ORIGINAL RESEARCH

Does Clinical Decision Support Increase Appropriate Medication Prescribing for Cardiovascular Risk Reduction?

David Boston, MD, MS, FACC, Annie E. Larson, PhD, Christina R. Sheppler, PhD, Patrick J. O'Connor, MD, MA, MPH, JoAnn M. Sperl-Hillen, MD, Jennifer Hauschildt, MPH, and Rachel Gold, PhD, MPH

Purpose: **To assess the impact of a clinical decision support (CDS) system's recommendations on prescribing patterns targeting cardiovascular disease (CVD) when the recommendations are prioritized in order from greatest to least benefit toward overall CVD risk reduction.**

Methods: **Secondary analysis of trial data from September 20, 2018, to March 15, 2020, where 70 community health center clinics were cluster-randomized to the CDS intervention (42 clinics; 8 organizations) or control group (28 clinics; 7 organizations). Included patients were medication-naïve and aged 40 to 75 years with ≥1 uncontrolled cardiovascular disease risk factor, with known diabetes or cardiovascular disease, or ≥10% 10-year reversible CVD risk.**

Results: **Among eligible encounters with 29,771 patients, the probability of prescribing a medication targeting hypertension was greater at intervention clinic encounters when CDS was used (34.9% [95% CI, 31.5 to 38.3]) versus dismissed (29.6% [95% CI, 26.7 to 32.6]; *P* < *.001*), but not when compared with control clinic encounters (34.9% [95% CI, 31.1 to 38.7]; *P* = *.998*). Prescribing for dyslipidemia was significantly higher at intervention encounters where the CDS system was used (11.3% [95% CI, 9.3 to 13.3]) compared with dismissed (7.7% [95% CI, 6.1 to 9.3]; *P* = *.003*) and to control encounters (8.7% [95% CI, 7.0 to 10.4]; *P* = *.044*); smoking cessation medication showed a similar pattern. Except for dyslipidemia, prescribing rates increased according to their prioritization.**

Conclusions: **Use of this CDS system was associated with significantly higher prescribing targeting most cardiovascular risk factors. These results highlight how displaying prioritized actions to reduce reversible CVD risk could improve risk management.**

Trial Registration: **ClinicalTrials.gov, NCT03001713, https://clinicaltrials.gov/. (J Am Board Fam Med 2023;36:777–788.)**

Keywords: **Cardiology, Cardiovascular Diseases, Clinical Decision Support Systems, Community Health Centers, Clinical Trials, Decision-making, Health Equity, Medical Informatics, Practice Guideline, Primary Health Care, Quality Improvement**

Introduction

Evidence-based management of cardiovascular disease (CVD) risk factors leads to decreased occurrence of strokes, myocardial infarction, and cardiovascular mortality.[1,2] Unfortunately, national rates of blood pressure (BP) control have declined since 2013,[3] and inadequate control of other modifiable CVD risk factors (eg, cholesterol level, tobacco usage, and glucose level in diabetes) adds burden to health care systems' capacity and costs.[4–8]

This article was externally peer reviewed.
Submitted 17 November 2022; revised 30 January 2023; 19 May 2023; accepted 25 May 2023.

From the OCHIN Inc., PO Box 5426, Portland, OR (DB, AEL, JH, RG); Kaiser Permanente Northwest, Center for Health Research, 3800 N Interstate Ave, Portland, OR (CRS); HealthPartners Institute, 8170 33rd Ave So 23301a, Minneapolis, MN (PJOC, JMSH).

Funding: National Heart, Lung, And Blood Institute of the National Institutes of Health (Award Number R01HL133793). National Institute of Health (Award Number P30DK092924) partially supported Drs. O'Connor and Sperl-Hillen.

Conflict of interest: We have no conficts of interest to declare.

Corresponding author: David Boston, MD, MS, FACC, OCHIN: Oregon Community Health Information Network Portland, OR 97201 (E-mail: bostond@ochin.org).

One cause of this vexing problem is that time limitations at primary care encounters make it challenging for providers to prioritize CVD risk management approaches.[9–11] Data-driven, electronic health record (EHR)-based clinical decision support (CDS) systems have been developed to identify patients with uncontrolled CVD risk factors. These systems can also provide evidence-based treatment recommendations tailored to a patient's current treatment regimen, comorbid conditions, medication allergies, and other factors.[12–16] Given the breadth of clinical domains managed in primary care, and the likelihood that a patient with elevated CVD risk will divide provider attention among multiple uncontrolled risk factors,[17,18] CDS systems should be optimized by prioritizing treatment suggestions based on their relative potential benefit to a given patient, based on American College of Cardiology/American Heart Association (ACC/AHA) and other evidence-based CVD risk prediction equations.[19] Communicating prioritized treatment options to both the clinician and patient can enable evidence-based shared decision making (SDM) and save time for clinic staff.[20] However, few studies have evaluated the impact of providing prioritized treatment recommendations on actions taken during and after clinical encounters.[21]

CV Wizard is a web-based EHR-linked CDS system designed for use at primary care encounters. It has been well-described elsewhere,[22–26] but in brief, when blood pressure is entered into the EHR, rooming staff see an alert if system use is recommended for a given patient. At that point, the rooming staff can opt to print out the CDS output (CVD risk assessment with prioritized recommendations) and give it to the provider. The provider can also elect to view it in the EHR. If the CDS output is viewed or printed, it is considered that the CDS was used.

