

ORIGINAL RESEARCH

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

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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 $\geq 10\%$ 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;00:000–000.)

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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}

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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, non-profit, 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.

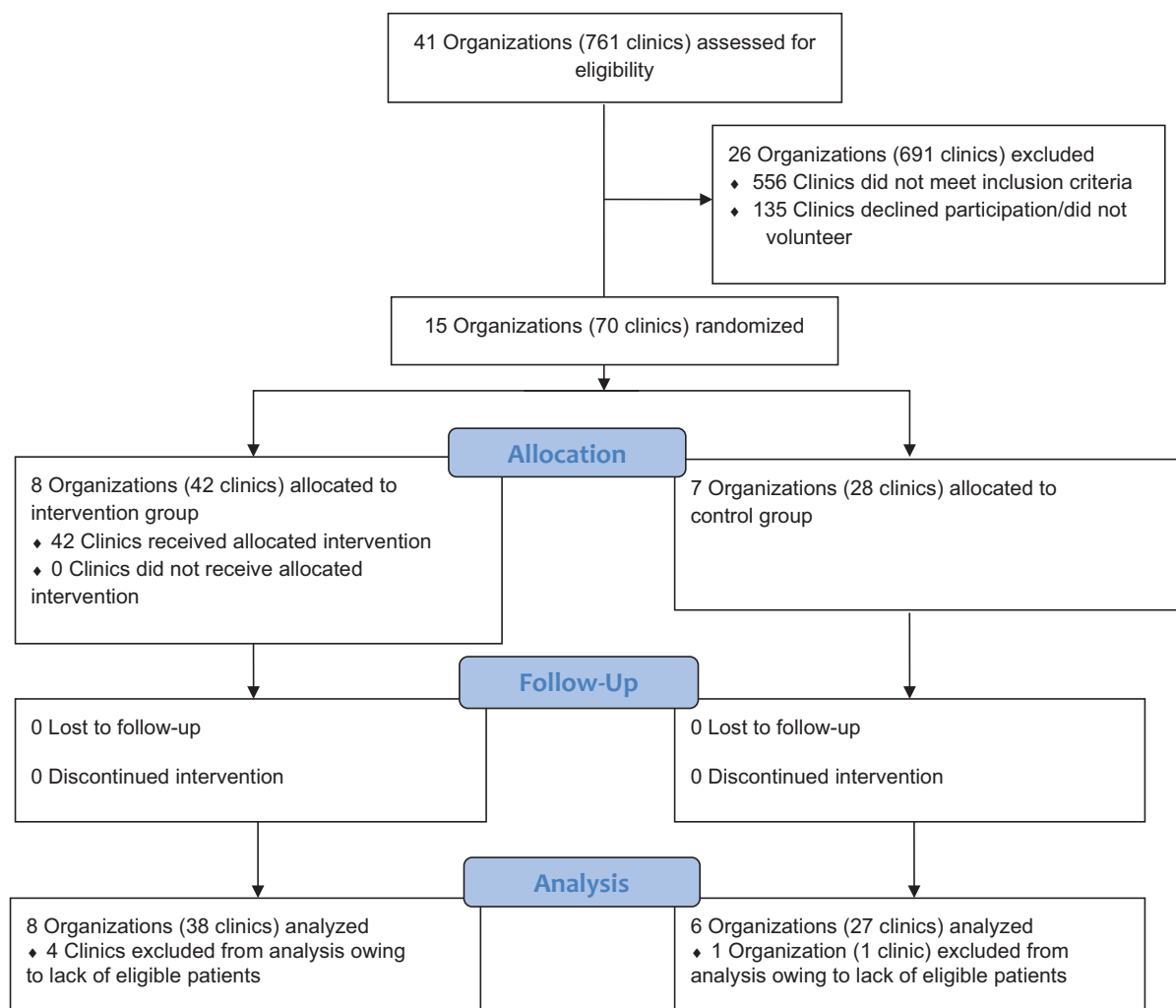
Statistical Analysis

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 (CDS_c). 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 it 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, CDS_c (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.

