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Impacting Management of Chronic Kidney Disease Through Primary Care Practice Audits: A Quality Improvement Study

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Abstract

Background: Risk prediction tools are important in chronic disease management, but their implementation into clinical workflow is often limited by lack of electronic health record (EHR)-linked solutions.
Objective: To implement the Khure Health (KH) clinical decision support platform with an artificial intelligence (AI)-enabled algorithm for chronic kidney disease (CKD) risk detection in 201 primary care provider practices across Ontario.
Design: Multi-practice quality improvement study.
Setting: The study was conducted in Ontario, Canada.
Participants: 201 primary care practices.
Measurements: Per-practice CKD risk stratification and clinician action.
Methods: Data for estimated glomerular filtration rate (eGFR), albuminuria, demographics, and comorbid conditions were extracted from the EHR using KH's natural language processing (NLP) algorithms. Patients already on dialysis, visiting a nephrologist, older than 85, or already on a sodium-glucose cotransporter 2 inhibitor (SGLT2i) were excluded. The remaining individuals were risk stratified using the kidney failure risk equation, presence or absence of cardiovascular disease (CVD), or other comorbid conditions. A dashboard with disease-specific educational information and links to the EHRs of the identified patients was created.
Results: We screened 361 299 individuals and identified 8194 patients with CKD Stage 3 at risk for progression or cardiovascular events. A total of 620 individuals were at high risk for CKD progression or CVD, and 2592 were at intermediate risk. A total of 2010 individuals (10 patients per practice) at high or moderate risk were selected for a chart audit, and appropriate additional testing (repeat eGFR or albuminuria) or prescription of disease-modifying therapy occurred in 24.32% of these patients.
Limitations: Data on comorbidities, medications, or demographic variables are not available for presentation or statistical analysis due to privacy legislation and primary care provider (PCP) custodianship over EHR data.
Conclusion: An AI-enabled EHR clinical decision support application that can detect and risk stratify patients with CKD can enable improved laboratory testing and management. Larger trials of clinical decision support and practice audit applications will be needed to impact CKD management nationally.

Abrégé

Contexte: Les outils de prédiction des risques sont importants dans la gestion des maladies chroniques, mais leur intégration dans le flux de travail clinique est souvent limitée par le manque de solutions liées aux dossiers de santé informatisés.
Objectif: Mettre en œuvre, dans 201 cabinets de soins primaires de l'Ontario, la plateforme d'aide à la décision clinique Khure Health (KH) dotée d'un algorithme basé sur l'intelligence artificielle (IA) pour détecter les risques d'insuffisance rénale chronique (IRC).
Conception: Étude d'amélioration de la qualité dans plusieurs cabinets.
Cadre: Étude menée en Ontario (Canada).
Sujets: 201 cabinets de soins primaires.
Mesures: Stratification du risque d'IRC par cabinet et actions du clinicien.
Méthodologie: Les données relatives au débit de filtration glomérulaire estimé (DFGe), à l'albuminurie, à la démographie et aux maladies concomitantes ont été extraites des dossiers de santé informatisés (DSI) à l'aide des algorithmes de traitement

du langage naturel (TLN) de KH. Ont été exclus les patients sous dialyse, suivis par un néphrologue, âgés de plus de 85 ans ou traités avec un inhibiteur du cotransporteur sodium-glucose de type 2 (SGLT2i). Les autres individus ont été stratifiés selon le risque évalué par l'équation prédictive du risque d'évolution vers l'insuffisance rénale, et par la présence ou l'absence de maladie cardiovasculaire ou d'autres affections concomitantes. Un tableau de bord contenant des informations éducatives sur la maladie et des liens vers les DSI des patients identifiés a été créé.

Résultats: Nous avons examiné les dossiers de 361 299 personnes et identifié 8 194 patients atteints d'IRC de stade 3 présentant un risque de progression de l'IRC ou d'événements cardiovasculaires. De ces 8 194 patients, 620 présentaient un risque jugé élevé et 2 592 un risque modéré. En tout, 2 010 personnes (10 patients par cabinet) présentant un risque élevé ou modéré ont été sélectionnées pour une vérification des dossiers. Les tests supplémentaires appropriés (répétition des mesures du DFGe ou de l'albuminurie) ou la prescription de traitement modifiant la maladie ont été ordonnés chez 24,32 % de ces patients.

