ORIGINAL ARTICLE

MAYO CLINIC PROCEEDINGS: DIGITAL HEALTH

Transforming Home Dialysis Management of Patients with Advanced Kidney Disease Using an Intelligent Automated Application in Practice

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Objective: To describe the design, development, and deployment of an electronic health record (EHR)-based application to manage the Mayo Clinic home dialysis program, improve staff efficiency, and ensure delivery of high-quality clinical care.

Patients and Methods: At Mayo Clinic, the Cohort Knowledge Intelligence Solutions (CKIS) team develops innovative patient cohort management solutions using the Epic Healthy Planet module. The CKIS team uses a collaborative and agile approach that incorporates feedback from clinical stakeholders and informatics to create these solutions that improve and automate processes for clinical staff, all managed within the EHR. Over several months (September 1, 2019, to December 30, 2020), the clinical nephrology and CKIS teams met regularly to develop in an iterative fashion 2 home dialysis applications. Time spent on various EHR-related home dialysis tasks was compared before and after the implementation of the applications based on the Nursing Efficiency Assessment Tool (NEAT).

Results: Two EHR applications were developed for managing home dialysis referrals and enrollments or monitoring, respectively. The applications consolidate all needed information and provide real-time data to manage patients at the individual or population level. Time saved for the 2 dialysis nurses who worked before and after the implementation was 25 and 20.4 minutes per 8-hour shift, respectively.

Conclusion: We developed and implemented 2 EHR applications that proved useful and increased efficiency in managing a home dialysis program. These digital tools can facilitate quality metrics reporting, scale the home dialysis program, and improve care delivery.

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The prevalence of chronic kidney disease (CKD) has increased worldwide, and currently about 14%-15% of the US population is affected.[1,2] More advanced CKD requiring kidney replacement therapy is much less common but contributes to disproportionate spending by Medicare because of the high cost of providing care for these individuals.[3]

Kidney transplantation is the preferred kidney replacement option for eligible individuals, but many patients remain dependent on dialysis owing to organ shortages.[4] Home dialysis modalities offer many advantages compared to in-center dialysis, such as increased flexibility, better quality of life, lower cost, and for peritoneal dialysis, better preservation of residual kidney function.[5-7] The requirement of home dialysis modalities (home hemodialysis and peritoneal dialysis), however, is lower in the United States compared with other developed countries.[5,8] In July 2019, the Department of Health and Human Services (HHS) released the Advancing American Kidney Health (AAKH) initiative that aims to incentivize home dialysis and transplantation, with an ambitious goal of having 80% of kidney replacement therapies be either a transplant or home dialysis by 2025.[9,10]

The logistics of establishing a home dialysis program, which include education, enrollment, modality training, and care coordination, is complex and requires significant investments in personnel, infrastructure, and technology. Nurses are the backbone of home dialysis programs and, in addition to necessitating specialized expertise, they need to support medically complex patients from the initial referral onward. Running an efficient program requires a reliable, real-time, and accurate digital health data collection and tracking system.

Until recently, our home dialysis program relied on Microsoft Excel workbooks on a secured network server as a registry to track some aspects of patient care. Although this solution was feasible when our program was small, over the last decade, the program has quadrupled in size. This growth rendered the existing manual system unsustainable and limited our ability to further scale our operation in an efficient and safe manner. When our institution transitioned in 2018 to a new single electronic health record (EHR) (Epic systems) across all campuses in 5 states, the nephrology department decided to seek a more intelligent and automated solution accessible by all care team members to help streamline and monitor the home dialysis program based on our protocol of care. The EHR-integrated population health management approach to manage various conditions (identification, risk stratification, care gap evaluation, and process or outcome monitoring) has been previously described with variable success. For example, 1 study of EHR-based digital health surveillance strategies reported the successful use of registries, custom dashboards, and operational reports to provide daily high-level summary for clinical practice use and up-to-date information to manage individual patients affected by COVID-19.[11] In another study, an EHR-based dashboard complementing an ongoing quality improvement program reduced all-cause 30-day readmission rates for heart failure.[12] An EHR-integrated Patient-Reported Outcomes application (eSyM) has also been deployed as part of routine clinical practice to optimize symptom management.[13] The tool was developed for patients, clinicians, and population health managers but presented technical and operational challenges with the clinical team expressing concern about the added workload. For CKD, particularly, 2 studies from large academic centers reported the successful development and validation of EHR-based registries.[14,15] One of these studies highlighted several opportunities to improve care delivery, such as annual testing for proteinuria, the use of medications to slow kidney disease progression, vascular access placement, and transplant referrals.[15] However, to our knowledge, limited studies have reported satisfaction or quantified the time saved by clinical team members, and no EHR-integrated application has been previously developed and validated for the management of a home dialysis program.[16,17] EHR-related workload is increasingly being recognized as a source of dissatisfaction and burnout among staff; hence, designing and demonstrating efficient workflows (in addition to improved clinical outcomes) is critical for the wellbeing of the health care workforce.[18-21]

