REVIEW

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The Impact of Guideline Integration into Electronic Medical Records on Outcomes for Patients with Diabetes: A Systematic Review

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ABSTRACT

Optimal strategies for integration of clinical practice guidelines into electronic medical records and its impact on processes of care and clinical outcomes in diabetic patients are not well understood. A systematic review of CINAHL, MEDLINE, PubMed, and Cochrane Library databases in August 2016, November 2017, and June 2020 was conducted. Studies investigating integration of diabetes guidelines into ambulatory care electronic medical records reporting quantitative results were included. After screening 15,783 records, 21 articles were included. Lipid and blood pressure control consistently improved with guideline integration, but A1c control remained equivocal. Electronic guideline integration improved microvascular complication screening, vaccination, and documentation of cardiovascular risk factors, while medication prescription and blood pressure, lipid, and A1c documentation did not improve. Studies employing a combination of electronic record intervention strategies were associated with improvement in monitoring and attainment of guideline and screening targets. Thus, strategies employing combinations of interventions to incorporate guidelines into electronic records may improve processes of care and some clinical outcomes.

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KEYWORDS: Clinical practice guideline; Diabetes; Electronic medical record; Systematic review

INTRODUCTION

Affecting over 2 million Canadians, diabetes is a prevalent chronic disease and leading cause of death.[1,2] Diabetes progression can be controlled through monitoring and management of hypertension, hyperglycemia, and dyslipidemia[3,4] within evolving guideline-specified targets.[5] To counter slow integration of guideline integration,[6,7] increased prevalence of electronic records in primary care presents an opportunity to promote guideline integration and improve the suboptimal achievement of guideline targets.[8]

Guideline-integrated computer-aided clinical decision support may facilitate a personalized and timely form of guideline-based care.[9] Diagnostic decision support, preventive care reminders, and bundles of reminders are other examples of guideline integration into electronic records.[9,10] The best intervention modality to ensure guideline implementation is not established. This review evaluates best practices and quantifies outcome attainment for interventions integrating guidelines into electronic medical records.

METHODS

The protocol for this systematic review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[11]

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Eligibility Criteria

We included studies of all study designs that investigated integration of diabetes guidelines into electronic records. Inclusion criteria included: 1) English-language primary research articles; 2) ambulatory care interventions; 3) electronic record-integrated interventions; and 4) quantitative outcomes. We excluded studies that were ongoing, describe no relevant outcomes, or lack detail to assess eligibility.

Information Sources and Literature Search

Four databases were searched (CINAHL, MEDLINE, PubMed, and Cochrane Library) in August 2016, November 2017, and June 2020. With assistance of an information scientist, a search strategy was developed for key terms: "electronic health records" "practice guidelines," and "ambulatory care" (Supplementary Table 1, available online). Reference lists of relevant studies were manually reviewed.

Study Selection Process

After abstract selection, full-text articles were reviewed independently by pairs of review authors. Disagreements were discussed and resolved with team members.

Data Items and Data Collection Process

Data were tabulated according to study setting, patient sample characteristics, duration, type of intervention, contextual factors (motivation, incentives, and training), and outcomes. Prior to full-text abstraction, a calibration exercise ensured consistent and accurate data abstraction. Each review author independently abstracted a full-text article and compared with another team member, with disagreements in abstraction resolved by discussion.

Risk of Bias Assessment

Methodological risk of bias of included studies was assessed using the Cochrane Collaboration's tool for assessing risk of bias in randomized controlled trials (RCTs)[12] and Quality Assessment Tool for Quantitative Studies by the Effective Public Health Practice Project for other studies.[13] Pairs of review authors independently assessed risk of bias of included studies, with disagreements resolved by discussion.

CLINICAL SIGNIFICANCE

- Clinical practice guideline integration in electronic medical record software improved lipid and blood pressure control, microvascular screening, and risk factor documentation; A1c control, medication prescription, and documentation of diabetes management parameters did not improve consistently with electronic medical record intervention.
- Combinations of electronic medical record interventions (including reminders, feedback, and clinical decision support systems) should be implemented to match a clinician's workflow, patient population, and target outcomes to improve clinical and process outcomes.

RESULTS

Results of the Search

The article search and inclusion process is depicted in the Figure.

Study Design

Twenty-one studies (Supplementary Table 2,[14-34] available online) were included: 9 experimental studies (5 randomized-controlled trials [RCTs][14-18] and 4 cluster RCTs[19-22]), 10 quasi-experimental studies (1 non-RCT,[23] 5 uncontrolled before-and-after studies,[24-28] 1 controlled before-and-after study,[29] 3 interrupted time series studies[30-32]), and 2 observational studies (1 retrospective cross-sectional study[33] and 1 retrospective cohort study[34]).

Study Settings and Population Characteristics

All studies were conducted in primary care settings between 1994[15] and 2020.[21] Fourteen studies were conducted in the United States.[14-17,19,20,24-26,28-32] Study durations ranged from 2 months[24] to 12 years,[33] and sample sizes ranged from 90[24] to 4,629,300 participants.[33]

Interventions

Intervention types are summarized in Table 1[14,20,24,28], with study designs described in Table 2, and outcomes detailed in Table 3.[14-34] Six studies implemented reminders/prompts,[15,16,19,24,29,30] 1 implemented feedback,[14] 4 implemented a Clinical Decision Support System,[17,20-22] and 10 implemented combinations of interventions.[18,23,25-28,31-34]

Outcomes Reported

Experimental and observational studies reported different outcomes and could not be directly compared; 3 of 9 RCTs[14-16] and 1 quasi-experimental study[29] reported physician compliance to the intervention, whereas the other quasi-experimental and observational studies reported patient and process-related outcomes (Table 2[14-34]). Results are described by clinical outcome, process outcome, and intervention, and are listed in Table 3.

A) Clinical Outcomes

Supplementary Table 3,[18,20-23,25-28,30,31,33,34] (available online) summarizes clinical outcomes described by the included studies.