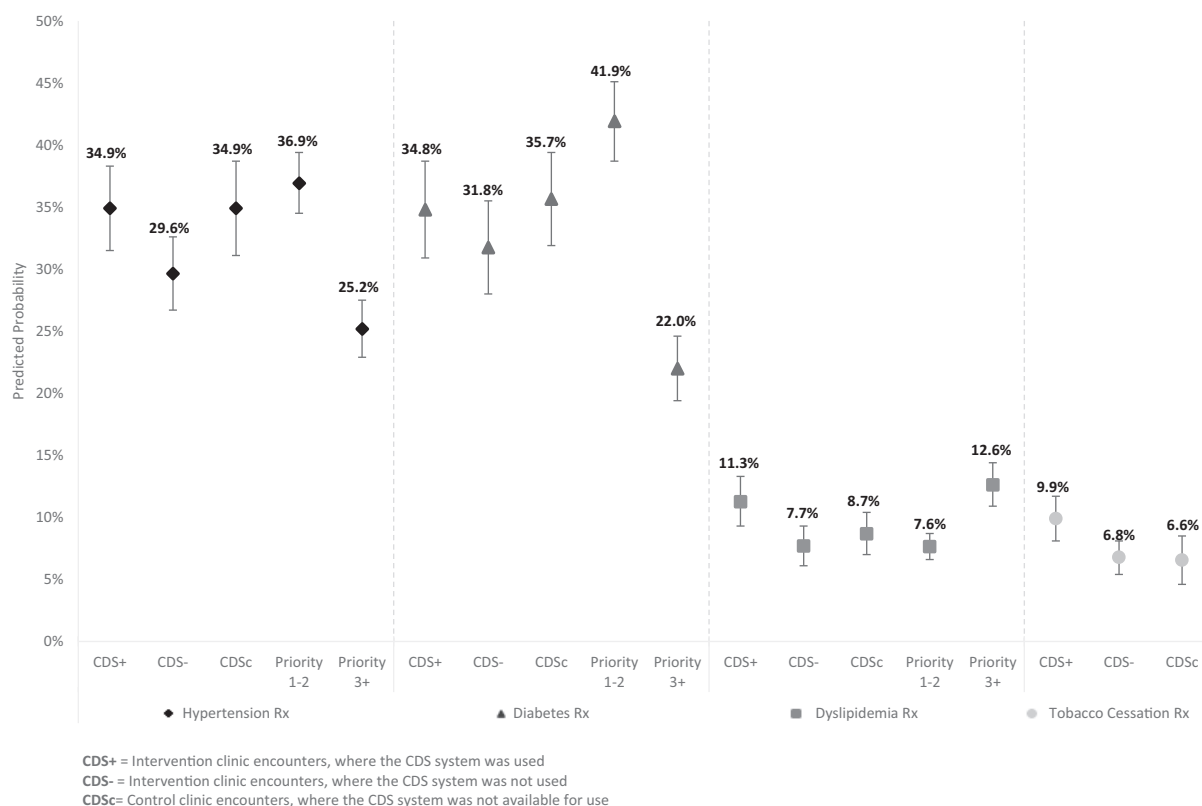
Probability of prescribing for lipid control was significantly higher when comparing intervention clinic encounters where the CDS system was used,

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, CDS_c (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, CDS_c (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.



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.