We present in this manuscript our experience in designing, developing, and deploying a system wide home dialysis application in our EHR and share its benefits, limitations, lessons learned, and future applications.

PATIENTS AND METHODS

Practice Setting

Mayo Clinic is an integrated multispecialty, multistate, and academic medical center with a local, regional, national, and international referral base and an annual volume of outpatient visits of more than 1.5 million. The Midwest campus serves a 1.2 million population coverage area and provides comprehensive kidney care for patients with CKD, including those in need of kidney replacement therapies. Mayo Clinic in Rochester, Minnesota has a very active transplant center with annual volumes of over 250 patients and owns most of the dialysis centers (11 dialysis units in addition to a home dialysis program totaling over 400 patients) and nearby community hospitals. This integration provides a unique advantage when caring longitudinally for patients with progressive CKD. In this article, we focus on the Midwest-based program, although the home dialysis application is system wide. The Mayo Clinic Rochester home dialysis program was established more than 2 decades ago and expanded from less than 10 patients in the early 2000s to over 60 with a goal of doubling its capacity in the next 3-5 years. The program is currently staffed by 6 registered nurses, 2 patient care technicians, 1 dietitian, 1 social worker, 2 nurse practitioners, and 5 nephrologists. More than 40 providers (nephrologists and nurse practitioners) within our practice refer patients to the home dialysis program. In the last 3 years, we have also expanded the home program to include home dialysis therapies in a nursing facility, with a census of 4-8 patients treated with hemodialysis.

Process of Development

The nephrology department assembled a large team of stakeholders to streamline the enrollment and monitoring of patients in the home dialysis program. The team included the chair of the nephrology clinical practice (Z.M.Z.), the medical director of the home dialysis program (A.G.K.), 2 home dialysis nurses (D.S., K.H.), a nurse practitioner (M.D.), and clinical informatics information technology application analysts and information technology developers experienced in the development of applications for the management of cohorts of patients called Cohort Knowledge Intelligence Solutions (CKIS) at Mayo Clinic. After an initial discussion of the goals of this project and based on the operational workflow and data needed for best practice, the clinical team determined the content of the application. The stakeholders met on average every 2 weeks over a 6-month period to develop in an iterative fashion the initial application and test the efficiency of the system over the subsequent 3-4 months (overall time frame: from September 1, 2019, to December 30, 2020). During this process, the team concluded that 2 applications were required to meet the clinical need. The purpose of the first one entitled home dialysis watch list is to manage the referral to the home program and to ensure that the patients are moving in a timely fashion through the evaluation phase (complete all necessary steps) before completion of the supervised in-center home training. Patients who are not eligible for the home program are removed from the watch-list application. Once the training is complete, a patient is moved and activated in the second application entitled home dialysis monitoring to track monthly visits, laboratory data (such as adequacy, hemoglobin, and chemistry panel), missing monthly and quarterly laboratory tests, relevant immunizations (influenza, hepatitis B, and pneumococcal), the last abnormal blood culture, the last abnormal dialysate analysis indicative of peritonitis, hospitalizations, and transplant status. In addition, active treatment with erythropoietin stimulating agents or iron supplements is automatically collected.

Before the transition to the integrated home dialysis applications within the EHR, data regarding patient wait lists, surgical planning, transfer set changes, monthly laboratory test reports, dialysis adequacy, and care plans were kept in a combination of papers and multiple individual Excel sheets. For example, patients who were being evaluated for home dialysis but were not yet active in the home dialysis program had their names and medical record numbers recorded manually on a paper sheet, stored in a binder, and updated by the dialysis program scheduler through regular chart review. For active patients in the home dialysis program, the required data was entered in Excel sheets maintained initially by a dialysis technician. With the subsequent growth of the program, each dialysis nurse helped maintain the data for his or her assigned patients. These Excel documents were stored in the department's secured electronic drive, accessible by the nephrology team. Finding the data for their paneled or individual patients, however, was cumbersome and time consuming because it was outside the usual workflow of the EHR. Supplemental Figure 1, available online at https://www.mcpdigitalhealth.org/, shows examples of these Excel documents.