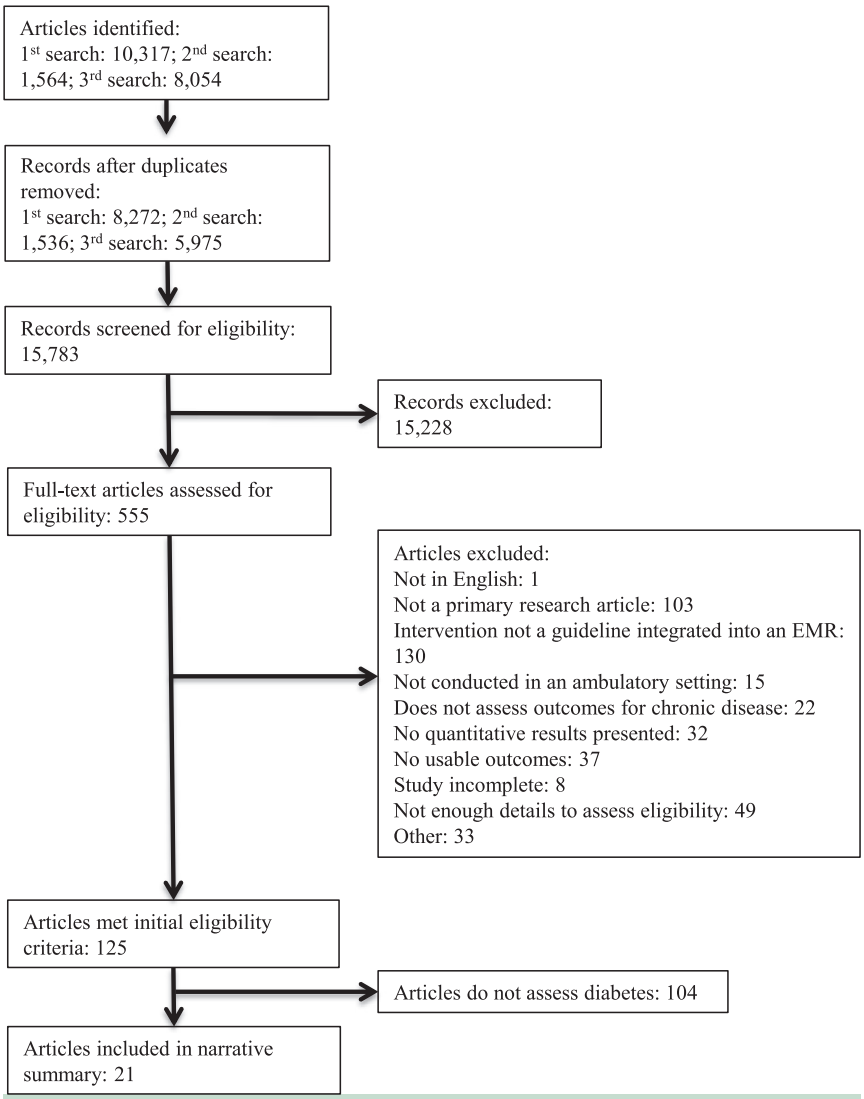

Figure A flow diagram of the article search and inclusion process.

Table 1 Types of Interventions and their Definitions

Intervention Type	Definition	Example
Reminders/Prompts	A computer-generated reminder system for diabetes care guidelines or recommended care that patient is due for.	A customized EMR alert recommending assessment of atherosclerotic cardiovascular disease (ASCVD) and statin therapy.[24]
Feedback	Feedback to provider about his/her response to the recommendations made by the EMR.	A computer-generated report summarizing the response to care guideline recommendations presented through a CAMP.[14]
Clinical Decision Support System (CDSS)	Based on patient characteristics, a CDSS uses an algorithm to generate recommendations, thereby guiding the provider in making decisions.	Diabetes Wizard made recommendations about medications, laboratory tests, and follow-up intervals based on detailed clinical algorithms.[20]
Combination	Some combination of reminders/prompts, performance audit and feedback, educational materials and workshops for staff on guidelines and changes in office workflow, decision support systems and appointment scheduling systems	A combination of enabling tools, reminders, audit and feedback, and financial incentives.[28]

CAMP = Computer-Assisted Management Protocol; EMR = electronic medical record.

Table 2 Study Outcomes Sorted by Study Design

	RCTs and Cluster RCTs	Quasi-Experimental	Observational
Patient-level outcomes			
Clinical outcomes	4 studies[18,20-22]	7 studies[23,25-28,30,31]	2 studies[33,34]
Processes of care	4 studies[17,19,21,22]	9 studies[23-28,30-32]	2 studies[33,34]
Provider-level outcomes	3 studies[14-16]	1 study[29]	0 studies

RCT = randomized controlled trial.