Limites: Les données sur les maladies concomitantes, la médication ou les variables démographiques n'étaient pas disponibles pour la présentation ou l'analyse statistique en raison de la loi sur la protection de la vie privée et du fait que les DSI sont sous la garde du médecin de soins primaires.

Conclusion: Une application d'aide à la prise de décisions cliniques basée sur l'IA pour les DSI, qui est capable de détecter et de stratifier les risques chez les patients atteints d'IRC, pourrait permettre d'améliorer la gestion de la maladie et les tests de laboratoire. Des essais à plus grande échelle portant sur les applications d'aide à la décision clinique et de vérification des pratiques seront nécessaires pour avoir une incidence sur la gestion de l'IRC à l'échelle nationale.

Keywords

kidney failure risk equation, risk stratification, EHR, clinical decision support software, quality improvement

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Introduction

Management of chronic kidney disease (CKD) is a public health challenge complicated by heterogeneity in clinical course, increasing incidence, and variability in treatment at the primary care level.[1,2] Though only a minority of patients progress to end-stage kidney disease, many more are at significant risk for adverse outcomes, including hospitalizations, cardiovascular disease (CVD), and reduced life expectancy.[3,4]

In Canada and the United States, most patients are referred to nephrology at an estimated glomerular filtration rate (eGFR) of 30 to 40 mL/min/1.73 m^2, by which time the therapeutic window initiating disease-modifying treatment is narrow, and focus tends to be on delaying dialysis initiation rather than reducing lifetime risk.[5] To address these challenges, organizations, including the Canadian Society of Nephrology, provide guidelines to optimize the management of CKD in primary care.[6] However, despite initiatives to disseminate these guidelines, variability in primary care persists.[7] Ongoing failure to identify patients with CKD early, stratify cohorts by risk of progression, and initiate disease-modifying therapy in high-risk individuals therefore represents a significant source of preventable morbidity.

In practice, early identification of CKD is a challenge at the primary care level given its asymptomatic nature and low disease awareness.[1,7] In this study, we sought to target these barriers in linkage to care by adapting the validated Kidney Failure Risk Equation (KFRE) to operate in a clinical decision support software (CDSS) employing artificial intelligence–based natural language processing (NLP) for automated electronic health record (EHR) screening.[8-10] The objective of the CDSS was to identify patients with CKD in eligible primary care practices in Ontario, stratify patients by risk of progression, identify high-risk cohorts whose treatment plan deviated from guidelines, and prompt evidence-based intervention by their primary care providers.

Methods

Study Population

Across the province of Ontario, 201 primary care practices were recruited for participation. The aggregate patient population for whom EHR records were available numbered 361 299. The study population included all adults with an eGFR $<$ 60 mL/min/1.73 m^2 in their most recent laboratory

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values, who were neither under active nephrology specialist care, or undergoing renal replacement therapy.

Clinical Decision Support Software

The CDSS was developed by Khure Health Inc, a subsidiary of MCI Onehealth Technologies Inc. The platform is predicated on EHR-based clinical NLP that extracts patient variables for subsequent algorithm input. Briefly, the NLP employs tokenization of sentences into individual words, and lemmatization of words into root forms that correspond to variables of interest. For this work, variables of interest were limited to demographics, comorbidities, medications, and laboratory values. As the variables of interest in this work correspond to structured forms of data, minimal NLP was required for feature extraction and was instead used for quality improvement over simple word search. To clinicians, the CDSS consists of a central user-interface presenting multiple (>100) clinical algorithms organized by pathology. Each clinical algorithm contains educational material, including description of the logical operator used for patient stratification, and presents lists of patients whose EHR variables dictated eligibility by a given algorithm. Within the patient lists, horizontal rows describe patients annotated by risk strata, with accompanying columns detailing laboratory, medication, and other medical history data relevant to the algorithm. The software was provided freely to physicians, and locally installed at each practice with an accompanying tutorial by an employee of Khure Health/MCI.