CKIS Architecture and Application Development

At Mayo Clinic, the CKIS team is behind the development of many innovative patient cohort management solutions using the Epic Healthy Planet module. The CKIS team uses a collaborative and agile approach that incorporates feedback from clinical stakeholders and informatics to create care management solutions based on agreed protocols of care, which improve and automate processes for clinical staff, all managed within the EHR. All projects are reviewed through a standard intake process that factors in the scope of the project, enterprise effect, patient safety, quality of care, and revenue effect, among other criteria. Once approved and assigned, a business analyst and a builder will work with a group of stakeholders anywhere from several weeks to several months, depending on the scope of the project to complete a solution.

After the scope of a project is defined, a registry is used to gather a patient cohort along with a subset of metrics required to support the practice's needs. The registry is an internal tool housed within Epic's software and uses a rule-based framework consisting of 2 main components, an inclusion rule and metrics. The inclusion rule is used to define the population and uses a combination of charted data, such as the patient's diagnosis, medication, surgeries, or general demographic characteristics (age, gender, etc.). The metrics also sets rules and define what data will be captured for the population. Once a patient meets the defined inclusion criteria, the underlying metrics are processed, and data is captured. Metrics are designed to support the monitoring workflow in addition to future quality analysis and outcomes. They typically capture dates, laboratory values, appointment information, patient demographic characteristics, and more. Finally, a report is built, allowing users to visualize and interact with the registry data. Within the reports, specific patient metrics are displayed pertinent to the practice that may include laboratory test results, appointment information, or customized algorithms to create alerts for care team members to help them prioritize their work. The last phase of the build process includes testing and ensuring that the initial agreed upon requirements have been met. Several months after the build is complete, the CKIS team meets with the customers to complete a value assessment that measures the effect of the solution provided.

Outcomes

To assess the effect of the new applications on the nursing staff, we used a tool available in the EHR that can track time spent on various tasks called NEAT: Nursing Efficiency Assessment Tool. This tool was created by the Epic team to help prioritize continuous improvement opportunities and to create targeted action plans for specific users. The tool can help review system efficiency data and identify users who could benefit from efficiency training to make changes. Informatics and project managers use the NEAT tool routinely to assess preimplementation and postimplementation of projects to ensure success in deployment. Time spent on 6 different tasks performed by the home dialysis nurses within the EHR (flowsheets, schedule, notes, orders, chart review, and communication) was compared numerically. The tasks that were chosen (a priori) for the NEAT data were activities in Epic that nurses spent the most time in, particularly reviewing patients that would be considered on the watch list. To minimize bias (related to time or experience and changes in case load over time), we used the month just before implementation as the baseline measurement. For the postimplementation measurement, and assuming a learning curve of a few months is needed for the nurses to be proficient in using the applications, we used the 6-month mark. We did not perform a formal statistical analysis because only 2 nurses showed efficiency data before and after implementation because of staff transitions.

Home Dialysis Personnel and Workload

Although the program expanded in 2022, during the development and for at least 6 months after the initiation of the home dialysis applications, the main personnel included 3 nurses and 1 certified dialysis technician. The 3 nurses worked in the following order: 1.0, 1.0, and 0.8 full-time equivalent (FTE), respectively. The 2 nurses who worked 1.0 FTE each were involved in the program before and after implementation. They were in the role for ∼2 years. The third nurse, who worked 0.8 FTE left the program and was replaced by another nurse during this time. The technician worked at 1.0 FTE. All personnel were considered full time in their role and worked 8-hour shifts, 5 days a week, except for the 0.8 FTE nurse who worked 4 days a week. No other relevant change, such as the number of patients in the program (case load), occurred during the implementation of the applications or the before-after comparison of the nursing time. The nurse's duties are multiple and include a variety of activities (that do not all occur on the same day), such as training patients (typically 5-6 h/d); postoperative visits such as evaluation after placement of a peritoneal dialysis catheter (0.5-1 hour); education classes (1-2 hours sessions); home visits (variable time commitment depending on the patient's geographical location); and clinic visits for enrolled patients (usually 4-5 hours on clinic days).