Table 3 Study Outcomes Organized by Intervention Type

Primary Author, Year, Study Type	Intervention Details	Outcomes Measured	Outcomes Reported
Bronner 2012;[30] Interrupted time series	Step-wise approach to EMR intervention with prompts for A1c, LDL, or microalbumin-to-creatinine testing.	Composite of care markers including screening for diabetic nephropathy, documentation of lipid profile and glycemic control; and lipids and A1c	Improvement in composite of care markers including screening for nephropathy, documentation of lipid profile and A1c; and no difference in LDL or A1c control
El-Kareh 2011;[19] Cluster RCT	Actionable reminders (electronic reminders linked to computerized order entry).	Documentation of lipid profile and glycemic control	No difference in documentation of lipid profile or A1c
Garza 2017;[24] Before-and-after study	Customized EMR alert recommending assessment of atherosclerotic cardiovascular disease (ASCVD) and statin therapy for the targeted group of patients.	Documentation of CAD risk score; and Medication prescription	Improvement in the prescription of lipid-lowering medications and documentation of CAD risk score
Lobach 1994;[15] RCT	Computer-Assisted Management Protocol (CAMP) that provided recommendations about which tests are indicated for the patient based on care guidelines.	Physician compliance with guideline recommendation	Improvement in physician compliance with guideline recommendation
Nilasena 1995;[16] RCT	Reminder system that summarized the patient's preventive-health status and listed a schedule of upcoming or past due preventive-health activities for the patient. Clinical alerts about high-risk aspects of the patient's current profile were also presented.	Physician compliance with guideline recommendation	Improvement in physician compliance with guideline recommendation
Ramirez 2020;[29] Before-and-after study	Implementation of EMR alert requiring action or reason for deferral prior to chart closure for patients with diabetes and hypertension eligible but not prescribed an ACEI or ARB.	Medication prescription	Increased probability of prescription of ACEI or ARB; Subgroup analysis demonstrated that the increased probability was significant where there was also a pharmacist-led medication management program
Lobach 1996;[14] RCT	Intervention group received biweekly e-mail message consisting of a computer-generated report summarizing his/her response to care guideline recommendations presented through the EMR.	Physician compliance with guideline recommendation	Improvement in physician compliance with guideline recommendation
Heselmans 2020;[21] Cluster RCT	CDSS that gives patient-specific reminders, therapeutic	Lipid, blood pressure and A1c control;	No difference in lipid, blood pressure, and A1c control; no

Table 3 (*Continued*)

Primary Author, Year, Study Type	Intervention Details	Outcomes Measured	Outcomes Reported
	suggestions, and diagnosis-specific guideline links to the user. Electronic forms and calculators are integrated into the system.	Process composite score: documentation of A1c, BP, LDL, microalbuminuria, and medication prescription; and patient composite score: lipids, BP and A1c	difference in process composite score: documentation of A1c, BP, LDL, microalbuminuria, and medication prescription; and no difference in patient composite score: lipids, BP, and A1c control
Hetlevik 2000;[22] Cluster RCT	CDSS that guided the doctors in diagnostics, history taking, physical examination, additional tests, and treatment.	Blood pressure and A1c control; and documentation of blood pressure, lipid profile and glycemic control, BMI, family history of CAD, CAD risk score, and smoking history	Improvement in BP control; no difference in A1c control; Improvement in documentation of BMI, smoking and family history, CAD risk score; and no difference in documentation of BP, lipids, or A1c
O'Connor 2011;[20] Cluster RCT	CDSS that made recommendations about medications, laboratory tests, and follow-up intervals based on detailed clinical algorithms.	Lipid, blood pressure, and A1c control	Improvement in BP, A1c control; and no difference in LDL control
Schnipper 2010;[17] RCT	CDSS that included assessments of the current state of clinical care and suggested actionable orders for medication additions or changes, laboratory studies, appointments and referrals, and printing of patient educational materials.	Screening for microvascular complications; documentation of glycemic control; and medication prescription	No difference in screening for microvascular complications; no difference in documentation of A1c; and no difference in ACEI/ARB prescription
Ali 2016;[18] RCT	Combination of electronic prompts to providers and non-physician care coordinators who individualized patient follow-up based on patients' risk level and adherence.	Lipid, blood pressure, and A1c control	Improvement in LDL, BP, and A1c control
Ciemins 2009;[31] Interrupted time series	Combination of diabetes management module for point-of-care alerts, electronic forms documenting foot and eye examinations, patient reports with individualized results and provider patient panel reports to track performance. Included education program for primary care staff on guidelines and changes in office workflow.	Lipid, blood pressure, and A1c control; screening for microvascular complications; documentation of lipid profile and glycemic control	Improvement in LDL, BP, and A1c control; Improvement in screening for microvascular complications; improvement in documentation of lipid profile; and no difference in documentation of A1c
Goldfracht 2011;[33] Retrospective cross-sectional study	Combination of educational strategies, registries, clinical pathways, care quality indicators, computerized reminders and feedback, feedback for physicians, and patient education tools.	Lipid and A1c control; screening for microvascular complications; documentation of blood pressure, lipid profile and glycemic control	Improvement in LDL and A1c control; improvement in screening for microvascular complications; and improvement in documentation of BP, LDL, and A1c
Gunathilake 2013;[34] Retrospective cohort study	Combination of provider reminder systems and patient reminder systems that prompted administrative staff to contact patients to attend	Composite of care markers including planned review of A1c, medication prescription, dietetic and nurse educator inputs; A1c control	Improvement in composite of planned review of A1c, adjustment of medication, prescription of statins, dietetic and

Table 3 (*Continued*)