The CDS system's risk assessment is created using EHR data to perform CVD risk calculations based on ACC/AHA CVD Pooled Risk Equations, as follows. It first assesses a given patient's modifiable CVD risk. It then prioritizes CVD risk factors and associated treatment suggestions by calculating the degree to which CVD risk could be lowered by more effective management of each of that patient's uncontrolled CVD risk factors. By presenting treatment suggestions prioritized by the risk factor whose control would offer the greatest benefit, this system allows the clinician to focus on the most beneficial treatment options during time-constrained encounters. This nonproprietary CDS system was developed at HealthPartners, a large, nonprofit, integrated care system. Its output is based on current evidence-based care guidelines and appropriate to each specific patient based on their comorbidities, medications, allergies, etc.[7,27–32]

In trials conducted in integrated care settings, use of the CDS system was associated with significantly improved CVD risk in diverse patient groups. We conducted a trial of its impact in community health centers (CHCs), which are the health care 'safety net' for socioeconomically vulnerable persons in the US and provide care regardless of patients' ability to pay. That trial is described elsewhere,[33] but in brief, 70 CHC clinics run by 15 CHC organizations were recruited and cluster-randomized 1:1 to 2 study arms: intervention (the CDS system was activated in September 2018) or control (not activated, but ran invisibly in the background to enable comparison). Implementation support for intervention clinics included a guide on use of the CDS system, staff training materials, examination room posters, several mandatory preactivation webinars, optional webinars for 6 months postactivation, monthly feedback on system-use rates at eligible encounters, and the ability to request additional support for the trial's first year.

The CHC trial found that use of the CDS system was associated with significant risk reduction among patients with high baseline CVD risk. Extended analyses from that trial, presented here, were conducted to better understand 1 aspect of the mechanisms underlying that trial's positive finding: whether prescribing patterns changed with system use and whether the decision to perform a clinical action was associated with the CDS system's individualized prioritization of CVD risk factors. These analyses were needed because although uptake of CDS systems has been well studied (a recent systematic review and meta-analysis demonstrated an overall CDS adoption rate of 34% across diverse clinical settings),[34] adoption of a CDS system is an imperfect predictor of how its recommendations are used. Furthermore, though use of some systems has been shown to be associated with increased pharmacotherapy,[14,35] most of this research was

conducted in academic settings and focused on a single clinical condition. Less is known about clinical actions taken after presentation of multiple prioritized risk factors that could benefit from attention, especially in CHC settings. Such knowledge could improve CDS design, adoption, and effectiveness in CHCs. To generate this knowledge, these analyses compared rates of prescribing at CDS-eligible encounters (where CDS use was suggested via EHR alert) at intervention clinics at which the CDS output was viewed or printed out, compared with those where the output was not thus 'used,' and also compared with eligible control clinic encounters (where the alert would have appeared if the CDS were live). We also assessed whether the CDS' priority ranking of a given prescription was associated with higher likelihood of a prescription being issued.

Methods

Data on CVD prioritization, recommendations, and ACC/AHA 10-year CVD risk score for each encounter were obtained from the CDS system's web service system. The CDS system generates these data regardless of whether clinic staff 'uses' the CDS output at a given encounter, and ran 'invisibly' in the control clinics, to generate the data needed for analyses. Additional data came from OCHIN (not an acronym), a nonprofit organization that provides a single instance of the Epic EHR to nearly 800 CHC clinics across 14 states (as of September 2018). Data extracted from this EHR were linked to the CDS system's data from HealthPartners, Inc. using a computer-generated, patient-specific study identifier.

Data presented here are based on use of the CDS output at eligible encounters in intervention clinics (n = 42 clinics, 8 organizations) and control clinics (n = 28 clinics, 7 organizations) over an 18-month period (09/18/2018-03/15/2020) (Figure 1). The Kaiser Permanente Northwest institutional review board reviewed and approved all research activities for this project.

Eligible encounters include those at all intervention clinics where the CDS output recommended starting any new hypertension medication, glucose-lowering medication, lipid-lowering medication (statin, ezetimibe or proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitor), or smoking cessation medication (bupropion or varenicline) to a medication-naïve patient; and those meeting the same eligibility criteria at control clinics, although at control clinics the CDS output could not be viewed. Outcomes were new evidence-based EHR prescriptions for blood pressure, glucose, lipid, or tobacco control medications within 7 days of an eligible encounter.