This work was reviewed by the Mayo Clinic Institutional Review Board (IRB # 21-005428) and is considered to be a quality improvement and not subject to any clinical research oversight.

RESULTS

The first (home dialysis watch list) and second (home dialysis monitoring) applications went live on May 29, 2020, and December 12, 2020, respectively. The clinical workflow is further explained. After a referral by a nephrology clinician, a patient meets with a home dialysis nurse for assessment and education. During this visit, the nurse fills out the home dialysis electronic form to activate the patient on the watch-list application (Figures 1 and 2). The application includes relevant data, such as the chosen home modality, the dates of the home education and home assessment, the referring clinician name, the surgical consult visit and surgical date of peritoneal dialysis catheter placement, the dates of the postoperative visits (to check the peritoneal dialysis catheter), the date when training started, the name of the training staff, and other relevant data. Once the home dialysis training is complete and treatment at home is started, the patient transitions to the home dialysis monitoring application. Figure 3 shows a screen shot of the main home dialysis application with the key data elements captured and agreed on by the clinical team. For example, the application includes the last contact date with the patient and the next outreach date recommended by the dialysis team (if needed), the date of the next appointment, and whether the monthly laboratory test reports are missing (red icon) or complete (green check mark). Supplemental Figure 2, available online at https://www.mcpdigitalhealth.org/, shows relevant data for individual patients, such as laboratory test report trends, most recent tuberculosis screening and hepatitis results, and the dates of the most recent dialysis plans of care. After the deployment into production, the CKIS team remained available for feedback and upgrades for the next 3 months. After stabilizing the application and officially closing the project, the clinical team was given the ability to reach out ad hoc to the informatics team to discuss or submit requests for further enhancements.

As of April 30, 2022, the home dialysis watch-list application included 59 patients, with 47 (80%) choosing peritoneal dialysis, 6

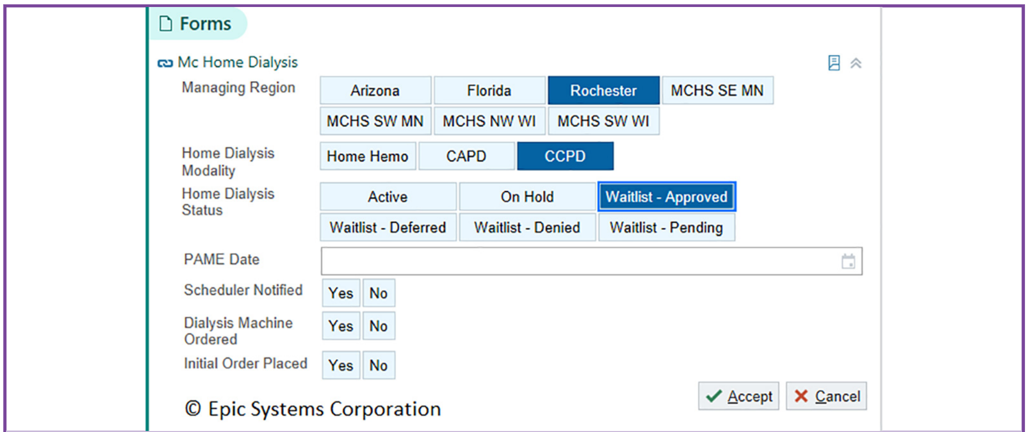

FIGURE 1. Electronic activation form after referral and evaluation in the home dialysis clinic.

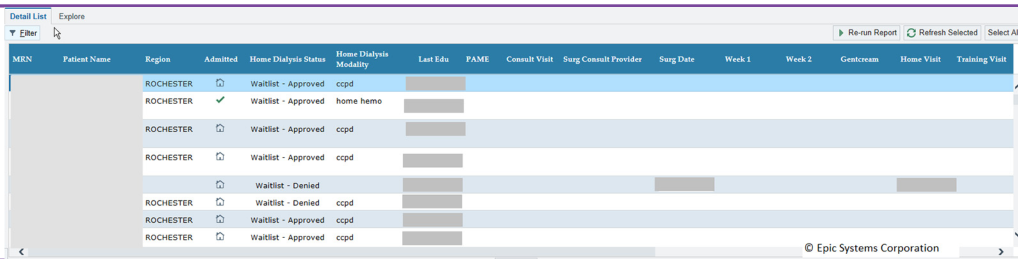

FIGURE 2. Snapshot of the home dialysis watch-list application.