Primary Author, Year, Study Type	Intervention Details	Outcomes Measured	Outcomes Reported
	appointments and to have regular monitoring. There was also a CDSS that would be applied if certain criteria were met.		nurse educator inputs; and improvement in A1c control
Guzek 2009;[25] Before-and-after study	Combination of changes in office visit structure, protocol-driven electronic prompts for nursing and physician staffs, clinical decision support built into a new electronic medical record form, and audit with feedback.	Lipid, blood pressure, and A1c control; screening for microvascular complications; and documentation of blood pressure, lipid profile, and glycemic control	Improvement in LDL and BP control; no difference in A1c control; improvement in screening for microvascular complications; no difference in documentation of BP, lipids; and improvement in documentation of A1c
Hunt 2009;[26] Before-and-after study	Combination of point-of-care decision support and care reminders, diabetes registry with care prompts, performance feedback with benchmarking and access to published evidence, and patient educational materials.	Lipid, blood pressure, and A1c control; screening for microvascular complications; and documentation of blood pressure, lipid rofile, glycemic control, and immunization status; and medication prescription	Improvement in LDL and BP control; no difference in A1c control; improvement in screening for microvascular complications; improvement in documentation of LDL and A1c; no difference in documentation of BP; improvement in frequency of vaccination; improvement in prescription of ACEI/ARB, lipid-lowering, oral antihyperglycemic, and antiplatelet medication
O'Reilly 2014;[27] Before-and-after study	Tracked and reported last result and time since result for each care component, with updated dashboard summary of overall care status and progress flow sheet. Reported data from all patients in order of urgency (lack of control or time elapsed since care); provided dashboard summary and chart of the registry's performance measures; and permitted approval of a patient list for reminder letters.	Lipid, blood pressure, and A1c control; screening for microvascular complications; documentation of blood pressure, lipid profile and glycemic control; and medication prescription	No difference in A1c control; improvement in lipid and BP control; decrease in screening for microvascular complications; improvement in documentation of BP; no difference in documentation of lipid profile, A1c; and decrease in ACEI/ARB prescription
Samoutis 2010;[23] Nonrandomized controlled trial	Combination of educational components, audit and feedback, and the introduction of an EMR system, including a decision support system enabled through e-library and electronic reminders.	Lipid, blood pressure, and A1c control; and screening for microvascular complications	Improvement in LDL and BP control; no difference in A1c control patients; improvement in screening for microvascular complications.
Weber 2008;[28] Before-and-after study	Combination of enabling tools, reminders, audit and feedback, and financial incentives.	Lipid, blood pressure, and A1c control; documentation of lipid profile, glycemic control, smoking history and immunization status; and composite of care markers (all of above)	Improvement in LDL, BP and A1c control; improvement in screening for microvascular complications; improvement in documentation of lipid profile and A1c; improvement in frequency of vaccination; improvement in documentation of smoking history; and improvement in number of

Table 3 (*Continued*)

Primary Author, Year, Study Type	Intervention Details	Outcomes Measured	Outcomes Reported
			patients receiving a "bundle" of best practice measures
Zhou 2011;[32] Interrupted time series	Combination of point-of-care recommendations, disease registry capabilities, and continuous performance feedback for providers.	Composite of care markers including medication prescription, documentation of glycemic control, lipid profile, immunization status, and screening for microvascular complications	No difference in patients receiving a "bundle" of care recommendations

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin receptor blocker; BP = blood pressure; CAD = coronary artery disease; CDSS = Clinical Decision Support System; EMR = electronic medical record; LDL = low-density lipoprotein; RCT = randomized controlled trial.

i) *Lipid Control*

Eight of 11 studies (Supplementary Table 4,[18,23,25-28,31,33] available online) reporting lipid control outcomes demonstrated improvement, while 3 demonstrated no change.[20,21,30] Studies demonstrated improved proportion of patients achieving low-density lipoprotein (LDL) target, [18,25,26,28,31,33] absolute change in LDL cholesterol,[23] total cholesterol,[23] and high-density lipoprotein-to-total-cholesterol ratio.[27] The proportion of patients who achieved LDL target <100 mg/dL after intervention ranged from 56%[26]-65.2%.[25]

ii) *Hypertension Optimization*

Nine of 10 studies (Supplementary Table 5,[18,20,22,23,25-28,31] available online) reporting hypertension outcomes demonstrated improvement after guideline-integration intervention. Hypertension outcomes included targets of blood pressure <130/80 mm Hg,[25,28,31] change in absolute values,[22,23,27] and a composite of proportion achieving target and change in absolute values.[18,20,26] One study reported significant change in proportion of patients achieving systolic but not diastolic blood pressure targets, and no significant change in mean systolic or diastolic pressures.[20] The proportions of patients who achieved systolic blood pressure <130 mm Hg, diastolic blood pressure <80 mm Hg, or both after intervention ranged from 43.9%[28,31]-80.2%.[20] The absolute change in mean diastolic blood pressure after intervention ranged from 1.2[27]-3 mm Hg,[26] and change in mean systolic blood pressure ranged from 3.5[23]-5 mm Hg.[26]

iii) *Glycemic Control*

Six of 13 studies (Supplementary Table 6,[18,20,28,31,33,34] available online) examining glycated hemoglobin (A1c) control demonstrated improvement, while 7 demonstrated no change.[21-23,25-27,30] Four studies reported improvement in proportion of patients achieving target A1c[28,31,33,34] and 2 studies reported improvement in proportion of patients achieving A1c target and absolute change in A1c.[18,20] Among these, the proportion attaining A1c targets ranged from 21.5%[18]-92.1%.[34]

B) **Process Outcomes**

iv) *Microvascular Complication Screening*

Six of 9 studies (Supplementary Table 7,[23,25,26,30,31,33] available online) reporting microvascular complication screening outcomes demonstrated improvement, 2[17,21] demonstrated no difference, and 1[27] demonstrated decreased screening. Documentation of retinal examinations, foot examinations, or urinary microalbumin testing were reported in 6 studies,[23,25-27,31,33] and nephropathy screening in a care bundle was reported in 2 studies.[21,30] One study reported no difference in number of patients with outstanding eye or foot examination and albumin/creatinine ratio tests within 1 month of intervention.[17]

v) *Vaccinations*

Two studies noted improvement in frequency of influenza and pneumococcal vaccination among diabetic patients after intervention.[26,28]

vi) *Up-to-Date Documentation of Cardiovascular Risk Factors*

Documentation of cardiovascular risk markers including blood pressure, lipid profile, or A1c improved in approximately half of the studies. Five of 9 studies demonstrated improvement[26,28,30,31,33] in documentation of lipid profile, while 4 demonstrated no change.[19,22,25,27] Two of 5 studies demonstrated improvement[27,33] in blood pressure documentation, while 3e demonstrated no change.[22,25,26] Five of 10 studies demonstrated improvement in A1c monitoring,[25,26,28,30,33] while 5 demonstrated no change.[17,19,22,27,31] Documentation of other risk factors such as body mass index,[22] smoking history,[22,28] and coronary disease family history[22] and risk score[22,24] showed consistent improvement.