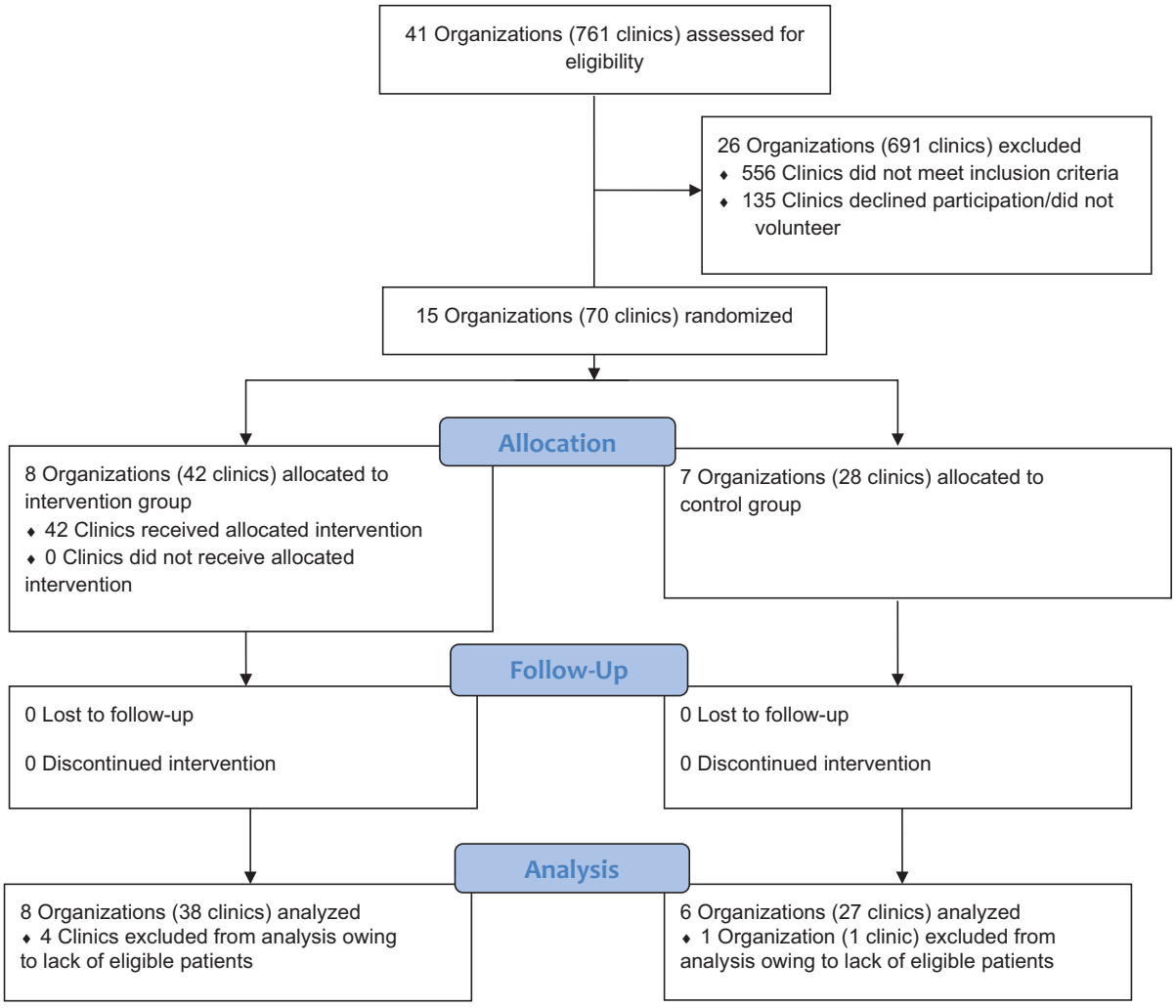
Statistical Analysis

Descriptive statistics show encounter characteristics included in these analyses. Characteristics of encounters with a recommendation to start a new medication at intervention clinic encounters were compared with control clinic encounters. In addition, characteristics of encounters at which a targeted prescription was made within 7 days of the recommendation were compared with encounters where a prescription was not made. P-values were calculated using chi-squared tests and unpaired *t* tests with unequal variance and significance set at 0.05.

Encounters where at least 1 new treatment suggestion was made were then identified. Analyses then compared the proportion of these encounters with a new prescription for an identified uncontrolled CVD risk factor at (1) intervention clinic encounters where the CDS system was used (displayed or printed), (2) intervention clinic encounters where the CDS system was not used, and (3) comparable control clinic encounters. The percentage of encounters with an associated prescription was also calculated for these groups based on prioritization of the treatment recommendations by the system (ranked as priority 1 to 2 or ranked as priority 3 to 6), as seen in Appendix. Two-tailed, unpaired *t* tests with significance set at 0.05 were used to test for significant differences within each group by priority. Because tobacco cessation was always priority 1 or 2, tests for significance between priority categories were not calculated for this CVD risk factor.