Natural Language Processing Risk Equation

The previously validated 3-factor KFRE was adapted to the CDSS.[8-10] Briefly, patient variables were locally extracted from practice EHR, with most recent eGFR, age, and gender used to calculate 5-year risk of progression to kidney failure. The 5-year risk of progression, current medications, history of nephrology referral, and comorbidities were subsequently used to stratify patients by risk of kidney failure (Figure 1). High risk was defined by a 5-year risk of kidney failure >6%, or between 3% and 6% with either a urine albumin-creatinine ratio (uACR) >30, or with 2 cardiovascular risk factors, including any of heart failure, diabetes, or hypertension, among patients with an age less than 85. Moderate risk was defined by a 5-year risk of kidney failure between 3% and 6%, without elevated uACR or CVD comorbidities, among patients with an age less than 85. Potential risk included the remaining patients with either a 1% to 3% 5-year risk of kidney failure, a 3% to 6% 5-year risk with an age between 75 and 85, a uACR >30 without a corresponding eGFR lab, or those with 2 CVD comorbidities for whom eGFR data were absent (Table 1). The natural language processor then excluded all patients with extracted variables positive for current sodium-glucose cotransporter-2 inhibitor usage (SGLT2i), which, due to recency of inclusion in treatment guidelines, was expected to be underutilized. Patients on renal replacement therapy, kidney transplant recipients, or those under active nephrology management were also excluded.

Practice Audit

Cohorts were stratified by priority level based on a composite risk of kidney failure or CVD event. For each participating primary practice, 10 individuals from the high priority groups were randomly selected for chart review. Khure Health clinical support staff attended the chart reviews to provide a tutorial on the software for the primary care provider (PCP). Reviews consisted of evaluating the 5-year risk of kidney failure for the identified individuals, determining the laboratory or other EHR data that informed risk-calculation, and assessing current treatment protocol in relation to established KDIGO guidelines, which were available for reference within the CDSS. Multiple pre-specified actions for each individual identified by the CDSS were available to the PCP. These included treatment optimization with SGLT2 inhibitors, lab requisition to assess eGFR and albuminuria, nephrology referrals, or flag for review, which annotates the patient record for subsequent, in-depth review. Patients deemed eligible by the primary care provider were then actioned during the audit, with number of actioned patients and specified actions collected as de-identified, aggregate data by Khure Health for subsequent analysis. Detailed data on comorbidities, medications, or demographic variables are not available for presentation due to privacy legislation and PCP custodianship over EHR data. Research ethics board approval was not indicated for this study, as practice audits constitute quality improvement, rather than research, in Canada.

Results

CDSS Identified Cohorts

We screened 361 299 individuals across 201 primary care practices in Ontario. In total, 8194 individuals, corresponding to 2.3% of all primary care patients, were identified by the CDSS as satisfying one of the priority tier inclusion criteria (Figure 2). Eight percent (620) of individuals identified were at high risk of progression to kidney failure (>6% 5-year risk), or at high risk (>3%-6%), with either Stage A3 albuminuria or 2 CVD comorbidities. An additional 32% of identified individuals (2592), or 0.72% of the screened population, were at moderate risk of kidney failure (3%-6%) without additional CVD comorbidities, or labs available to ascertain albuminuria. The remaining cohort of identified individuals (4982) were either at potential risk of kidney failure (1%-3%), missing eGFR values but with confirmed albuminuria or 2 CVD comorbidities, or were at high risk of kidney failure (3%-6%), but over the age of 75. All individuals either under nephrology specialist care, with a <1% risk