vii) *Medication Prescription*

Four studies assessing medication prescription outcomes demonstrated improvement in prescription of one or more of: angiotensin-converting enzyme inhibitor (ACEI)/angiotensin receptor blocker (ARB), lipid-lowering, oral antihyperglycemic and antiplatelet therapies,[24,26,29,34] while one

RCT demonstrated no difference in ACEI/ARB prescription[17] and one before-and-after study demonstrated possible decrease.[27] Two studies investigating insulin prescription rates demonstrated no change.[26,34]

viii) *Composite Outcomes*

Five studies listed a composite of care markers as an outcome.[21,28,30,32,34] An interrupted time-series study evaluating intervention effect on a composite of process outcomes including medication prescription, documentation of glycemic control, lipid profile, immunization status, and microvascular complication screening reported no significant difference after 20 months of intervention.[32] A before-and-after study demonstrated postintervention improvement in proportion of patients receiving a "bundle" of diabetes best practices (attainment of dyslipidemia, hypertension, and glycemic targets, and documentation of lipid profile, glycemic control, smoking history, and immunization status) from 2.4% to 6.5% ($P < .0001$) over a 12-month period.[28] A retrospective cohort study demonstrated that electronic record integration of decision support was associated with improved frequency of review of glycemic control, medications (including statins), and dietetic and nurse educator inputs (71.3% vs 58.5%, $P = .001$).[34] In one interrupted time series, the introduction of prompts improved frequency of ordering all indicated tests (A1c, LDL, urine microalbumin-to-creatinine ratio) from 29% to 49% ($P < .001$).[30] However, a cluster RCT demonstrated that implementation of clinical decision support resulted in no significant difference in a composite score of hypertension, lipid and glycemic control, or a process composite score incorporating documentation of glycemic, hypertension, and lipid control, microalbuminuria, and appropriate statin, antiplatelet, and ACEI/ARB prescription.[21]

ix) *Physician Compliance to Guideline Recommendation*

All 3 RCTs demonstrated improved physician compliance to guidelines after intervention.[14-16] Prompts for indicated tests (32.0% vs 15.6%, $P = .02$),[15] computerized reminders (19.7% vs 7.6%, $P = .006$),[16] and computer-generated individualized feedback about adherence to care guidelines (35% vs 6.1%, $P < .01$)[14] improved clinician compliance with the guideline recommendations.

C) **Intervention Characteristics**

Improvements in lipid and hypertension control, lipid and glycemic monitoring, and microvascular complication screening, but not documentation of blood pressure, were consistently seen with studies employing a combination of intervention strategies (Table 3). No relationship between type(s) of intervention and change in A1c was identified.

D) **Quality Assessment**

x) *RCT*

Of 9 included RCTs and cluster RCTs, the risk of bias was moderate in 5,[14,15,17,20,21] high in 3,[16,19,22] and low in one trial.[18] RCTs at moderate or high risk of bias lacked description of blinding or concealment, in contrast to one study that reported baseline characteristics and blinding procedures.

xi) *Non-RCT*

Two[26,27] of 12[23-34] non-RCT studies were of moderate quality and the remainder were of weak quality. None of the studies described participant awareness of the research question, consistency of the intervention, or the reliability or validity of data collection tools.

DISCUSSION

Previous reviews examined the effect of specific electronic record intervention strategies on diabetes outcomes. To our knowledge, this is the first systematic review comparing diabetes outcomes of various electronic record intervention strategies.[35,36]

Summary of Findings

In this systematic review of 21 studies, we analyzed clinical and process-related outcomes after various electronic record interventions in diabetic patients.

While clinical outcomes of dyslipidemia and hypertension control consistently improved with electronic record guideline integration, glycemic control improvements did not consistently improve. The A1c is known to be more difficult to positively influence, may require longer intervention periods,[23] and may be less responsive to available therapies in comparison with hypertension and dyslipidemia. Other patient-related factors such as comorbidities, medication access and side effects, lack of time, and nonadherence to lifestyle and medications contribute to unmet A1c targets in other studies.[37]

Process-related outcomes including microvascular complication screening, immunization status, and documentation of body mass index, smoking history, family history, and risk score for coronary disease largely improved with interventions. The effect of interventions on prescription of related medications, and documentation of blood pressure, lipids, or A1c did not consistently improve across studies.

All 3 RCTs[14-16] evaluating physician compliance to guideline recommendations demonstrated improvement in clinical and process outcomes such as hypertension and dyslipidemia optimization, microvascular complication screening, and monitoring of lipids and A1c by using a combination of electronic record interventions. However, there was no consistent relationship between type of electronic record intervention and change in A1c or rate of documentation of blood pressure.

Comparison with Other Studies

A review of 49 studies by Solomon et al[38] evaluating interventions to improve laboratory testing practices found that interventions targeting multiple behavioral factors (including educational materials, audits, consensus building,

targeted behavioral change, and reassessments) trended toward improved outcomes. While not specific to electronic record interventions, this supports the conclusion that studies implementing a combination of intervention strategies were more likely to demonstrate improvement in clinical or process-related outcomes. Thus, simultaneous multifaceted interventions targeting barriers to behavioral change at various levels[39] may be more effective than interventions addressing single barriers to behavioral change.[40]

Electronic record interventions have shown utility in other risk factor mitigation interventions by promoting smoking cessation and human immunodeficiency virus testing. An electronic record smoking cessation protocol identified tobacco users and prompted improved referral to smoking cessation resources.[41] Another electronic record intervention increased human immunodeficiency virus testing among hospitalized patients.[42]

Ali et al[36] reviewed 21 studies exploring process, self-care, or patient-level outcomes after electronic record integration of clinical decision support in patients with diabetes. Improvements in process outcomes ranged from no difference to approximately 30% increases in patients receiving annual A1c, blood pressure, lipid, foot, urine, and eye examinations. Most interventions yielded A1c reductions of 0.3%-0.9% over 1 year and increased proportion of patients attaining A1c targets by up to 20%. Blood pressure improved up to 10/13 mm Hg reduction from baseline, and target attainment increased in up to 22% more participants. LDL reductions up to 15 mg/dL were observed, along with 8%-35% more participants achieving targets. Compared with that review, we included fewer studies analyzing the difference in absolute value and more studies analyzing change in proportion of patients achieving targets. Our study included various intervention strategies and not exclusively clinical decision support. Ali et al[36] noted more consistent associations between clinical decision support intervention and improvements in process outcomes than improved risk-factor optimization. In contrast, we noted clear improvements in dyslipidemia and hypertension optimization with no consistent reductions in A1c, and improvement in process outcomes of microvascular complication screening but not documentation of lipid profile, A1c, or blood pressure. Therefore, we cannot conclude the same as Ali et al,[36] as our results for risk factor control and process-related outcomes were mixed.