Multilevel logistic regression models were used to assess differences in new medication orders at (1) intervention clinic encounters where the CDS system was used (ie, the output was viewed) (CDS+) vs not used (CDS-), compared with (2) intervention clinic encounters where the CDS system was used, and compared with control clinic encounters where the CDS ran invisibly but did not alert users to eligible patients (CDSc). The association between recommendation priority assigned by

Figure 1. CV Wizard CONSORT flow diagram.



the CDS system and prescription likelihood was also assessed across these groups. All models adjusted for patient (age, sex, race, and ethnicity) and encounter (health insurance, percent of federal poverty level, appointment length, time behind schedule, and total encounters during the study period) characteristics and included random effects for clinician and clinic and robust sandwich estimators. Post estimation predicted probabilities were obtained and statistical significance set at 0.05. SAS EG 8.3 and Stata version 15.1 were used for all analyses.

Results

Characteristics of the 106,769 eligible encounters involving 29,771 unique patients are shown in Table 1. Eligible encounters at intervention clinics, compared with control clinics, were on average more likely to be with patients (1) with lower 10-year atherosclerotic cardiovascular disease (ASCVD) risk (mean: 16.5% vs 18.1%); (2) of Hispanic ethnicity (32.0% vs 16.8%); (3) of Black race (21.2% vs 17.7%); (4) from households <138% of the federal poverty level (62.2% vs 40.6%); and (5) be time-constrained (21.0% vs 13.4%).

New prescriptions were issued at 35,078 (32.9%) of the encounters (Table 2). Encounters more often resulting in prescriptions were those where (1) the CDS system was used (16.2% of 35,078 encounters) versus those where is could have been used but was not (14.7% of 71,691 encounters); (2) the 10-year ASCVD risk was higher (mean: 17.9, vs 16.8); (3) the patient was of Hispanic ethnicity (30.4% vs 23.2% in those with a new prescription vs without a new

Table 1. Encounters with a Recommendation to Start a Hypertension, Diabetes, Statin, or Tobacco Cessation Medication Stratified by Those Where a Prescription Was versus Was Not Written Within 1 Week of Encounter

	All CDS-Eligible Encounters (n = 106,769)	Intervention CDS Eligible Encounters (n = 61,219)	Control CDS Eligible Encounters (n = 45,550)	*p*-Value
Encounter Risk				
Avg. Reversible Risk (SD)	10.4 (10.3)	9.7 (10.2)	11.3 (10.5)	<0.001
Avg. 10-Year ASCVD Risk (SD)	17.2 (12.8)	16.5 (12.5)	18.1 (13.0)	<0.001
Average Age at Encounter (SD)	58.5 (8.8)	58.0 (8.8)	59.2 (8.7)	<0.001
Avg # Visits During Study (SD)	7.1 (6.2)	11.1 (9.8)	10.5 (8.7)	<0.001
Gender				<0.001
Woman	56,388 (52.2%)	33,232 (54.3%)	23,156 (50.8%)	
Ethnicity				<0.001
Hispanic	27,269 (25.5%)	19,615 (32.0%)	7654 (16.8%)	
Non-Hispanic	75,680 (70.9%)	38,854 (63.5%)	36,826 (80.9%)	
Unknown Ethnicity	3820 (3.6%)	2750 (4.5%)	7654 (16.8%)	
Race				<0.001
Asian	4262 (4.0%)	2721 (4.4%)	1541 (3.4%)	
Black	21,056 (19.7%)	13,002 (21.2%)	8054 (17.7%)	
Other*	3110 (2.9%)	2026 (3.3%)	1084 (2.4%)	
White	70,151 (65.7%)	36,810 (60.1%)	33,341 (73.2%)	
Unknown	8190 (7.7%)	6660 (10.9%)	1530 (3.4%)	
Insurance at Encounter				<0.001
Medicaid	36,451 (34.1%)	22,543 (36.8%)	13,908 (30.5%)	
Medicare	37,270 (34.9%)	19,311 (31.5%)	17,959 (39.4%)	
Other Public	3175 (3.0%)	2771 (4.5%)	404 (0.9%)	
Private	14,097 (13.2%)	6768 (11.1%)	7329 (16.1%)	
Uninsured	15,776 (14.8%)	9826 (16.1%)	5950 (13.1%)	
FPL at Encounter				<0.001
<138%	56,554 (53.0%)	38,051 (62.2%)	18,503 (40.6%)	
≥138%	18,079 (16.9%)	12,287 (20.1%)	5792 (12.7%)	
Missing	32,136 (30.1%)	10,881 (17.8%)	21,255 (46.7%)	
Avg Appt Length (mins)				<0.001
5 to 15 minutes	18,943 (17.7%)	12,851 (21.0%)	6092 (13.4%)	
≥20 minutes	87,508 (82.0%)	48,086 (78.6%)	39,422 (86.6%)	
Missing	318 (0.3%)	282 (0.5%)	36 (0.1%)	
Avg Time Behind Schedule (mins)				0.272
≤10 minutes	81,166 (76.0%)	46,463 (75.9%)	34,703 (76.2%)	

