.

DISCLOSURE

DS reports consulting with Accordant (CVS). SLT received research funding from Scanwell Health, SAIGroup; and travel support from the International Society of Nephrology, unrelated to the submitted work. FL reports consulting from Outset Medical, medical advisor to CVS/ Accordant, and speakers bureau for AstraZeneca. JS reports consulting fees from Alkahest, Bayer AG, and Kaneka unrelated to this work and cochairs the American Society of Nephrology COVID-19 Response Team and Emergency Partnership Initiative. All the other authors declared no competing interests.

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SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Figure S1. Screenshot of patient review tool.

Figure S2. Chronic Care Model (reproduced from Epping-Jordan *et al.*).

Table S1. List of ICD-10 codes used to identify comorbidities.

Table S2. Characteristics of Program for Education in Advanced Kidney disease (PEAK) participants in analytic sample versus lost to follow-up.

Table S3. Characteristics of PEAK patients initiating in-center hemodialysis with a central venous catheter versus arteriovenous fistula or graft.

Table S4. Odds of optimal transition to end-stage kidney disease and secondary outcomes within the Program for Education in Advanced Kidney disease (PEAK) program over time.

Table S5. Optimal transitions to end-stage kidney disease and home dialysis by race and ethnicity and insurance payor.

Table S6. Home dialysis and preemptive transplantation in PEAK versus national and regional averages.

STROBE Checklist.

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