Ivers et al[43] found that audit and feedback generally lead to small but important improvements in clinical practice and patient outcomes, with increased effectiveness when baseline performance is low, and when feedback is provided by supervisor or colleague, provided repeatedly, is in verbal and written format, and includes explicit targets and action plan. As baseline performance for each practice may vary, feedback strategies may not demonstrate consistent superiority over other methods, and may cause reminder fatigue, especially if there are no clear suggestions for future actions. This may explain why only one study[14] implemented feedback alone and other studies combined feedback or audit with other interventions, by incorporating next steps and an action plan, as suggested by Ivers et al.[43]

Shojania et al[44] quantified the expected magnitude of improvement in process-related outcomes from computer reminder-based interventions, finding that adherence to target processes-of-care increased by a median of 4.2%, below the clinical significance threshold. There was no difference in effect between automatic reminders ("push") and user-initiated reminders ("pull"). Our qualitative study only analyzed statistical significance and did not assess clinical significance.

Strengths and Limitations

Our study's strengths include the use of PRISMA guidelines for creating thorough systematic reviews.[11] Our robust search strategy included 4 databases coupled with a rigorous data abstraction approach. Pairs of review authors, working independently, extracted data and referred disagreements to a third review author for resolution.

Of the included RCTs, 5 RCTs[14-18] and 4 cluster RCTs[19-22] tested physician compliance to guideline recommendations,[14-16] while only few examined clinical[18,20-22] or process-related outcomes,[17,19,21,22] limiting interpretation of our findings.

Furthermore, several studies relied on the International Classification of Diseases, Ninth Revision coding system or patient registries to identify study populations, potentially missing some patients with diabetes due to variation of diagnostic criteria. The completeness of data within the patient registries is unclear.

The included studies evaluated various electronic record interventions applied in primary care settings and included diabetic patients of diverse backgrounds. Fourteen of the 21 studies were conducted in the United States. Although we cannot be certain, we believe that the results are generalizable to other settings and patient groups.

While all studies included an electronic record intervention as a major component, some implemented non-electronic record components as part of their intervention; such as educational components including educational materials and sessions,[23,24,31,33] pharmacist-led interventions,[29] and changes in office structure.[18,25,31] Thus, we cannot attribute all observed effects directly to electronic record intervention.

There is potential for bias in our review process. Interpretation of results may have been influenced by the heterogeneity of the interventions and outcomes included.[45] Inclusion of only English-language studies may have resulted in publication bias. However, inclusion of randomized trials published in languages other than English in systematic reviews found that language did not bias results of conventional interventions.[46] The diversity of approaches and outcome measures used in these studies made it difficult to pool results, necessitating a qualitative analysis.

CONCLUSION

Guideline integration into electronic medical record software improves clinical and process-related outcomes in patients with diabetes, with greater effect when combining intervention strategies. As evidence from RCTs is limited and there is heterogeneity in strategies and outcome measures, the current evidence cannot support a specific intervention strategy to optimize diabetes care. While no specific intervention was uniformly superior, a combination of interventions that incorporate reminders with guideline-based decision support may support clinicians in providing evidence-based diabetes care. Specifically, clinicians can implement a facilitated quality improvement initiative by conducting a practice audit, identifying care gaps, implementing an electronic record-based intervention to improve outcomes, and repeating the practice audit.[47] Our comprehensive review will inform future interventions, particularly head-to-head comparisons of electronic record-based interventions to identify components contributing to the effectiveness of multifaceted interventions,[48] and metanalyses that will increase statistical power and improve the estimates of the effect sizes of interventions.[49] Ultimately, this review identified benefits in clinical and process-related outcomes from electronic record-based interventions but did not examine cost-effectiveness, necessitating further studies of the economic impact of such interventions.[50]