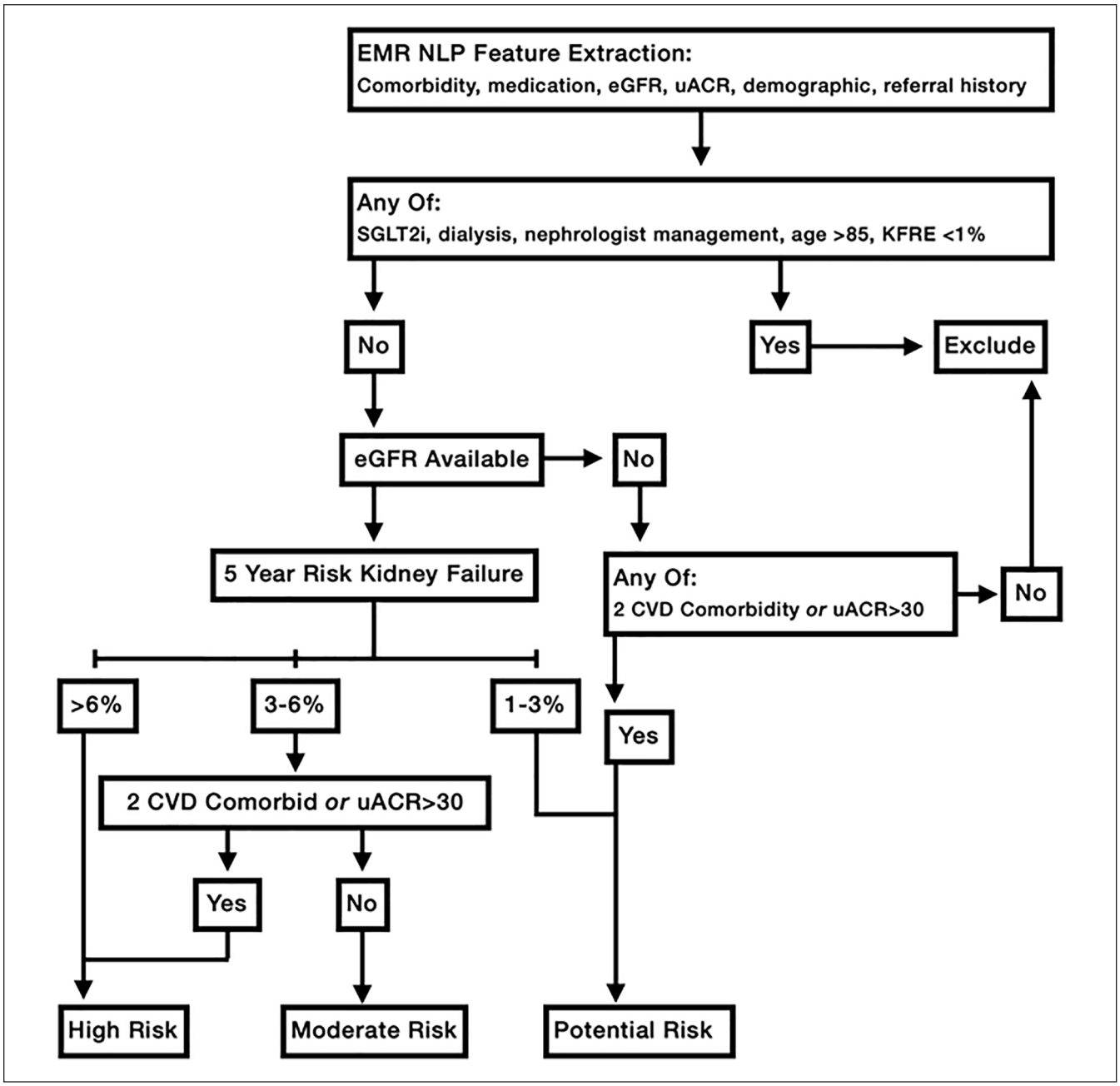

Figure 1. Patient stratification.
Notes. EHR NLP extraction performed using Khure Health's clinical decision support software. EHR = electronic health record; NLP = natural language processing; eGFR = estimated glomerular filtration rate (mL/min/1.73 m^2); uACR = urine albumin to creatine ratio (mg/g); SGLT2i = sodium-glucose cotransporter-2 inhibitors; KFRE = kidney failure risk equation; CVD = cardiovascular disease.

Table 1. Risk Groups.

Potential risk	Moderate risk	High risk
1%-3% 5-year risk of kidney failure	3%-6% 5-yearrisk of kidney failure	>6% 5-year risk of kidney failure
Missing eGFR (+) 2 CVD comorbidity		3%-6% 5-year risk of kidney failure (+) 2 CVD comorbidity
Missing eGFR (+) uACR >30		3%-6% 5-year risk of kidney failure (+) uACR >30
3%-6% 5-year risk of kidney failure (+) Age 75-85		

Notes. CVD = cardiovascular disease.

