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Provider perspectives of clinical decision support for chronic kidney disease management: a cross-sectional study

Robert Goldberg[1], Henry Li[2], Cory E. Goldstein[3,4], Kevin Yau[5], Shannon M Ruzycki[1,6,7,8], Maoliosa Donald[1,8], Meghan J Elliott[1,6,7,8], Brenda R Hemmelgarn[2], Matthew T James[1,6,7,8], Pietro Ravani[1,6,7,8], Neesh Pannu[2], Derek Chew[6,7,8,9], Dilaram Acharya[1,10] and Tyrone G. Harrison[1,6,7,8,11*]

Abstract

Background Chronic kidney disease (CKD) affects approximately one in ten adults globally. Multiple studies have identified underuse of effective therapies in eligible patients with CKD despite guideline endorsement. Clinical decision support (CDS) may increase confidence in prescribing recommended medications, but how end-users perceive it is unknown.

Objectives To evaluate clinician-reported perspectives and acceptability of CDS elements for ambulatory CKD management and inform the development of a CKD-specific CDS intervention.

Methods Eligible participants for this electronic cross-sectional study were prescribing clinicians from Alberta, Canada, that practiced in ambulatory care settings, including physicians, nurse practitioners, and pharmacists. The survey presented examples of a proposed CDS' content and format, and collected information on clinician demographics, CKD workflows, perceptions of CDS design, perceived acceptability and clinical utility. Knowledge, comfort, and prescribing patterns were examined for renin-angiotensin system inhibitors (RASi), statins, sodium-glucose cotransporter-2 inhibitors (SGLT2i), glucagon-like peptide-1 receptor agonists (GLP-1RA), and non-steroidal mineralocorticoid receptor agonists (nsMRA). Participant comfort prescribing each medication class was compared using mean paired differences before and after viewing the proposed CDS.

Results Between May and June 2025, 137 clinicians engaged with the survey, 131 completed demographics and 111 completed all survey elements. Most were nephrologists ($n=42$; 32%) or general internal medicine specialists ($n=36$; 27%). Overall, 88 (79%) supported CDS integration. RASi had the highest self-reported comfort with prescribing followed by statins, SGLT2i, GLP-1RA, and nsMRA. Clinicians reported higher comfort prescribing GLP-1RA and nsMRA with CDS support (median +1 on 9-point scale; $p<0.001$), but no change for RASi, statins, and SGLT2i. Participants with low baseline comfort (≤6 on 9-point Likert scale) had statistically significant improvements in comfort with CDS for GLP-1RA and nsMRA ($p<0.05$), but no change was observed for those with high baseline comfort.

*Correspondence:
Tyrone G. Harrison
tgharris@ucalgary.ca

Full list of author information is available at the end of the article

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Conclusions Clinicians support CDS integration to enhance CKD care in ambulatory settings. The proposed CDS increased perceived prescribing confidence, particularly for GLP-1RA and nsMRA.

Lay summary Chronic kidney disease (CKD) affects about one in ten adults and is becoming more common. As the population ages and rates of diabetes, high blood pressure, and heart disease rise, so does CKD. Effective medicines can help people with CKD, but many patients are not receiving them. We are designing a set of digital recommendations for the electronic medical record to remind doctors and other health care providers to think about these medicines when they see people living with kidney disease in clinic. To see if this tool would be helpful and easy to use, we surveyed health care providers that care for people with CKD across Alberta, Canada. Of the 111 people who answered questions about the advisory, 79% supported its use. Many health care providers also said it would make them feel more confident in prescribing newer classes of medications.

Keywords Chronic kidney disease, Clinical decision support, Guideline-recommended care, Electronic health record

Introduction

Chronic kidney disease (CKD), defined by either a reduced estimated glomerular filtration rate (eGFR) or kidney damage, affects over 10% of the global population, amounting to over 840 million individuals [1, 2]. As the population ages and the prevalence of CKD risk factors such as diabetes, hypertension, and cardiovascular disease continue to increase over time, this medically complex population is expected to continue to grow [3]. Multiple evidence-based pharmacotherapies exist that can slow CKD progression and reduce adverse outcomes [1].

Despite strong evidence from randomized clinical trials and endorsement by international guidelines, many established therapies, such as renin-angiotensin system inhibitors (RASi) and statins, remain underutilized in clinical practice [1, 4]. More recently available disease-modifying medications, such as the sodium-glucose cotransporter-2 inhibitors (SGLT2i), glucagon-like peptide-1 receptor agonists (GLP-1RA), and non-steroidal mineralocorticoid receptor antagonists (nsMRA) have demonstrated benefit in reducing CKD progression [1]. Despite this, their uptake remains limited even with their recommendation in recent international clinical practice guidelines for CKD management [1, 4–6]. This underutilization may be due to a lack of physician knowledge of indications, monitoring requirements, workflow complexity, competing priorities, or their comfort with prescribing these agents, all of which have been identified as key barriers to implementation in multiple studies [7–9]. Interventions to address this evidence-to-practice gap should be guided by implementation science principles.

One viable option to address these barriers is the implementation of clinical decision support (CDS) tools designed to promote guideline recommendations and help facilitate adoption of these evidence-based interventions. CDS tools are designed to enhance clinical decision-making by providing clinical information, patient-specific assessments, or recommendations for clinicians [10, 11]. In recent years, there has been increasing interest in the integration of CDS tools into electronic health records (EHRs) to support the implementation of guideline-recommended interventions. However, their effectiveness varies depending on their intensity and design [12–16]. Among the most commonly used forms of CDS are interruptive alerts that can prompt and promote prescribing at the point of care [11, 17]. Before implementing a tool for use in CKD ambulatory management, it is essential to understand the perspectives and preferences of clinicians to ensure that such an intervention is acceptable, feasible, aligned with their needs, and easily integrated into clinical workflows.

To inform the development and optimization of a CKD-specific CDS intervention, we conducted a cross-sectional survey of ambulatory clinicians across Alberta, Canada. Our primary objective was to assess clinician acceptability and support for integration of the proposed CDS. Secondary objectives evaluated prescribing comfort, workflow preferences, perceived productivity burden, and preferred CDS design elements.