References

1. Statistics Canada. *Table 13-10-0394-01 Leading causes of death, total population, by age group*. Ottawa, Ontario: Statistics Canada; 2019. Available at https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310039401. Accessed April 1, 2021.
2. Statistics Canada. *Health fact sheets: Diabetes, 2017*. Ottawa, Ontario: Statistics Canada; 2018. Available at https://www150.statcan.gc.ca/n1/pub/82-625-x/2018001/article/54982-eng.htm. Accessed April 1, 2021.
3. Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. *BMJ* 2000;321(7258):405–12.
4. Margolis KL, O'Connor PJ, Morgan TM, et al. Outcomes of combined cardiovascular risk factor management strategies in type 2 diabetes: the ACCORD randomized trial. *Diabetes Care* 2014;37(6):1721–8.
5. Diabetes Canada Clinical Practice Guidelines Expert Committee. Diabetes Canada 2018 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada. *Can J Diabetes* 2018;42(suppl 1)[A1-A15, S1-S325].
6. Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients' care. *Lancet* 2003;362(9391):1225–30.
7. Grol R. Successes and failures in the implementation of evidence-based guidelines for clinical practice. *Med Care* 2001;39(8 suppl 2):II46–54.
8. Khunti K, Ceriello A, Cos X, De Block C. Achievement of guideline targets for blood pressure, lipid, and glycaemic control in type 2 diabetes: a meta-analysis. *Diabetes Res Clin Pract* 2018;137:137–48.
9. Institute of Medicine (US) Committee on Standards for Developing Trustworthy Clinical Practice Guidelines. *Clinical Practice Guidelines We Can Trust*. Washington, DC: National Academies Press; 2011.
10. Garg AX, Adhikari NK, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA* 2005;293(10):1223–38.
11. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339:b2535.
12. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343(x):d5928.
13. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews Evid Based Nurs* 2004;1(3):176–84.
14. Lobach DF. Electronically distributed, computer-generated, individualized feedback enhances the use of a computerized practice guideline. *Proc AMIA Annu Fall Symp* 1996:493–7.
15. Lobach DF, Hammond WE. Development and evaluation of a Computer-Assisted Management Protocol (CAMP): improved compliance with care guidelines for diabetes mellitus. *Proc Annu Symp Comput Appl Med Care* 1994:787–91.
16. Nilasena DS, Lincoln MJ. A computer-generated reminder system improves physician compliance with diabetes preventive care guidelines. *Proc Annu Symp Comput Appl Med Care* 1995:640–5.
17. Schnipper JL, Linder JA, Palchuk MB, et al. Effects of documentation-based decision support on chronic disease management. *Am J Manag Care* 2010;16(12 suppl HIT):SP72–81.
18. Ali MK, Singh K, Kondal D, et al. Effectiveness of a multicomponent quality improvement strategy to improve achievement of diabetes care goals: a randomized, controlled trial. *Ann Intern Med* 2016;165(6):399–408.
19. El-Kareh RE, Gandhi TK, Poon EG, et al. Actionable reminders did not improve performance over passive reminders for overdue tests in the primary care setting. *J Am Med Inform Assoc* 2011;18(2):160–3.
20. 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(1):12–21.
21. Heselmans A, Delvaux N, Laenen A, et al. Computerized clinical decision support system for diabetes in primary care does not improve quality of care: a cluster-randomized controlled trial. *Implement Sci* 2020;15(1):5.
22. Hetlevik I, Holmen J, Krüger O, Kristensen P, Iversen H, Furuseth K. Implementing clinical guidelines in the treatment of diabetes mellitus in general practice. Evaluation of effort, process, and patient outcome related to implementation of a computer-based decision support system. *Int J Technol Assess Health Care* 2000;16(1):210–27.
23. Samoutis GA, Soteriades ES, Stoffers HE, Philalithis A, Delicha EM, Lionis C. A pilot quality improvement intervention in patients with diabetes and hypertension in primary care settings of Cyprus. *Family Pract* 2010;27(3):263–70.
24. Garza L, Dols J, Gillespie M. An initiative to improve primary prevention of cardiovascular disease in adults with type II diabetes based on the ACC/AHA (2013) and ADA (2016) guidelines. *J Am Assoc Nurse Pract* 2017;29(10):606–11.
25. Guzek J, Guzek S, Murphy K, Gallacher P, Lesneski C. Improving diabetes care using a multitiered quality improvement model. *Am J Med Qual* 2009;24(6):505–11.
26. Hunt JS, Siemienczuk J, Gillanders W, et al. The impact of a physician-directed health information technology system on diabetes outcomes in primary care: a pre- and post-implementation study. *Inform Prim Care* 2009;17(3):165–74.
27. O'Reilly DJ, Bowen JM, Sebaldt RJ, et al. Evaluation of a chronic disease management system for the treatment and management of diabetes in primary health care practices in Ontario: an observational study. *Ont Health Technol Assess Ser* 2014;14(3):1–37.
28. Weber V, Bloom F, Pierdon S, Wood C. Employing the electronic health record to improve diabetes care: a multifaceted intervention in an integrated delivery system. *J Gen Intern Med* 2008;23(4):379–82.
29. Ramirez M, Chen K, Follett RW, Mangione CM, Moreno G, Bell DS. Impact of a "chart closure" hard stop alert on prescribing for elevated blood pressures among patients with diabetes: quasi-experimental study. *JMIR Med Inform* 2020;8(4):e16421.