Abbreviations: CDS, Clinical decision support; SD, Standard deviation; FPL, Federal poverty level; ASCVD, Atherosclerotic cardiovascular disease.
*Other race includes American Indian, Alaska Native, Native Hawaiian, Pacific Islander, those who selected more than one race, and all other race.

prescription, respectively) or Black race (23.6% vs 17.8%); and (4) the patient was uninsured (20.3% vs 12.1%) or below 138% of the federal poverty level (55.1% vs 51.9%). Encounter characteristics such as average scheduled appointment length, amount of time clinician was behind schedule, and patient's age, gender, and care utilization patterns were not meaningfully associated with medication prescription rates.

Prescription Frequency by Risk Factor and Recommendation Priority

The unadjusted probability of prescriptions associated with encounters in which the CDS system suggested starting new medication is shown in Table 3 by CVD risk factor and priority ranking. The numbers of encounters at which new medication was suggested was highest for hypertension (n = 48,352), followed by dyslipidemia (n = 27,273),

Table 2. Encounters with a Recommendation to Start a Hypertension, Diabetes, Statin, or Tobacco Cessation Medication Stratified by Those Where a Prescription Was versus Was Not Written Within 1 Week of Encounter

	All Encounters with a Recommendation (n = 106,769)	Recommendations with a Prescription Within 1 Week (n = 35,078)	Recommendations with No Prescription Within 1 Week (n = 71,691)	*p*-Value
Group				<0.001
Intervention - CDS Used	15.2	16.2	14.7	
Intervention - CDS Not Used	42.2	41.2	42.6	
Control	42.7	42.6	42.7	
Encounter Risk				
Avg. Reversible Risk (SD)	10.4 (10.3)	11.5 (11.4)	9.8 (9.7)	<0.001
Avg. 10-Year ASCVD Risk (SD)	17.2 (12.8)	17.9 (13.4)	16.8 (12.4)	<0.001
Avg. Age at Encounter, years (SD)	58.5 (8.8)	57.9 (8.7)	58.8 (8.8)	<0.001
Avg. No. Visits During Study (SD)	7.1 (6.2)	7.1 (5.8)	7.1 (6.3)	<0.001
Gender				<0.001
Woman	52.2	51.3	53.6	
Ethnicity				<0.001
Hispanic	25.5	30.4	23.2	
Non-Hispanic	70.9	66.2	73.2	
Unknown Ethnicity	3.6	3.4	3.7	
Race				<0.001
Asian	4.0	4.4	3.8	
Black	19.7	23.6	17.8	
Other*	2.9	2.6	3.1	
White	65.7	61.2	67.9	
Unknown	7.7	8.2	7.4	
Insurance at Encounter				<0.001
Medicaid	34.1	33.5	34.5	
Medicare	34.9	29.3	37.7	
Other Public	3.0	3.5	2.7	
Private	13.2	13.4	13.1	
Uninsured	14.8	20.3	12.1	
FPL at Encounter				<0.001
<138%	53.0	55.1	51.9	
≥138%	16.9	16.8	17.0	
Missing	30.1	28.2	31.0	
Avg Appt Length (mins)				<0.001
5 to 15 minutes	17.7	17.4	17.9	
≥20 minutes	82.0	82.2	81.9	
Missing	0.3	0.4	0.2	
Avg Time Behind Schedule (mins)				0.024
≤10 minutes	76.0	75.6	76.2	
>10 minutes	24.0	24.4	23.8	

Abbreviations: CDS, Clinical decision support; SD, Standard deviation; FPL, Federal poverty level; ASCVD, Atherosclerotic cardiovascular disease.
*Other race includes American Indian, Alaska Native, Native Hawaiian, Pacific Islander, those who selected more than one race, and all other race.

tobacco cessation (n = 19,659), and glucose control (n = 8299).