Methods

This cross-sectional electronic survey study was administered and reported following recommendations from the consensus-based checklist for reporting survey studies (CROSS; Supplementary Table 1) and the checklist for reporting results of internet E-Surveys (CHERRIES; Supplementary Table 2) [18, 19]. The study protocol was approved by the University of Calgary Conjoint Health Research Ethics Board.

Selection of participants and recruitment

We used purposive sampling to recruit clinicians from Alberta, Canada across provider types and specialty, genders, and geographic regions. Respondent characteristics were monitored during recruitment to support balanced representation among specialities, gender identities, and locations of practice. Recruitment efforts targeted various regions across Alberta, recognizing that clinician experiences and priorities may differ by geographic

context [20, 21]. The majority of recruitment targeted Calgary and Edmonton, two most populous cities in Alberta, with a combined population of over 2.3 million per the 2021 Canadian Census [22].

Eligible participants were licensed clinicians practicing in Alberta ambulatory care settings that use the Epic Systems-based EHR called Connect Care, including physicians, nurse practitioners, and pharmacists. Participants were invited through direct email contact as well as through departmental leaders of targeted specialty groups at the University of Calgary, the University of Alberta, and ambulatory clinics within Alberta. Recruitment occurred between May and June 2025, and one reminder email sent if no response was received. Snowball recruitment of participants was encouraged. Because of this, the total number of clinicians who received the survey invitation could not be assessed and a complete response rate cannot be determined.

Sample size targets were informed by the need to capture variation in provider perspectives and geographic settings rather than statistical power. Recruitment concluded once each key specialty group was represented by at least five participants. The survey was completed through Qualtrics, and participants who completed the survey received a $25 electronic gift card. All participants provided electronic consent prior to participation. Internet protocol (IP) addresses were evaluated to identify multiple responses from the same participant [23]. Participant identifiers were not recorded to ensure anonymity and only select study team members had access to the responses.

Survey topics and format

We followed the Burns methodology for the design of self-administered surveys which emphasizes systematic item development, pretesting, and transparent reporting [24]. Survey items were initially generated through literature review and iterative discussion among the multidisciplinary study team to ensure relevance to CKD management and CDS implementation. Items were then pre-tested and refined through multiple consensus meetings by the authors, followed by pilot testing including study members who had not participated in item development to assess clarity and relevance. Authors involved in pre-testing represented a variety of demographics and disciplines, including clinicians in Alberta involved in CKD care, ensuring contextual alignment with the target survey population. The survey included items across three domains: participant demographics, current clinical CKD management practices, and perspectives on the proposed CDS (Supplementary Item 1).

Participant demographics included location, language, age, sex, gender identity, racial identity, clinical role, specialty, and years of practice. Items were developed using guidance from the Canadian Institute for Health Information (CIHI) and Statistics Canada to ensure inclusive, standardized demographic measurement [25, 26]. All questions were mandatory, and propagation to subsequent survey items was dependent on answering preceding questions. Survey questions assessed clinicians' current CKD management practices, including the number of patients with CKD that they manage, the clinical metrics they use to guide decision-making, and use of an existing CKD management resource at CKD-pathway.ca which was developed in Alberta and is used as a provincial clinical pathway [27]. Additional items evaluated clinician confidence and comfort in prescribing goal directed medical therapies for CKD and discussing prognosis.

Participants reviewed an example of the proposed CDS tool and were asked about preferred content, format, and whether the CDS would increase confidence in prescribing each medication class (Figs. 1 and 2). Throughout the survey, the CDS was referred to as a Best Practice Advisory (BPA), a term commonly used in Epic Systems-based EHRs and familiar to clinicians working within Connect Care. The proposed CDS in its current form includes an alert to notify clinicians of their patients' CKD and provides medication recommendations in a patient-specific order set based on their comorbidities, laboratory measures (eGFR, albumin-to-creatinine ratio (ACR), and serum potassium), current list of medications, and contraindications. Confidence and acceptability items were measured using a 9-point Likert scale, where 1 represented the lowest possible response and 9 the highest.

Analysis

Participant demographics were summarized descriptively and stratified by primary provider specialty. For survey items, we reported the median and interquartile range (IQR) for Likert scale responses, and proportions for categorical questions, both overall and stratified by provider group. Each question was analyzed using the total number of participants that responded to the question (i.e., complete case analysis). Primary analyses included responses related to acceptability whereas subgroup, prescribing comfort, and design elements were considered as exploratory analyses. Mean paired differences (MPD) were reported descriptively to summarize the average magnitude and direction of change in prescribing comfort with and without CDS support from the 9-point Likert scale responses. Because Likert responses are ordinal and paired differences were not normally distributed, statistical significance was assessed using a Wilcoxon sign rank test (using $p < 0.05$ as the threshold for statistical significance). We further examined pre-post comfort stratified by initial comfort pre-CDS comfort, comparing within-person changes among those with baseline