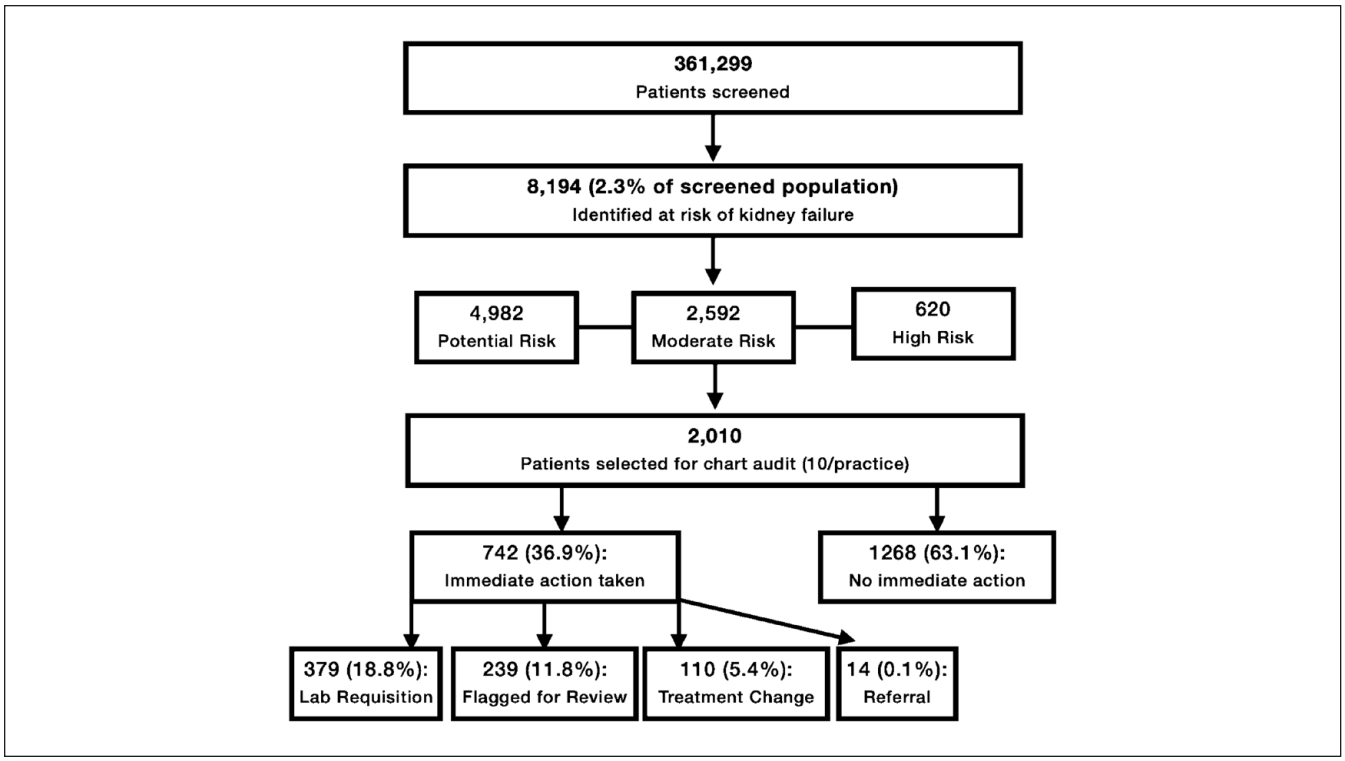

Figure 2. Patients actioned following chart review.
Notes. Actions reported based on initial practice audit. EHR = electronic health record; NLP = natural language processing; eGFR = estimated glomerular filtration rate; uACR = urine albumin to creatine ratio; SGLT2i = sodium-glucose cotransporter-2 inhibitors; KFRE = kidney failure risk equation; CVD = cardiovascular disease.

of 5-year kidney failure, or engaged in a treatment regimen consistent with guidelines, were excluded by the CDSS.

Primary Care Audit

Of the 2010 individuals selected for chart review, 36.9% (742 patients) were actioned along the pre-specified pathways (Figure 2). The most common actions taken were lab requisition for repeat testing of eGFR and albuminuria (51%), followed by a flag to review chart at the next clinic visit (32%), treatment optimization through initiation of disease-modifying therapy (15%), and new nephrology referral (2%). When the chart was not immediately actioned, the most common reasons provided by PCP was a desire to review the charts at a later time, or because patients were undergoing palliative support or in long-term care. Other noted reasons included patients being lost to follow-up, particularly out of the country, or already under non-nephrology specialist care.