Across all 4 CVD risk factors, in descriptive analyses, unadjusted prescription rates were higher in the intervention arm when the CDS system was used (CDS+) compared with the intervention cohort when it was not used (CDS-) and the control arm (CDSc). In all 3 cohorts, a higher rate of new prescriptions was seen when the CVD risk factor priority was high (ranked 1 or 2) versus low (ranked 3 to

Table 3. Unadjusted Frequency of Provider Action Taken Related to Encounters in Which CDS Recommended New Medication

	Intervention Clinic Encs, Tool Used (CDS+)	Intervention Clinic Encs, Tool Not Used (CDS-)	Control Clinic Encs (CDSc)
BP Meds	(n = 6820)	(n = 18,265)	(n = 23,267)
Any BP Rx Recommendation	34.9	32.7	33.7
Recommendation High Priority (1 to 2)	40.4	37.1	37.4
Recommendation Low Priority (3 to 6)	26.1	24.6	25.7
Between rec p-value	<0.001	<0.001	<0.001
Diabetes (DM) Meds	(n = 1354)	(n = 3951)	(n = 2994)
Any DM Rx Recommendation	36.0	34.5	32.9
Recommendation High Priority (1 to 2)	45.5	44.8	43.9
Recommendation Low Priority (3 to 6)	23.5	18.5	20.6
Between rec p-value	<0.001	<0.001	<0.001
Dyslipidemia Meds	(n = 4383)	(n = 10,186)	(n = 12,704)
Any Dyslipidemia Rx Recommendation	10.3	6.6	6.5
Recommendation High Priority (1 to 2)	11.6	6.9	6.6
Recommendation Low Priority (3 to 6)	17.0	14.6	14.2
Between rec p-value	0.140	<0.001	<0.001
Tobacco Cessation Meds	(n = 3006)	(n = 7110)	(n = 9543)
Any Tobacco Cessation Rx Recommendation	9.1	6.9	6.7
Priority 1	9.4	7.0	6.8
Priority 2	6.3	6.0	5.9

Abbreviations: CDS, Clinical decision support; BP, Blood pressure.
Notes: N = count of encounters for patients with a recommendation to start a medication who were not prescribed any type of that medication in the past 6 months. Two-tailed, unpaired *t* test with significance level set at 0.05 assuming unequal variances.

6), except for dyslipidemia prescriptions. Suggestions for tobacco cessation medication were always a top priority for smokers, so a comparison of differences in prioritization of tobacco cessation medications could not be performed.

Adjusted Probability of Issued Prescriptions by Type of Prescription

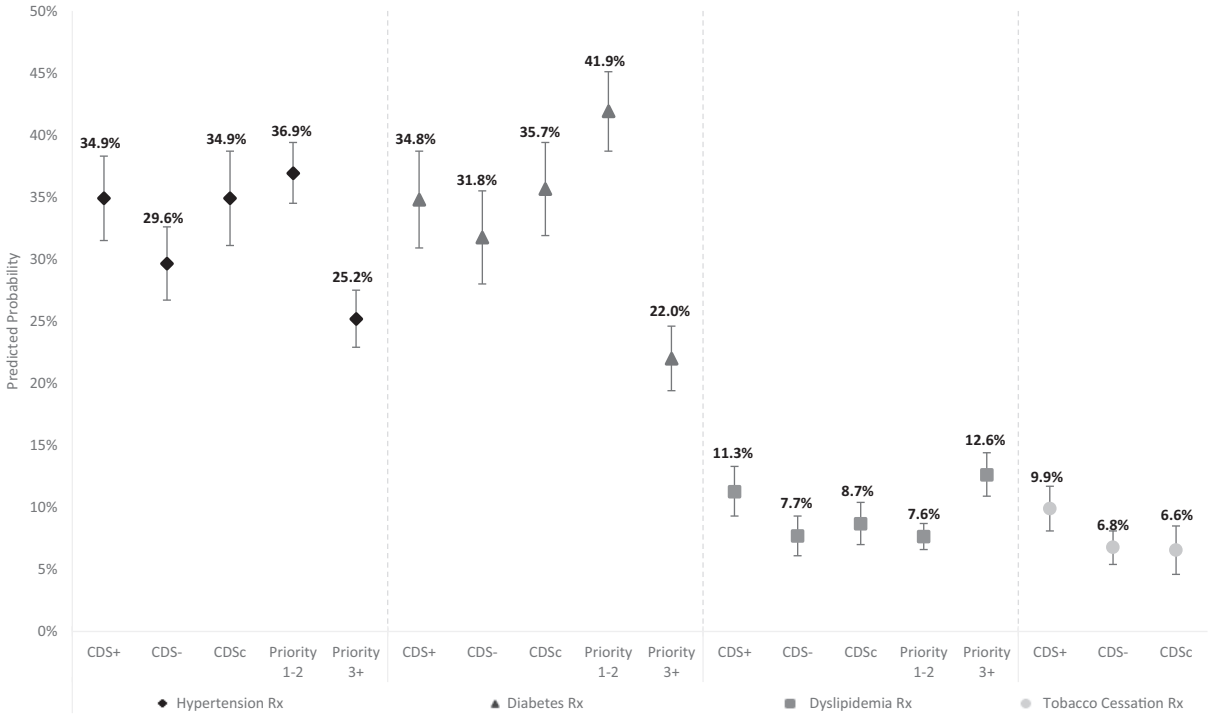
Predicted probabilities obtained from adjusted logistic regression models (Figure 2) show that prescriptions were more likely to be written for uncontrolled hypertension at intervention clinic encounters if the CDS system was used, CDS+ (34.9% [95% CI, 31.5 to 38.3]) versus not used, CDS- (29.6% [95% CI, 26.7 to 32.6]; *P* < *.001*), but not when CDS system use was compared with control clinic encounters, CDSc (34.9% [95% CI, 31.1 to 38.7]; *P* = *.998*). There were no significant differences in the probability of diabetes-related prescriptions between any of the 3 groups.