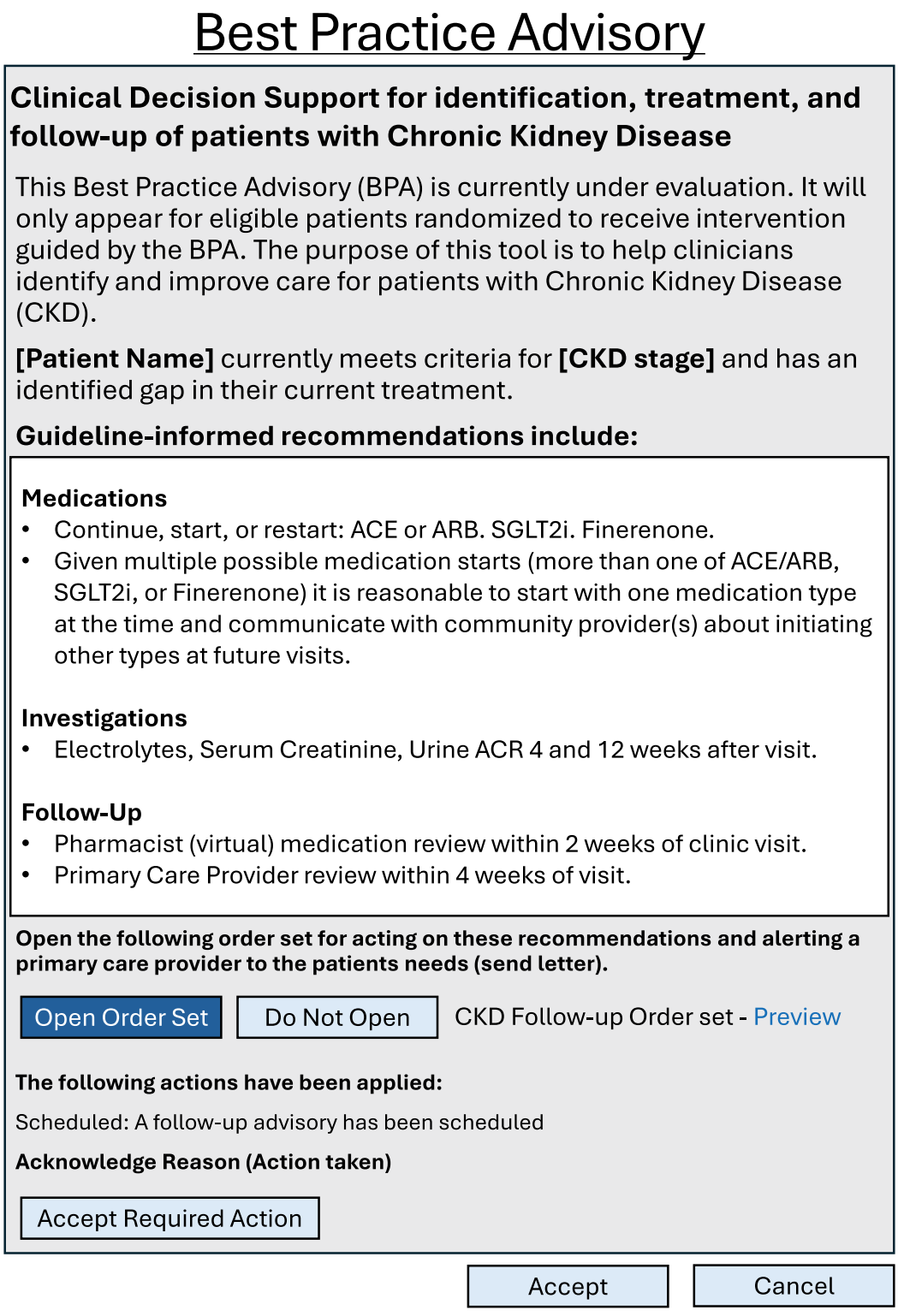


Fig. 1 Example clinical decision support advisory notification, individualized for a potential patient profile. Example shown is individualized and not a comprehensive example of all possible guideline-informed recommendation contents or combinations (i.e., statins and GLP-1RAs are not suggested for this patient)

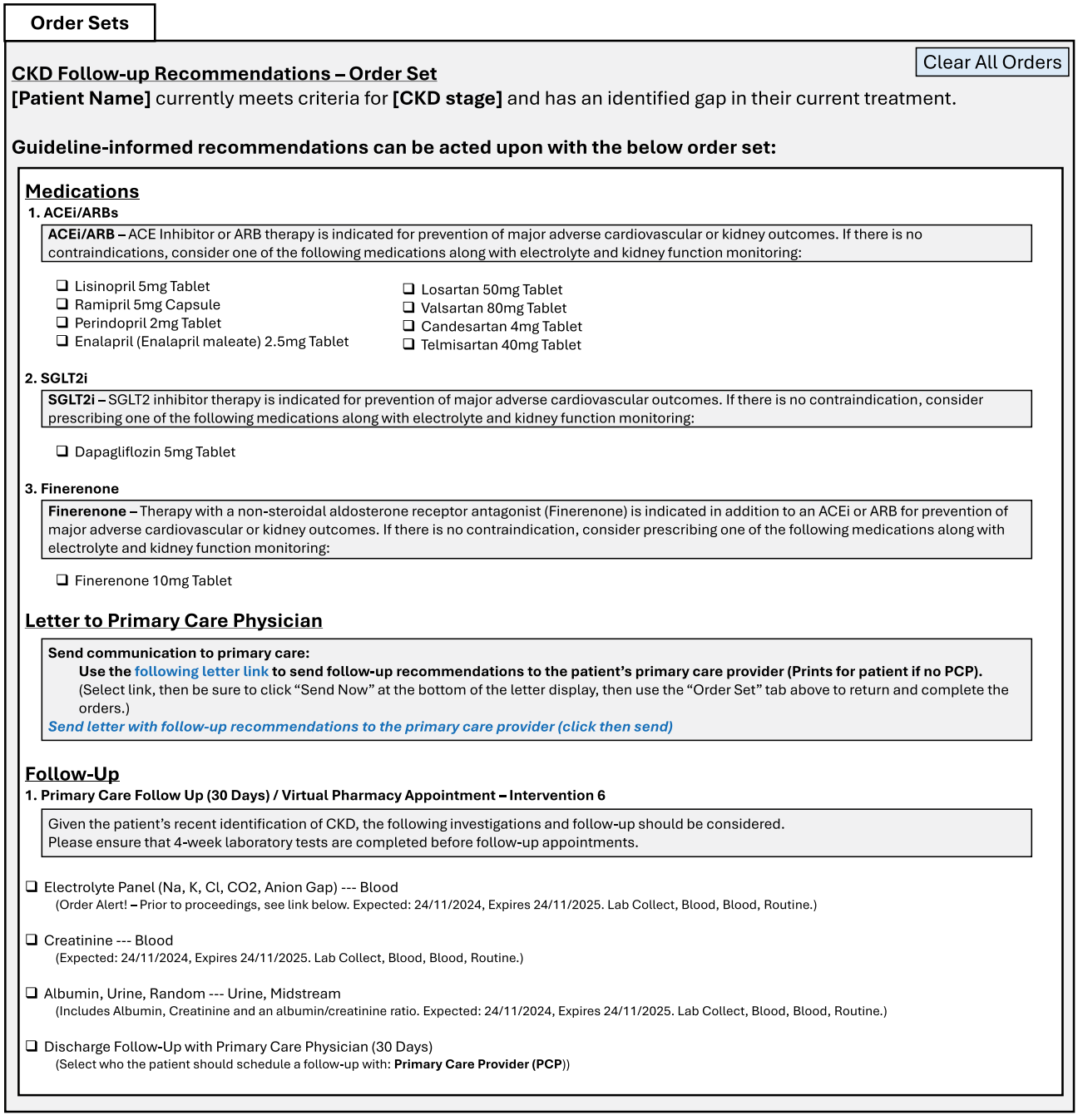


Fig. 2 Example clinical decision support order-set, individualized for a potential patient profile. Example shown is individualized and not a comprehensive example of all possible order-set contents or combinations (i.e., statins and GLP-1RAs are not suggested for this patient)