(9%) home hemodialysis, and 6 (9%) still undecided. The home dialysis application includes a total of 96 patients; however, we describe only the 67 patients enrolled in the Rochester-based program. The baseline characteristics of these patients with their most recent monthly laboratory test reports are summarized in Table 1. The average age is 64 years (range 21-93), 41 (61.2%) are male, 55 (82%) White, 52 (77.6%) are treated with peritoneal dialysis, and 17 (25.4%) treated with home hemodialysis. Quarterly laboratory test reports were missing in 9 (13%) patients, whereas monthly laboratory test reports were missing in 64% because the data abstraction for this manuscript was done during the first week of the month when most of the patients have not yet completed their blood collection. The missing laboratory reports are flagged in the application and allow our dialysis team to reach out to patients to remind them to do their blood testing if needed before the end of the month. Twelve (18%) and 16 (24%) patients were hospitalized in the last 30 and 90 days, respectively. Using NEAT, the time spent by 2 nurses on the various home dialysis tasks within the EHR improved after implementation of the applications, with a total time reduction of 25 and 20.4 minutes per 8-hour shift, respectively (Table 2).

DISCUSSION

Our clinical team-led initiative successfully developed, with our information technology partners, 2 home dialysis applications to manage advanced CKD referrals and home dialysis monitoring. This enhanced process streamlined the dialysis staff's workflow and increased their efficiency by integrating the required clinical data in the EHR, saving 20-25 minutes per day. The new process also allows any stakeholder involved in the home dialysis program to easily access and review the relevant data and clinical information at any time. In addition, the application informs the users of the tasks needed based on the management protocols, thus bringing intelligence and automation to the application. This upfront investment allows more time for staff to interact with patients face to face

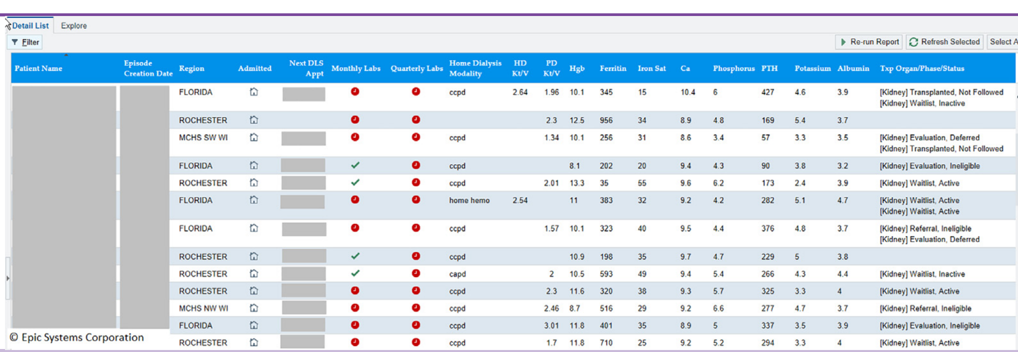

FIGURE 3. Snapshots of the home dialysis application main screen.

TABLE 1. Baseline Characteristics of Patients Enrolled in the Home Dialysis Program

Variables	Home dialysis patients (n=67)
Mean age in y (range)	64 (21-93)
Male sex, n (%)	41 (61.2%)
Race, n (%)	
White	55 (82.1%)
Black	5 (7.5%)
Asians	2 (3%)
Others	7 (10.4%)
Peritoneal dialysis	50 (77.6%)
Home hemodialysis	17 (25.4%)
Months on dialysis, median (IQR)	21 (11-39)
Most recent monthly laboratory test results	
Weekly KT/V (peritoneal dialysis)	2 (1.7-2.2)
Weekly KT/V (home hemodialysis)	2.2 (1.9-2.4)
Hemoglobin, g/dL	10.6 (9.8-11.3)
Ferritin, ng/mL	373 (266-644)
Transferrin saturation, %	28 (21-36)
Serum Calcium, mg/dL	9 (8.6-9.4)
Serum Phosphorus, mg/dL	4.8 (4.1-6.3)
PTH, pg/mL	288 (130-392)
Serum albumin, g/dL	3.9 (3.7-4.1)
Hospitalizations past 30 days	12 (18%)
Hospitalizations past 90 days	21 (31%)

K, the dialyzer clearance of urea; KT/V, a number used to quantify dialysis treatment adequacy; IQR, interquartile range; T, the dialysis time; V, the volume of distribution of urea.

or virtually. Communication with patients through the portal is readily accessible, and bulk messaging (ability to send the same message to multiple patients at the same time rather than individually in one click; a functionality similar to group messaging or communication through a distribution list) is an excellent feature of the applications. For example, staff can easily remind patients to do their monthly labs when they have lapsed, send them relevant educational material, and do a quick health check after hospitalization or a visit to the emergency department.