Probability of prescribing for lipid control was significantly higher when comparing intervention clinic encounters where the CDS system was used, CDS+ (11.3% [95% CI, 9.3 to 13.3]) with those where it was not used, CDS- (7.7% [95% CI, 6.1 to 9.3]; *P* = *.003*) and to control clinic encounters, CDSc (8.7% [95% CI, 7.0 to 10.4]; *P* = *.044*). The same pattern was seen for tobacco cessation medication when comparing encounters when the CDS system was used, CDS+ (9.9% [95% CI 8.1 to 11.7]) to encounters where it was not used, CDS- (6.8% [95% CI 5.4 to 8.1]; *p*=<0.001) and to control clinic encounters, CDSc (6.6% [95% CI 4.6 to 8.5]; *P* = *.031*).

Adjusted Probability of Issued Prescriptions by Recommendation Priority

The probability of a new medication order was associated with the priority ranking of its corresponding CVD risk factor (Figure 2), directly so for hypertension medication (36.9% for high priority vs 25.2% for low priority; *P* < *.001*) and for diabetes medication (41.9% for high priority vs 22.0% for low priority; *P* < *.001*). In contrast, there was a strong inverse association between dyslipidemia prescriptions and priority ranking (7.6% for high

Figure 2. Predicted probability of receiving a prescription for recommended medication. Abbreviation: CDS, Clinical decision support.



CDS+ = Intervention clinic encounters, where the CDS system was used
CDS- = Intervention clinic encounters, where the CDS system was not used
CDSc= Control clinic encounters, where the CDS system was not available for use

priority vs 12.6% for low priority; $P<.001$). Associations between priority ranking and ordering tobacco cessation medications could not be ascertained because quitting smoking always ranked as a top priority for smokers.

Discussion

Study results suggest that (a) medication ordering can increase with higher risk factor prioritization of hypertension and hyperglycemia, and (b) in intervention clinics, use of this CDS system can yield a significantly increased probability of new prescriptions for uncontrolled hypertension, but not glucose control, and (c) there is an increased probability of new prescriptions to address dyslipidemia and tobacco use when the CDS system was used among intervention clinics compared with control clinics. These results add knowledge by focusing on the impact of CDS care recommendation prioritization in the CHC setting, which has not been studied previously.

The likelihood that CDS system use was significantly associated with issuance of a given prescription varied by type of recommended medication. For example, a new prescription was added in approximately one-third of encounters where medications were suggested to treat uncontrolled hypertension or diabetes, whereas only 10% of encounters suggesting new treatment for dyslipidemia or smoking were associated with a new prescription. This is despite the fact that the provider was 3 times more likely to see a medication recommendation for lipid control and more than twice as likely to see a medication recommendation for tobacco cessation than one for hyperglycemia. This outcome is consistent with higher patient resistance to taking statins and quitting smoking, both well described; convincing patients to do either can be difficult and time-consuming.[8,36–38] As this trend was seen across all comparison groups, it may also reflect training or systemic biases leading to preferences for addressing some risk factors over others. Further study of differences between how varying CVD risk factors are managed would be useful.

This difficulty might also explain the finding that dyslipidemia as a lower priority was associated with *more* statin prescriptions than when it was a

higher priority, even in encounters where the CDS system was used. One potential explanation of this is that patients for whom it was of higher priority were more likely to have been previously identified for treatment with statins but were not taking one due to prior refusal, or side effects. Conversely, patients for whom lipid control was a lower priority may have been more likely to be receiving this recommendation for the first time, and thus may be less reticent to try medication. This may demonstrate that a specific value of this CDS system is that its use can focus attention on addressing or readdressing more challenging risk factors which, like tobacco cessation, may have been previously advocated and abandoned, but are apt to benefit from repeated attempts.[36] Patient compliance with these medications prescribed for smoking tobacco and for dyslipidemia would be expected to reduce the rate of major adverse cardiovascular events (MACE),[39,40] and follow-up studies to quantify the extent of impact on these outcomes would be useful.