comfort ≥ 7 versus <7 using a Wilcoxon sign rank test. Given multiple related comparisons across medication classes, sensitivity analyses using Benjamini-Hochberg (BH) false discovery rate adjustment were performed. All analyses were performed using RStudio version 4.5.0 [28, 29].

Results

A total of 137 participants consented to participate in this survey. Of these, 131 (96%) completed the demographics section and 111 (81%) completed the full survey (Supplementary Figure 1), reflecting a mid-survey attrition rate of 19%.

Participant characteristics

Among the 131 participants who completed the demographics portion (Table 1), 88 (67%) were based in Calgary, 39 (30%) in Edmonton, and 4 (3%) identified their location as rural or other (Table 1). English was reported as the primary language for 125 of 131 participants (95%). Most participants were physicians ($n = 127$; 96%), including attending physicians ($n = 122$, 92%), fellows ($n = 4$; 3%), and a resident ($n = 1$; 1%). There were also nurse practitioners ($n = 2$; 2%) and pharmacists ($n = 2$; 2%) included. The most common specialties were nephrology ($n = 42$; 32%), general internal medicine ($n = 36$; 27%), and other internal medicine subspecialties ($n = 26$; 20%). Most had been working in healthcare for over a decade; many reported 11-to-20 years of experience ($n = 50$; 38%), and several had more than 20 years ($n = 36$; 28%, Table 1). Mid-survey attrition ($n = 20$) differed across observed participant characteristics and was high among general internists ($n = 14$; 55%) and those with 11–20 years of experience ($n = 10$; 50%).

Current clinic and CKD processes

Of the 123 participants who completed this section, most reported dedicating more than half of their time to clinical practice ($n = 84$; 68%; Table 1). They reported participating in an average of 3.9 (Standard deviation (SD) 2.36) half-day clinics per week, with 3.4 (SD 2.32) of these typically managed using the Epic Systems-based Connect Care. Of 123 participants, many reported that their clinic employs or has access to a clinic-based pharmacist ($n = 50$; 41%), half reported no access ($n = 62$; 50%), and the remainder selected 'Other' ($n = 11$; 9%), clarifying that they had access to a clinic-based pharmacist in some, but not all, of their practice settings. Participants estimated managing a median of 10 (IQR 15) patients with CKD per week, of whom 81% were managed through Connect Care.

Participants reported visiting CKDpathway.ca a median of 1.0 (IQR 7.5) times annually. When making clinical decisions involving medication initiation with eGFR cutoffs, 45 (37%) participants reported using the most recent eGFR/ACR value, while 57 (46%) used average values over the past 3 months. Fewer participants relied on longer-term averages, with 9 (7%) using 12-month averages and 12 (10%) selecting 'Other' and noting context-specific or hybrid approaches.

Confidence in the ability to diagnose CKD was highest (Median 7, where 9 represents maximum confidence; IQR 2.5), followed by the ability to monitor CKD (Median 7, IQR 3) and ability to manage CKD (Median 6; IQR 3.5, Table 1). Many participants prescribed RASi and SGLT2i frequently, including 62 and 50% reporting at least one daily prescription (Table 2). Some participants reported never prescribing the medication classes included in

Table 1 Demographic characteristics of survey participants and self-reported comfort with CKD management

Variable	N (%)
Participant Role (n = 131)	
Physician	127 (96.9)
Pharmacist	2 (1.5)
Nurse Practitioner	2 (1.5)
Region (n = 131)	
Calgary	88 (67.2)
Edmonton	39 (29.8)
Rural/Other	4 (3.1)
Gender (n = 131)	
Man	66 (50.4)
Woman	57 (43.5)
Other/Prefer not to say	8 (6.1)
Primary Language(s) (n = 131) *	
English	125 (95.4)
Mandarin	6 (4.6)
Cantonese	4 (3.1)
Hindi	4 (3.1)
French	3 (2.3)
Punjabi	3 (2.3)
Other	9 (6.9)
Age Group (n = 131)	
26–35	13 (9.9)
36–45	70 (53.4)
46–55	32 (24.4)
56–65	14 (10.7)
66–75	2 (1.5)
Race (n = 131) *	
White	75 (57.3)
East Asian	19 (14.5)
South Asian	18 (13.7)
Black	3 (2.3)
Middle Eastern	3 (2.3)
Other/Prefer not to say	17 (13.0)
Specialty (n = 131)	
Nephrology	42 (32.1)
General Internal Medicine	36 (27.5)
Internal Medicine Subspecialty	26 (19.8)
Primary Care	10 (7.6)
Cardiology	10 (7.6)
Surgical Specialty	5 (3.8)
Other/Prefer not to say	2 (1.5)
Time Working in Healthcare (n = 131)	
2-to-5 Years	11 (8.4)
6-to-10 Years	34 (26.0)
11-to-20 Years	50 (38.2)
>20 Years	36 (27.5)
Access to Clinic-Based Pharmacist (n = 123)	
Yes	50 (40.7)
No	62 (50.4)
Other	11 (8.9)
Time Dedicated to Clinical Practice (n = 123)	

Table 1 (continued)