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References

1. Arnett DK, Blumenthal RS, Albert MA, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 2019;140:e596–e646.
2. Joseph JJ, Deedwania P, Acharya T, American Heart Association Diabetes Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Clinical Cardiology; and Council on Hypertension, et al. Comprehensive management of cardiovascular risk factors for adults with type 2 diabetes: a scientific statement from the American Heart Association. *Circulation* 2022;145:e722–e759.
3. Muntner P, Hardy ST, Fine LJ, et al. Trends in blood pressure control among US adults with hypertension, 1999–2000 to 2017–2018. *JAMA* 2020;324:1190–200.
4. Virani SS, Alonso A, Aparicio HJ, American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee, et al. Heart disease and stroke statistics—2021 update: a report from the American Heart Association. *Circulation*. 2021;143:e254–e743.
5. Mitchell S, Roso S, Samuel M, Pladevall-Vila M. Unmet need in the hyperlipidaemia population with high risk of cardiovascular disease: a targeted literature review of observational studies. *BMC Cardiovasc Disord* 2016;16:74.
6. Garrett BE, Martell BN, Caraballo RS, King BA. Socioeconomic differences in cigarette smoking among sociodemographic groups. *Prev Chronic Dis* 2019;16:E74.
7. Obesity Expert Panel. Managing overweight and obesity in adults: systematic evidence review, 2013. National Heart, Lung, and Blood Institute, National Institutes of Health, US Department of Health and Human Services. Accessed December 8, 2020. Available at: <https://www.nhlbi.nih.gov/sites/default/files/media/docs/obesity-evidence-review.pdf>.
8. Nelson AJ, Haynes K, Shambhu S, et al. High-Intensity statin use among patients with atherosclerosis in the U.S. *J Am Coll Cardiol* 2022;79:1802–13.
9. Parchman ML, Pugh JA, Romero RL, Bowers KW. Competing demands or clinical inertia: the case of elevated glycosylated hemoglobin. *Ann Fam Med* 2007;5:196–201. doi:10.1370/afm.679
10. Yawn B, Goodwin MA, Zyzanski SJ, Stange KC. Time use during acute and chronic illness visits to a family physician. *Fam Pract* 2003;20:474–7.
11. Beasley JW, Wetterneck TB, Temte J, et al. Information chaos in primary care: implications for physician performance and patient safety. *J Am Board Fam Med* 2011;24:745–51.
12. Jean-Jacques M, Persell SD, Thompson JA, Hasnain-Wynia R, Baker DW. Changes in disparities following the implementation of a health information technology-supported quality improvement initiative. *J Gen Intern Med* 2012;27:71–7.
13. Goud R, de Keizer NF, ter Riet G, et al. Effect of guideline based computerised decision support on decision making of multidisciplinary teams: cluster randomised trial in cardiac rehabilitation. *BMJ* 2009;338:b1440.
14. Bright TJ, Wong A, Dhurjati R, et al. Effect of clinical decision-support systems: a systematic review. *Ann Intern Med* 2012;157:29–43.
15. Lobach D, Sanders GD, Bright TJ, et al. Enabling health care decision-making through clinical decision support and knowledge management. *Evid Report Technology Assess* 2012;1–784.
16. Souza NM, Sebaldt RJ, Mackay JA, CCDSS Systematic Review Team, et al. Computerized clinical decision support systems for primary preventive care: a decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. *Implement Sci* 2011;6:87.
17. Yarnall KSH, Pollak KI, Østbye T, Krause KM, Michener JL. Primary care: is there enough time for prevention? *Am J Public Health* 2003;93:635–41.
18. Østbye T, Yarnall KSH, Krause KM, Pollak KI, Gradison M, Michener JL. Is there time for management of patients with chronic diseases in primary care? *Ann Fam Med* 2005;3:209–14.
19. Goff DC, Lloyd-Jones DM, Bennett G, et al. 2013 ACC/AHA guideline on the assessment of cardiovascular risk. *J Am Coll Cardiol* 2014;63:2935–59.
20. Koopman RJ, Kochendorfer KM, Moore JL, et al. A diabetes dashboard and physician efficiency and accuracy in accessing data needed for high-quality diabetes care. *Ann Fam Med* 2011;9:398–405.
21. O'Connor PJ, Sperl-Hillen JM. Current status and future directions for electronic point-of-care clinical decision support to improve diabetes management in primary care. *Diabetes Technol Ther* 2019;21:S226–S234.
22. O'Connor PJ, Sperl-Hillen JM, Rush WA, et al. Impact of electronic health record clinical decision support on diabetes care: a randomized trial. *Ann Fam Med* 2011;9:12–21.
23. Sperl-Hillen J, Crain L, Ekstrom H, Margolis K. A clinical decision support system promotes shared decision-making and cardiovascular risk factor management. *J Patient-Centered Res Rev* 2017;4:158–9.
24. Sperl-Hillen JM, Crain AL, Margolis KL, et al. Clinical decision support directed to primary care patients and providers reduces cardiovascular risk: a randomized trial. *J Am Med Inform Assoc* 2018;25:1137–46.
25. O'Connor P. Opportunities to Increase the Effectiveness of EHR-Based Diabetes Clinical Decision Support. *Appl Clin Inform* 2011;02:350–4.