By focusing attention on prioritized CVD risk factors, this CDS may also help address inequitable gaps in risk management. The regression analyses presented here adjusted for differences seen in the baseline characteristics of the intervention and control populations. Yet we note that it is possible that these baseline differences explain the variation seen related to these characteristics in new medication prescriptions, as patients in disparate populations may have been more likely to be indicated for a medication which they had not previously been prescribed. Additional research is needed to explore this potential.

Last, low overall use of this CDS system at eligible encounters limited its impact. This CDS system was proven effective in integrated care settings, where its use rates were far higher than those seen here; research is needed on strategies for increasing CDS use rates in the CHC setting, which differs substantially from other care settings. Higher use rates could potentially have a greater impact in CHCs, where baseline rates of CVD management are low. Yet attaining these higher use rates is challenging for many reasons, including 'alert fatigue.' It is possible, however, that care recommendation prioritization would increase the CDS system's utility and thus its use; these analyses demonstrate the benefits of such prioritization.

Limitations

The study was performed in CHCs sharing a single instance of an EHR, and results should be confirmed in other populations and care systems. We restricted our analysis to new prescriptions because of the decreased data completeness and veracity associated with medication usage and dosage adjustments in our system. We did not include aspirin recommendations in the analysis because it is commonly taken without a prescription and thus not reliably documented in EHRs. Many potential confounding effects were controlled by regression analysis, but other variables that were not considered or feasible to measure may have affected outcomes; for example, we cannot account for other actions taken by the study clinics to address CVD risk. Compliance with medication prescription and subsequent effect on outcomes and cost could not be ascertained in these analyses' scope but would benefit from further investigation.

Conclusions

These results provide evidence that prioritization of CDS treatment suggestions related to blood pressure and hyperglycemia seems to increase ordering of new medication to address those CVD risk factors. They also show that use of this CDS system has a significant favorable impact on prescriptions for dyslipidemia and tobacco use, and within the intervention group, for uncontrolled hypertension, but not hyperglycemia. Additional effort is needed to maximize CDS use by improving intervention efficiency, integration into clinic workflows, including additional clinical domains, and communication of treatment benefits and risks to clinicians and patients in an accurate and comprehensible way.

This work was conducted with the Accelerating Data Value Across a National Community Health Center Network (ADVANCE) Clinical Research Network (CRN). ADVANCE is led by OCHIN in partnership with Health Choice Network, Fenway Health, and Oregon Health & Science University. ADVANCE is funded through the Patient-Centered Outcomes Research Institute (PCORI), contract number RI-OCHIN-01-MC.

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Appendix.

Example of CV Wizard Provider View.

#1 TOBACCO Potential CV Risk Reduction: 13.9%

Treatment Considerations

- Assess interest in quitting, consider a referral for tobacco cessation services and/or use of medications such as varenicline (Chantix), bupropion (Zyban), or nicotine patch, gum, lozenge, or inhaler.

Results	
Smoking Status/Review Date	Current
Smokeless Tobacco	NEVER

No relevant medications

#2 LIPID Potential CV Risk Reduction: 11.0%

Goal: Consider statin initiation.

Important

- Liver disease or elevated liver tests (AST or ALT) have been identified. If verified, consider risks of statin use.
- Statins are safe to use in women who are not pregnant but may become pregnant. Unintended exposure to statins in early pregnancy is unlikely to cause harm to the developing fetus. Reliable birth control can be used in conjunction with statins in women of childbearing age.

Treatment Considerations

- Statin initiation or intensification is recommended due to diabetes and CV risk. Many experts recommend high intensity statin doses for CV risk >= 7.5%.

Other Alerts

- The last lipid labs were more than a year ago. Consider ordering lipid tests to ensure that CV risk and statin recommendations are up-to-date.

Results	
LDL (mg/dl)	111
HDL (mg/dl)	19
TRIG (mg/dl)	141
TC (mg/dl)	158
ALT (mg/dl)	16

No relevant medications

ASPIRIN OR ANTICOAGULANT

Important

- Aspirin allergy or intolerance has been identified.
- Previous diagnosis of anemia, blood disorder or splenic abnormality could increase risks due to aspirin use.

Treatment Considerations

- For patients age 40-59 with high cardiovascular risk, aspirin start or continued use for primary prevention of heart attacks and strokes might be considered after considering bleeding risk and patient preference.

Allergies

ASPIRIN

No relevant medications

RELEVANT INFORMATION AND RECOMMENDATIONS

BLOOD PRESSURE

- A past diagnosis of hyponatremia was identified.
- A serum K may be due and is often recommended yearly for people on hypertensive medications.
- A serum Cr/GFR test may be due and is often recommended yearly for people on BP medications.

Results	
BP (mm Hg)	113/73
Last BP (mm Hg)	113/73
eGFR(ml/min)	>60
K (mmol/L)	4.3

Medications

Spironolactone Tab 50 MG
Furosemide Tab 20 MG