Variable	N (%)
<25%	15 (12.2)
25–50%	24 (19.5)
>50%	84 (68.3)
Half-Day Clinics per Week (n = 123)	
Total (Mean; Standard Deviation)	3.9 (2.36)
With Connect Care (Mean; Standard Deviation)	3.4 (2.32)
eGFR Cutoffs Used (n = 123)	
3-Month Average of eGFR/ACR	57 (46.3)
Most Recent eGFR/ACR	45 (36.6)
12-Month Average of eGFR/ACR	9 (7.3)
Other	12 (9.8)
Self-Reported Chronic Kidney Disease (CKD) Confidence (n = 123)	
Ability to diagnose patients with CKD (Likert scale Median 1–9; 1 = none, 9 = expert; IQR)	7 (2.5)
Ability to monitor patients with CKD (Likert scale Median 1–9; 1 = none, 9 = expert; IQR)	7 (3)
Ability to manage patients with CKD (Likert scale Median 1–9; 1 = none, 9 = expert; IQR)	6 (3.5)

*Participants may select multiple responses

ACR, albumin-to-creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; IQR, interquartile range

the proposed CDS, however this varied significantly by medication class and physician specialty (Supplementary Table 3). When assessing familiarity with specific aspects of each CDS-targeted medication, participants reported the highest knowledge for RASi (Median 8; IQR 2); statins (Median 7; IQR 2) and SGLT2is (Median 7; IQR 3). Knowledge was rated lower for GLP-1RA (Median 7; IQR 3), and nsMRA (Median 5; IQR 5). Additionally, participants' comfort with prescribing these interventions was highest for RASi, statins, and SGLT2i (Median 9; IQR 2 for all), followed by GLP-1RA (Median 7; IQR 4), and was lowest for nsMRA (Median 6; IQR 6, Table 2).

CDS elements and preferences

After providing an explanation of the proposed CDS (Supplementary Figures 2 and 3), 79% of participants indicated full support for using the automated order sets and referrals as described in the survey (Supplementary Table 4). This included 85% of nephrologists, 80% of general internists, 70% of internal medicine subspecialists, 80% of cardiologists, 100% of family physicians, 50% of surgical specialists, and 50% among those who selected other/prefer not to say.

Participants were then asked to rate their comfort prescribing five classes of medications after receiving patient-specific advice from the proposed CDS. For RASi, statins, and SGLT2i, no significant difference in comfort was observed (MPD = −0.06 ± 0.17, −0.05 ± 0.19, 0.04 ± 0.22; $p = 0.58$, 0.63, 0.70; Fig. 3, Table 3). However, mean comfort prescribing GLP-1RA increased from 6.45 to 7.02 (MPD = 0.53 ± 0.26; $p = 0.00013$; BH-adjusted $p = 0.0003$), and for nsMRA increased from 5.12 to 6.14 (MPD = 0.99 ± 0.32; $p < 0.0001$; BH-adjusted $p < 0.0001$). When stratified by high and low comfort without CDS support, significant increases were observed for SGLT2i, GLP-1RA, and nsMRA, in participants who initially ranked comfort as 6 or less ($p = 0.036$, 0.0007, <0.0001, Table 3); however after adjustment for multiple testing, the increase in perceived comfort only remained significant for GLP-1RA and nsMRA (Table 3). No significant difference was observed for RASi or statins upon stratification ($p = 0.33$, 0.42).

Participants most frequently wanted the CDS to be provided 'when opening order entry' ($n = 46$; 41.4%) and 'when first opening the patient chart' ($n = 33$; 29.7%) (Table 4). Free-text responses from participants reflected preferences for less disruptive implementation, including manual triggering or the ability to suppress alerts for specific patients. In terms of CDS elements to include, participants supported inclusion of 'contraindications to interventions' ($n = 91$; 82.0%) and 'monitoring and follow-up recommendations' ($n = 75$; 67.6%) (Table 4).

Participants most frequently indicated that interaction times of up to 30 seconds where acceptable ($n = 88$; 79.3%), while 56 (50.4%) of these respondents also considered longer interaction times acceptable (Table 4). For both items, the median response was 3, which corresponds with 'Minimal loss of productivity'. There was a small difference between the mean scores for acceptable productivity loss (2.92) and anticipated productivity loss (3.69). Similar results were observed upon stratification by clinician specialty (Supplementary Table 5).

Discussion

This cross-sectional survey of clinicians from a large Canadian province suggests general acceptability and informs the design of a CDS tool to assist with improving prescribing guideline recommended medications for patients living with CKD in ambulatory care settings. Most participants were supportive of CDS integration across clinical specialties, and there were perceived improvements in comfort prescribing CKD guideline-recommended therapies if included in the CDS. These findings are derived from a predominantly urban, physician-based sample with substantial representation from nephrology and general internal medicine. The insights provided may help guide clinician-informed design and optimization of CDS elements prior to implementation.

Our findings suggest that although there was comfort with prescribing RASi and statins, there was relatively less comfort in prescribing SGLT2i, and particularly GLP-1RA and nsMRA, which are more recently approved medication classes for treatment of CKD (Table 3). However, participants also reported the greatest increase in

Table 2 Self-reported familiarity, prescribing frequency, and comfort with and without clinical decision support (CDS) for chronic kidney disease-indicated medication classes ($n = 113$)

Participant Response	RASi	Statin	SGLT2i	GLP-1RA	nsMRA
Self-reported prescribing frequency (n, %)	5 (4.4%)	10 (8.8%)	15	22 (19.5%)	50
Never	9 (8.0%)	9 (8.0%)	(13.3%)	14 (12.4%)	(44.2%)
Once per year	11 (9.7%)	30	10 (8.8%)	25 (22.1%)	14
Once per month	18	(26.5%)	11 (9.7%)	26 (23.0%)	(12.4%)
Once per week	(15.9%)	21	21	10 (8.8%)	24
Once per clinic	25	(18.6%)	(18.6%)	16 (14.2%)	(21.2%)
Multiple times per clinic	(22.1%)	12	22		15
	45	(10.6%)	(19.5%)		(13.3%)
	(39.8%)	31	34		6 (5.3%)
		(27.4%)	(30.1%)		4 (3.5%)
Familiarity with intervention (Median on Likert scale 1–9; 1 = none, 9 = Expert; IQR)	8 (2)	7 (2)	7 (3)	7 (3)	5 (5)
Comfort prescribing without CDS guidance (Median on Likert scale 1–9; 1 = not at all comfortable, 9 = completely comfortable; IQR)	9 (2)	9 (2)	9 (2)	7 (4)	6 (6)
Comfort prescribing with CDS guidance (Median on Likert scale 1–9; 1 = not at all comfortable, 9 = completely comfortable; IQR)	9 (2)	9 (1.5)	9 (2)	8 (3)	7 (3)