In addition, the application allows near-real-time quality metrics assessments and can serve as the basis for the creation of a home dialysis dashboard of key performance indicators and monthly reports that can assist the leadership team in making appropriate decisions and adjustments. The advantages of these applications, dashboards, and data analytics capabilities within the EHR have been previously well described for various diseases and conditions, including more recently COVID-19 related activities to manage the clinical practice safely, however, none specifically focused on home dialysis.[11,15,22-30]

We have not yet leveraged the functionality options offered by the CKIS application. Our team continues to explore enhancements and optimizations based on regular input from the dialysis staff and providers that will help us align with the HHS AAKH initiative. Supplemental Figure 3, available online at https://www.mcpdigitalhealth.org/, illustrates

TABLE 2. Time (in minutes) Spent per 8-h Shift in EHR-Related Home Dialysis Tasks by 2 Nurses Before (1 mo) and After (6 mo) Implementation of the Applications

	Nurse 1			Nurse 2		
Tasks[a]	Before	After	Difference	Before	After	Difference
Flowsheets	35	21	-14	35	19	-16
Schedule	8	7	-1	6	8	2
Notes	6	4	-2	4.5	5	0.5
Orders	5	3.5	-1.5	3.6	3.7	0.1
Chart review	4.2	3.7	-0.5	6	6	0
Communication	11	5	-6	13	6	-7
Total time	69.2	44.2	-25	68.1	47.7	-20.4

[a]Based on the Nursing Efficiency Assessment Tool (NEAT), an electronic health record tool. The time is a 1-mo average for each of the 2 full-time nurses.
EHR, electronic health record.

hospitalizations and emergency department visits that are being tracked, including information captured from other organizations (Supplemental Figure 3 shows the diagnoses of 2 emergency department visits at another health care system). Our team has also developed a β-version of dialysis related quality data readily available for clinicians and program leaders, such as dialysis adequacy and other laboratory test report metrics, transplant referrals, and transplant status (Supplemental Figure 4, available online at https://www.mcpdigitalhealth.org/).

Some of the challenges and limitations encountered are the inability to automatically capture some data, such as hospitalization events or transplant evaluations, that occur in other health care facilities that do not have interconnectivity with our EHR. Home dialysis machine integration with Epic is also unavailable at this time but would help the clinical team review the adequacy of each dialysis session and track missed or aborted sessions. This digital surveillance tool could facilitate proactive intervention to address avoidable issues and prevent hospitalizations and urgent visits to the emergency department.[31,32] Epic is working on such integration with home dialysis machine vendors, and an upgrade to the foundation system is anticipated. Regarding the outcome, the main limitation is the inability to confidently infer causation between the implementation of the applications and the nursing time saved. Although, during the preimplementation period, the nurses' responsibilities did not change and the number of staff, their FTE, and case load was relatively stable and unaccounted factors cannot be completely excluded. Another limitation is that patient care-related improvements (our ultimate goal), such as decrease time spent on the watch list before starting home dialysis, decrease in missing laboratory test reports, and decrease in hospitalizations were not captured and cannot be reliably reported retrospectively.

CONCLUSION

We developed and successfully implemented 2 EHR applications that proved useful and increased efficiency in managing a home dialysis program. These digital tools can facilitate quality metrics reporting, scale the home dialysis program, and possibly improve care delivery.

POTENTIAL COMPETING INTEREST

Given their role as Editorial Board Member, Dr. Rajeev Chaudhry, had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Ziad M. Zoghby, MD, MBA serves a member of the Epic nephrology steering board committee. All other authors report no competing interests.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at https://www.mcpdigitalhealth.org/. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **AAKH,** advancing the American Kidney Health; **CKD,** chronic kidney disease; **CKIS,** cohort knowledge intelligent solutions; **EHR,** electronic health record; **FTE,** full-time equivalent; **HHS,** Department of Health and Human Services; **NEAT,** Nursing Efficiency Assessment Tool

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