26. Sperl-Hillen JM, Rossom RC, Kharbanda EO, et al. Priorities wizard: multisite web-based primary care clinical decision support improved chronic care outcomes with high use rates and high clinician satisfaction rates. *EGEMS (Wash DC)* 2019;7:9.
27. U.S. Preventive Services Task Force. Final recommendation statement; tobacco smoking cessation in adults, including pregnant persons: interventions. January 19, 2021. Accessed April 8, 2019. Available at: <https://www.uspreventiveservicestaskforce.org/uspstf/document/RecommendationStatementFinal/tobacco-use-in-adults-and-pregnant-women-counseling-and-interventions>.
28. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension* 2018;71:1269–324.
29. American Diabetes Association. 6. Glycemic Targets: *Standards of Medical Care in Diabetes—2018*. *Diabetes Care* 2018;41:S55–S64.
30. Rothwell PM, Cook NR, Gaziano JM, et al. Effects of aspirin on risks of vascular events and cancer according to bodyweight and dose: analysis of individual patient data from randomised trials. *Lancet* 2018;392:387–99.
31. Casey DE, Thomas RJ, Bhalla V, et al. 2019 AHA/ACC clinical performance and quality measures for adults with high blood pressure: a report of the American College of Cardiology/American Heart Association Task Force on Performance Measures. *Circ Cardiovasc Qual Outcomes* 2019;12:e000057.
32. Bibbins-Domingo K, Grossman DC, Curry SJ, US Preventive Services Task Force, et al. Statin use for the primary prevention of cardiovascular disease in adults: US Preventive Services Task Force Recommendation Statement. *JAMA* 2016;316:1997–2007.
33. Gold R, Larson AE, Sperl-Hillen JM, et al. Effect of clinical decision support at community health centers on the risk of cardiovascular disease: a cluster randomized clinical trial. *JAMA Netw Open* 2022;5:e2146519.
34. Kouri A, Yamada J, Lam Shin Cheung J, Van de Velde S, Gupta S. Do providers use computerized clinical decision support systems? A systematic review and meta-regression of clinical decision support uptake. *Implement Sci* 2022;17:21.
35. Kwan JL, Lo L, Ferguson J, et al. Computerised clinical decision support systems and absolute improvements in care: meta-analysis of controlled clinical trials. *BMJ*. 2020;370:m3216. Published online September.
36. Bradley CK, Wang TY, Li S, et al. Patient-reported reasons for declining or discontinuing statin therapy: insights from the PALM registry. *J Am Heart Assoc* 2019;8:e011765.
37. Hirsh BJ, Smilowitz NR, Rosenson RS, Fuster V, Sperling LS. Utilization of and adherence to guideline-recommended lipid-lowering therapy after acute coronary syndrome: opportunities for improvement. *J Am Coll Cardiol* 2015;66:184–92.
38. Virani SS, Ballantyne CM, Petersen LA. Guideline-concordant statin therapy use in secondary prevention: should the medical community wait for divine intervention? *J Am Coll Cardiol* 2022;79:1814–7.
39. Wu AD, Lindson N, Hartmann-Boyce J, et al. Smoking cessation for secondary prevention of cardiovascular disease. *Cochrane Database Syst Rev* 2022;8:CD014936.
40. Taylor F, Huffman MD, Macedo AF, et al. Statins for the primary prevention of cardiovascular disease. *Cochrane Database Syst Rev* 2013;2013:CD004816. Published 2013 Jan 31.

Appendix.

Example of CV Wizard Provider View.

| | | |
|---|--|--|
| <div>#1 TOBACCO</div> <div>Potential CV Risk Reduction: 13.9%</div> | <div>Results</div> <div>Smoking Status/Review Date</div> <div>Current</div> <div>Smokeless Tobacco</div> <div>NEVER</div> | No relevant medications |
| <div>#2 LIPID</div> <div>Potential CV Risk Reduction: 11.0%</div> | <div>Results</div> <div>LDL (mg/dl)</div> <div>111</div> <div>HDL (mg/dl)</div> <div>19</div> <div>TRIG (mg/dl)</div> <div>141</div> <div>TC (mg/dl)</div> <div>158</div> <div>ALT (mg/dl)</div> <div>16</div> | No relevant medications |
| <div>ASPIRIN OR ANTICOAGULANT</div> | <div>Allergies</div> <div>ASPIRIN</div> | No relevant medications |
| <div>RELEVANT INFORMATION AND RECOMMENDATIONS</div> | <div>Results</div> <div>BP (mm Hg)</div> <div>113/73</div> <div>Last BP (mm Hg)</div> <div>113/73</div> <div>eGFR(ml/min)</div> <div>>60</div> <div>K (mmol/L)</div> <div>4.3</div> | <div>Medications</div> <div>Spironolactone Tab 50 MG</div> <div>Furosemide Tab 20 MG</div> |