Responses are presented as count and percent or median and interquartile range (IQR). CDS, clinical decision support; GLP-1RA, glucagon-like peptide-1 receptor agonists; IQR, interquartile range; nsMRA, non-steroidal mineralocorticoid receptor agonists; RASi, renin-angiotensin system inhibitors; SGLT2i, sodium-glucose cotransporter-2 inhibitors

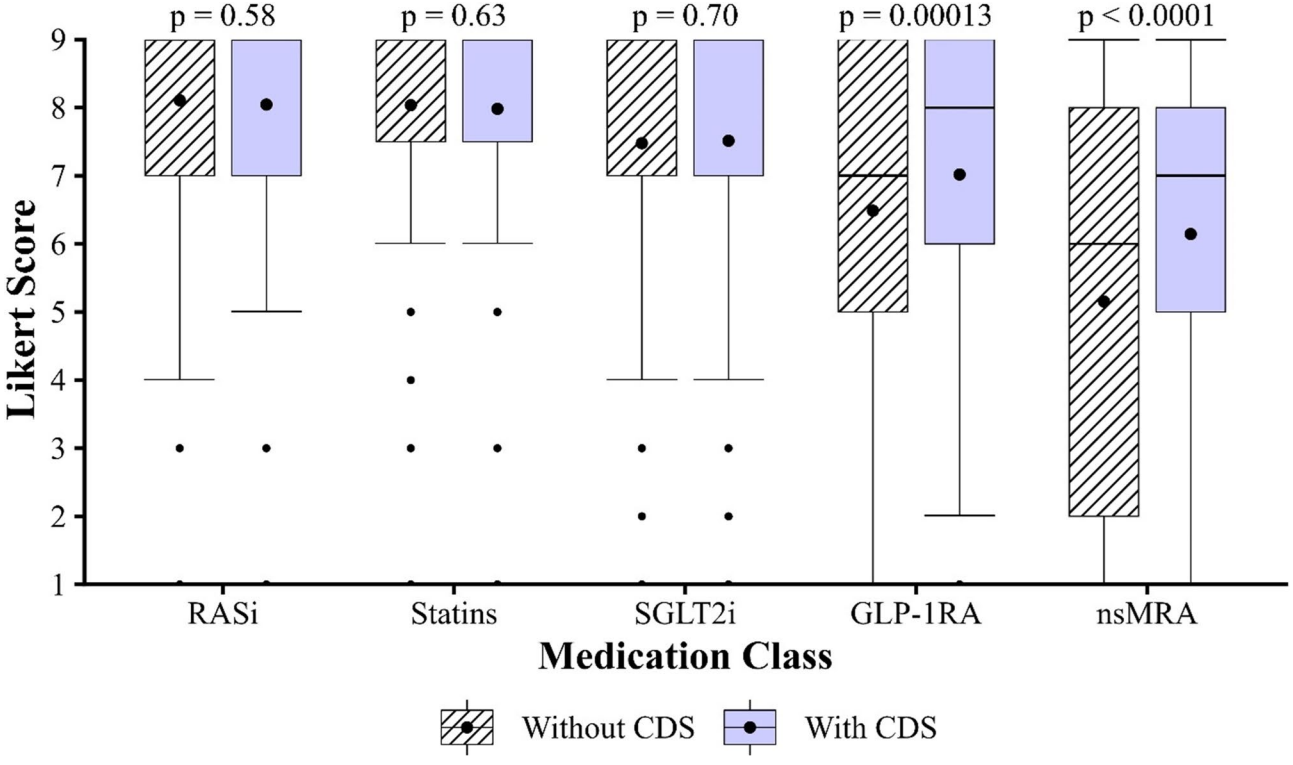


Fig. 3 Clinician ($n = 111$) prescribing comfort with and without clinical decision support (CDS) guidance across five medication classes. Comfort was assessed using 9-point Likert scale (1 = not at all comfortable, 9 = completely comfortable). RASi, renin-angiotensin system inhibitors; SGLT2i, sodium-glucose cotransporter-2 inhibitors; GLP-1RA, glucagon-like peptide-1 receptor agonists; nsMRA, non-steroidal mineralocorticoid receptor agonists. $p < 0.05$ denotes statistical significance

prescribing comfort for these classes following exposure to the proposed CDS, providing a potential opportunity to support their uptake, particularly among those with low baseline prescribing comfort. Some clinicians may lack sufficient knowledge regarding GLP-1RA and nsMRA, and thus may be less likely to prescribe these medications when indicated despite established clinical benefit [8]. In our study, 19.5% of participants reported never prescribing GLP-1RA and 44.2% never prescribed nsMRA. Outside of nephrology, these numbers increased to 27.7% and 60.8%, respectively (Supplementary Table 3). Despite the high co-occurrence of CKD, diabetes, and

Table 3 Clinician ($n=111$) prescribing comfort with and without clinical decision support (CDS) guidance across five medication classes, stratified by 'without CDS support' score below 7 (<7) and 7 and above (≥7)