Discussion

In this study of 201 primary care practices in Ontario, we screened 361 299 individuals and found 1 in 40 were both at high risk of kidney failure or CVD events, and undertreated with KIDIGO guideline directed disease-modifying medications. Subsequent on-site chart reviews resulted in clinically meaningful actions, including referral, lab requisition, and treatment optimization, for 36.9% of patients. These findings suggest CKD management at the level of primary care requires significant optimization and that automated identification of these individuals with a CDSS implementing a modified version of the validated KFRE can improve clinical workflow and accelerate adherence to current CKD guidelines.

In the past 5 years, there have been multiple studies that have targeted improvements in care of CKD and its associated risk factors in both the primary care and nephrology settings. These studies have used different methods and accordingly achieved mixed results.[11-14] In one of the largest studies conducted to date, investigators from the United Kingdom randomized 46 practices, and 23 35 patients with CKD to a nurse-led intervention that targeted several process measures including proteinuria measurements, coding for CKD, and clinical outcomes including blood pressure control and change in kidney function.[13] Although they did not find an effect on eGFR, several positive effects on CKD diagnosis, management, and blood pressure control were noted with the primary care intervention. Our intervention targeted similar process and quality measures, but perhaps is even more cost-effective due to the use of EHR-linked

solution rather than a nurse-practitioner. More recently, investigators from the University of California, San Francisco, studied 524 patients across 80 primary care providers using a CDSS and found improvement in CKD awareness among PCPs but no change in prescription.[14] They did find higher uptake of the recommendations in an as-treated analysis, when compared with intention to treat, which would be consistent with our observational study.

We believe that there are important clinical and research implications of our findings. From a clinical perspective, our findings present a solution that is EHR agnostic and can be used by primary care providers across Canada, and other countries as a tool to perform practice audits for CKD and improve quality of care. From a research perspective, this solution has the potential to be leveraged, in compliance with privacy regulations, as an aid in identifying patients who may be eligible for clinical trials based on inclusion and exclusion criteria, and may therefore increase the access to innovative treatments for patients and physicians. Finally, while other physicians have been cautious about data sharing, we believe that the benefits from interoperability of EHRs, and better portals for both patients and providers, when created with the appropriate data security safeguards, can have more benefit than harm.

There are some limitations to our findings. Due to the family physicians' custody of the data, we are unable to report on detailed patient characteristics or perform additional statistical analyses beyond the scope of the quality improvement framework (practice audit). This is an inherent challenge in quality improvement studies. Furthermore, because Khure health clinical support staff assisted physicians with chart reviews, engagement may be lower if this program is expanded to physicians without support staff. In addition, this project focused on risk of CKD progression and targeted patients who may benefit from SGLT2i to slow CKD progression. These drugs have other major benefits and indications, namely a reduction in heart failure hospitalizations, in patients with or without heart failure, and this population was not examined in this intervention.[15] Similarly, undertreatment with renin angiotensin aldosterone system (RAAS) inhibitors was not evaluated in this study, though recent finding suggests less than half of Canadians with CKD receive treatment with RAAS inhibitors.[16] Finally, interventions like ours can only demonstrate improvement in processes of care such as albuminuria testing, and appropriate drug prescription in a short time frame. It may take years to demonstrate a benefit on kidney outcomes such as time to dialysis, and these should not be considered appropriate outcomes for quality improvement studies. Moreover, following initial data collection, additional actioning from subsequent chart audits have been reported, with year 1 data likely to show further linkage to care in this population. Strengths of this quality improvement project include a focus on primary care, inclusion of a large number of patients and practice, and demonstration of an EHR agnostic CDSS as an effective tool for practice change.

Conclusion

Our findings demonstrate that an EHR agnostic CDSS may improve the quality of CKD care for high-risk patients in the primary care setting. Application of these tools to both primary and nephrology practice EHRs is needed to improve CKD outcomes across the spectrum of disease.

Ethics Approval and Consent to Participate

Primary care providers have implied consent for quality improvement.

Consent for Publication

All the authors provide consent for publication.

Availability of Data and Materials

The de-identified aggregated data underlying this article will be shared on reasonable request to the corresponding author.

Author Contributions

A.M., D.W., and N.T. conceived of the study. A.M. performed data collection and analysis. A.M. and N.T. prepared the manuscript.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: D. Watts is an employee of MCI One Health. A. Mosa and N. Tangri received consulting fees from MCI One Health.

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