Group	Responses	Without CDS support	With CDS support	Mean Paired Change (95% CI)	p-value	Adjusted p-value*
RASi < 7	12	4.42	4.75	0.33 (−0.29, 0.96)	0.33	0.41
RASi ≥ 7	99	8.56	8.44	−0.12 (−0.29, 0.07)	0.31	0.41
RASi Total	111	8.11	8.05	−0.06 (−0.24, 0.11)	0.58	0.70
Statin < 7	13	4.08	4.46	0.38 (−0.56, 1.33)	0.42	0.46
Statin ≥ 7	98	8.56	8.44	−0.12 (−0.30, 0.07)	0.30	0.41
Statin Total	111	8.04	7.98	−0.05 (−0.25, 0.14)	0.63	0.70
SGLT2i < 7	24	3.50	4.29	0.79 (0.06, 1.53)	**0.036**	0.12
SGLT2i ≥ 7	87	8.57	8.40	−0.17 (−0.37, 0.02)	0.11	0.21
SGLT2i Total	111	7.48	7.51	0.04 (−0.19, 0.26)	0.70	0.70
GLP-1RA < 7	45	4.07	5.11	1.04 (0.50, 1.59)	**0.0007**	**0.003**
GLP-1RA ≥ 7	66	8.14	8.32	0.18 (−0.38, 0.40)	0.10	0.21
GLP-1RA Total	111	6.49	7.02	0.53 (0.27, 0.80)	**0.0001**	**0.003**
nsMRA < 7	61	2.75	4.59	1.84 (1.42, 2.26)	$\mathbf{9.6\times10^{-9}}$	$\mathbf{9.6\times10^{-9}}$
nsMRA ≥ 7	50	8.08	8.04	−0.04 (−0.36, 0.28)	0.93	0.93
nsMRA Total	111	5.15	6.14	0.99 (0.67, 1.31)	$\mathbf{1.1\times10^{-7}}$	$\mathbf{5.5\times10^{-7}}$

*Adjusted *p*-values were calculated using the Benjamini-Hochberg false discovery rate procedure. Adjustments were applied separately to overall medication-class comparisons and exploratory baseline comfort subgroup analyses

Comfort was assessed using 9-point Likert scale (1 = not at all comfortable, 9 = completely comfortable). CDS, clinical decision support; CI, confidence interval; GLP-1RA, glucagon-like peptide-1 receptor agonists; nsMRA, non-steroidal mineralocorticoid receptor agonists; RASi, renin-angiotensin system inhibitors; SGLT2i, sodium-glucose cotransporter-2 inhibitors. $p<0.05$ denotes statistical significance

cardiovascular disease, and the ability to reduce morbidity and mortality with GLP-1RA or nsMRA, these medications appear to be largely under-prescribed [1, 9]. These findings suggest that a CDS may help address these therapeutic gaps where they exist, particularly for more recent medication classes such as GLP-1RA and nsMRA.

CDS tools are increasingly being used to help clinicians make informed decisions for their patients. Between 2006 and 2013, uptake in Canada grew from 20% to 62% of practitioners [30]. By providing individualized diagnostics, alerts, and interventional suggestions to improve individual outcomes, CDS tools are paving the way for precision medicine in electronic systems [11]. CDS tools may also improve coordination of care for patients through targeted notifications and automated referrals [11]. In this study, preferences for the timing of the CDS delivered as an alert varied substantially, with no single timepoint receiving majority support. The most endorsed option, triggering the alert upon opening order entry, was selected by only 41.4% of participants. This highlights the challenge of designing any single alert that integrates seamlessly into diverse clinical workflows, as individual clinician needs and desired usage varies. Several free-text comments emphasized the need for alerts to be minimally disruptive, customizable, and suppressible for irrelevant patient contexts. These findings align with broader concerns in the literature about alert fatigue and resistance to intrusive CDS interventions, reinforcing the importance of offering flexible alert logic and opt-out mechanisms where feasible [31]. Moreover, other investigators have similarly reported that identifying an optimal timepoint for CDS alert presentation can be challenging, with effectiveness influenced by clinical context, workflow integration, and user receptiveness [32].

Participants also prioritized the inclusion of actionable, clinically relevant information within the CDS. The most strongly endorsed features were contraindications to interventions, monitoring and follow-up recommendations, side effect profiles, and guidance on the timing of medication initiation when multiple therapies are considered. These selections suggest that clinicians are more likely to engage with the CDS if it informs rapid prescribing decisions rather than simply presenting prompts or risk scores. Additionally, participants expressed a desire for embedded links to the CKD Pathway (http://www.ckdpathway.ca), relevant clinical guidelines, and patient education materials, as these features may further increase the utility of the tool by providing key resources at the point of care. Given the number of items that received support for inclusion, the proposed CDS should use embedded links and interfaces to balance information depth with the need to minimize workflow interruption which is a commonly cited issue among other CDS tools designed to improve medication prescribing [33].

The survey responses indicated a possible discrepancy between anticipated and acceptable productivity loss due to CDS engagement. The median values for both measures corresponded to 'Minimal loss of productivity'. However, the mean scores suggested that the expected burden slightly exceeds what participants reported as acceptable, suggesting that the perceived impact on productivity may be unacceptable. Although subtle, the

Table 4 Preferences for alert presentation timing and information to include within the alert among survey participants ($n = 111$)

Preferences for Clinical Decision Support (CDS) Design	N (%)
CDS Alert Presentation	
When opening order entry	46 (41.4)
When first opening patient chart	33 (29.7)
When signing orders	26 (23.4)
When a patient note is started	25 (22.5)
When signing off clinic visit	17 (15.3)
Other timepoint	12 (10.8)
Additional Information to Include	
Contraindications to interventions	91 (82.0)
Monitoring and follow-up recommendations	75 (67.6)
Side effects of interventions	63 (56.8)
Patient educational resources	59 (53.2)
Initiation timing for multiple medications	55 (49.5)
Links to guideline sources	48 (43.2)
Links to CKD Pathway	46 (41.4)
Links to primary research	17 (15.3)
Acceptable Interaction Time*	
Under 15 seconds	23 (20.7); 111 (100)
Under 30 seconds	32 (28.8); 88 (79.3)
Under 60 seconds	42 (37.8); 56 (50.6)
Under 3 minutes	11 (9.9); 14 (12.6)
Under 5 minutes	3 (2.7); 3 (2.7)
Productivity Loss Associated with CDS Use	
Anticipated productivity loss (Mean; median (IQR) on Likert scale 1–9; 1 = no loss of productivity, 9 = extreme loss of productivity)	3.62, 3 (2)†
Acceptable productivity loss (Mean; median (IQR) on Likert scale 1–9; 1 = no loss of productivity, 9 = extreme loss of productivity)	2.92, 3 (1)†

*Results are shown for each individual option and cumulative accepted interaction times

†The median result of 3 corresponds to 'minimal loss of productivity'

Responses are presented as count and percent or median and interquartile range (IQR). CDS, clinical decision support; CKD, chronic kidney disease; IQR, interquartile range

observed difference highlights the potential risk to uptake and sustained engagement if the tool is too cumbersome to integrate within clinic flows. This may be particularly true in high-volume settings where cumulative seconds can scale substantially across the day. As such, the tool must ensure that clinician interaction time remains minimal. A 30-second maximum usage was considered tolerable by roughly 80% of participants, although it may not be feasible to deliver a meaningful alert with paired action in such a short period of time. Strategies to minimize interaction burden while preserving informational depth may therefore be important for implementation success. Additionally, a less disruptive CDS approach for RASi and statin-related alerts may be considered given the limited perceived benefit observed for these medication classes.

A key consideration in maintaining the pragmatism of our CDS intervention is ensuring that the alert logic aligns with how clinicians currently use eGFR and ACR to inform decision-making. In our sample, most participants based prescribing decisions on either the most recent (37%) or 3-month average (46%) eGFR/ACR values. Very few reported relying on 12-month trends or more complex longitudinal data. This preference highlights that decision-making around nephroprotective therapies tends to prioritize recent kidney function and albuminuria status over longer-term averages. Structuring the CDS to match existing decision-making norms therefore supports its integration into routine care, and aligns with commonly used tools such as the KD Predict and Kidney Failure Risk Equation (KFRE), in addition to Kidney Disease | Improving Global Outcomes (KDIGO)-based guidance, which also typically rely on more recent eGFR/ACR data in determining risk of kidney disease progression [1, 34].

Our study has several limitations. Despite targeted outreach across Alberta, rural participation was minimal, with only a small number of participants identifying a rural or non-urban practice setting. This likely reflects the lower overall number of rural physicians in the province who may be less connected with academic centres but nonetheless limits generalizability to these contexts [20]. Additionally, increased participation among primary care physicians would have strengthened our findings as they care for many of the patients this tool would provide recommendations for. Participation among non-physicians was also low. Nonetheless, because Connect Care implementation is predominantly within specialist and academic-affiliated settings, the sample likely reflects many of the clinicians that the CDS is intended to impact once implemented. Further, the generalizability of our findings to other jurisdictions without widespread EHR use or without similar comprehensive drug coverage, is unknown. However, as an estimated 93% of primary care is delivered using EHRs in Canada and other countries, our results are applicable to many settings [35]. It is possible that the length of the survey may have contributed to response fatigue, as evidenced by the gradual decline in completion across sections. Although 95.6% of initial participants completed the demographic portion, only 81.0% completed the CDS-related items. This missingness may not have been completely at random and could reflect mild response bias, particularly if later items preferentially retained more engaged clinicians. Because purposive and snowball recruitment via email was utilized, we are unable to determine a response rate for the survey.

Finally, while the survey captured comfort and preferences, it did not assess actual prescribing behavior or CDS usage and this should be evaluated at a more appropriate stage once the CDS is tested.

Conclusion

In summary, the proposed CDS for outpatient CKD management in a province-wide EHR was generally well supported and was associated with greater self-reported confidence in prescribing of important CKD therapies. Our results suggest that future implementation success likely depends not only on the perceived clinical utility of the alert content, but also on the extent to which it respects user autonomy and accommodates different workflow styles. This work highlights the need to incorporate stakeholder input when designing any population-level CDS tool. Given the high global prevalence of CKD, and recent advancements in CKD care, studies evaluating the implementation of a CDS for CKD are warranted.

Abbreviations

ACR	Albumin-to-creatinine ratio
BH	Benjamini-Hochberg
BPA	Best Practice Advisory
CDS	Clinical decision support
CHERRIES	The Checklist for Reporting Results of Internet E-Surveys
CI	Confidence interval
CIHI	Canadian Institute for Health Information
CKD	Chronic kidney disease
CROSS	Consensus-Based Checklist for Reporting of Survey Studies
EHR	Electronic health record
eGFR	Estimated glomerular filtration rate
GLP-1RA	Glucagon-like peptide-1 receptor agonists
IP	Internet protocol
IQR	Interquartile range
KDIGO	Kidney Disease | Improving Global Outcomes
KFRE	Kidney failure risk equation
MPD	Mean paired differences
nsMRA	Non-steroidal mineralocorticoid receptor agonists
RASi	Renin-angiotensin system inhibitors
SD	Standard deviation
SGLT2i	Sodium-glucose cotransporter-2 inhibitors

Supplementary Information

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Supplementary material 1

Supplementary material 2

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Authors contributions

Research idea and study design: RG, TGH, CEG, HL, KY; statistical analysis: RG, TGH; data analysis and interpretation: all authors; drafting manuscript: RG, TGH; editing and revising manuscript: all authors.

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Data availability

Our aggregate dataset is available upon reasonable request by contacting the corresponding author. We are not able to provide participant level data as per our ethics approval.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the University of Calgary Conjoint Health Research Ethics Board (REB25-0604) and conducted in accordance with the ethical standards of the institutional research committee, relevant guidelines and regulations, the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2), and the Declaration of Helsinki. All participants provided electronic informed consent prior to participation and data collection.

Consent for publication

All authors have read and approved the final manuscript and consent to its publication. No identifiable individual participant data are included in this manuscript.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Medicine, University of Calgary, Calgary, Alberta, Canada
[2]Faculty of Medicine & Dentistry, University of Alberta, Edmonton, Alberta, Canada
[3]Methodological and Implementation Research (MIR) Program, Ottawa Hospital Research Institute, Ottawa, ON, Canada
[4]School of Epidemiology and Public Health (SEPH), University of Ottawa, Ottawa, Ontario, Canada
[5]Department of Medicine, University of Toronto, Toronto, Ontario, Canada
[6]Department of Community Health Sciences, University of Calgary, Calgary, Canada
[7]Libin Cardiovascular Institute, University of Calgary, Calgary, Canada
[8]O'Brien Institute for Public Health, University of Calgary, Calgary, Canada
[9]Department of Cardiac Sciences, University of Calgary, Alberta, Canada
[10]Division of Nephrology, Department of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA
[11]Department of Medicine, University of Calgary, Health Research Innovation Centre, Rm 2AC58, 3230 Hospital Dr NW, Calgary, AB T2N 4Z6, Canada

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