30. Bronner JP, Fontanesi J, Goel A. Improving prompt effectiveness in diabetes care: an intervention study. *Am J Med Qual* 2012;27(5):406–10.
31. Ciemins EL, Coon PJ, Fowles JB, Min SJ. Beyond health information technology: critical factors necessary for effective diabetes disease management. *J Diabetes Sci Technol* 2009;3(3):452–60.
32. Zhou YY, Unitan R, Wang JJ, et al. Improving population care with an integrated electronic panel support tool. *Popul Health Manag* 2011;14 (1):3–9.
33. Goldfracht M, Levin D, Peled O, et al. Twelve-year follow-up of a population-based primary care diabetes program in Israel. *Int J Qual Health Care* 2011;23(5):674–81.
34. Gunathilake W, Gunawardena S, Fernando R, Thomson G, Fernando D. The impact of a decision support tool linked to an electronic medical record on glycemic control in people with type 2 diabetes. *J Diabetes Sci Technol* 2013;7(3):653–9.
35. Cleveringa FG, Gorter KJ, van den Donk M, van Gijsel J, Rutten GE. Computerized decision support systems in primary care for type 2 diabetes patients only improve patients' outcomes when combined with feedback on performance and case management: a systematic review. *Diabetes Technol Ther* 2013;15(2):180–92.
36. Ali MK, Shah S, Tandon N. Review of electronic decision-support tools for diabetes care: a viable option for low- and middle-income countries? *J Diabetes Sci Technol* 2011;5(3):553–70.
37. Leiter LA, Cheng AYY, Ekoé JM, et al. Glycated Hemoglobin Level Goal Achievement in Adults With Type 2 Diabetes in Canada: Still Room for Improvement. *Can J Diabetes* 2019;43(6):384–91.
38. Solomon DH, Hashimoto H, Daltroy L, Liang MH. Techniques to improve physicians' use of diagnostic tests: a new conceptual framework. *JAMA* 1998;280(23):2020–7.
39. Grimshaw JM, Eccles MP, Lavis JN, Hill SJ, Squires JE. Knowledge translation of research findings. *Implement Sci* 2012;7:50.
40. Squires JE, Sullivan K, Eccles MP, Worswick J, Grimshaw JM. Are multifaceted interventions more effective than single-component interventions in changing health-care professionals' behaviours? An overview of systematic reviews. *Implement Sci* 2014;9:152.
41. Karn S, Fernandez A, Grossberg LA, et al. Systematically improving tobacco cessation patient services through electronic medical record integration. *Health Promot Pract* 2016;17(4):482–9.
42. Felsen UR, Cunningham CO, Zingman BS. Increased HIV testing among hospitalized patients who declined testing in the emergency department. *AIDS Care* 2016;28(5):591–7.
43. Ivers N, Jamtvedt G, Flottorp S, et al. Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev* 2012(6):CD000259.
44. Shojania KG, Jennings A, Mayhew A, Ramsay C, Eccles M, Grimshaw J. Effect of point-of-care computer reminders on physician behaviour: a systematic review. *CMAJ* 2010;182(5): E216–25.
45. Chia FS, Kuys S, Low Choy N. Sensory retraining of the leg after stroke: systematic review and meta-analysis. *Clin Rehabil* 2019;33 (6):964–79.
46. Moher D, Pham B, Lawson ML, Klassen TP. The inclusion of reports of randomised trials published in languages other than English in systematic reviews. *Health Technol Assess* 2003;7(41):1–90.
47. Hemler JR, Hall JD, Cholan RA, et al. Practice facilitator strategies for addressing electronic health record data challenges for quality improvement: EvidenceNOW. *J Am Board Fam Med* 2018;31 (3):398–409.
48. Eccles M, Grimshaw J, Campbell M, Ramsay C. Research designs for studies evaluating the effectiveness of change and improvement strategies. *Qual Saf Health Care* 2003;12(1):47–52.
49. Fagard RH, Staessen JA, Thijs L. Advantages and disadvantages of the meta-analysis approach. *J Hypertens Suppl* 1996;14(2):S9–S12 [discussion S13.
50. Reis ZSN, Maia TA, Marcolino MS, Becerra-Posada F, Novillo-Ortiz D, Ribeiro ALP. Is there evidence of cost benefits of electronic medical records, standards, or interoperability in hospital information systems? Overview of systematic reviews. *JMIR Med Inform* 2017;5(e): e26.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjmed.2021.03.004.

Supplementary Table 1 CINAHL Search Strategy

1.	(MH “Computerized Patient Record”)
2.	(MH “Electronic Order Entry”)
3.	(online OR computer* OR digital OR electronic or automated) N3 (record*)
4.	(health*) N2 (information technolog*)
5.	(MH "Reminder Systems")
6.	(MH "Decision Making, Computer Assisted")
7.	(MH “Therapy, Computer Assisted”)
8.	(computer assisted) N2 (protocol* or therap* or decision*)
9.	(computer* or medical) N2 (order entr*)
10.	(MH "Decision Support Systems, Clinical")
11.	(MH "Decision Support Techniques+")
12.	(prompt* OR alert* OR reminder*) N3 (automat* OR computer* OR electronic*)
13.	(prompt* OR alert* OR reminder*) N2 (system* OR support*)
14.	decision N2 support*
15.	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14
16.	(MH “practice guidelines”)
17.	(MH “Guideline Adherence”)
18.	(MH "Medical Practice, Evidence-Based")
19.	(MH "Nursing Practice, Evidence-Based")
20.	guideline*
21.	“best practice*”
22.	(care) N4 (standard OR path* OR map* OR plan* or protocol*)
23.	(evidence based) N2 (care or practice* or management or medicine)
24.	(MH "Consensus")
25.	S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24
26.	(MH “Family Practice”)
27.	(MH “Physicians, Family”)
28.	(MH “Primary Health Care”)
29.	(MH “Community Medicine”)
30.	(MH “Group Practice”)
31.	(MH “Independent Practice Associations”)
32.	(MH “Joint Practice”)
33.	(MH “Nurse Practitioners”)
34.	(MH “Family Nurse Practitioners”)
35.	(MH “Ambulatory Care Facilities”)
36.	(MH “Ambulatory Care”)
37.	(MH “Office Visits”)
38.	(MH “Community Health Services+”)
39.	(general OR community OR family OR primary or ambulatory) N2 (practi* OR physician* OR provider OR medicine OR doctor* OR care OR healthcare OR team OR clinic* OR office)
40.	“health care practitioner*”
41.	“nurse practitioner*”
42.	outpatient*
43.	“urgent care*”
44.	(clinic or office) N1 (visit*)
45.	(free-standing) N1 (facility* OR clinic* OR cent*)
46.	S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45
47.	S15 AND S25 AND S46
48.	PT commentary OR Letter OR editorial
49.	S47 NOT S48

Supplementary Table 2 Characteristics of the Included Studies

Primary Author and Year	Intervention	Study Type	Number of Participants	Country	Global Quality or Risk of Bias Rating
Ali 2016[18]	Combination	RCT	1146	India and Pakistan	Low risk of bias
Bronner 2012[30]	Reminders/prompts	Interrupted time series	3730	USA	Weak quality
Ciemins 2009[31]	Combination	Interrupted time series	495	USA	Weak quality
El-Kareh 2011[19]	Reminders/prompts	Cluster RCT	Unknown	USA	High risk of bias
Garza 2017[24]	Reminders/prompts	Before-and-after study	90	USA	Weak quality
Goldfracht 2011[33]	Combination	Retrospective cross-sectional study	4,629,300	Israel	Weak quality
Gunathilake 2013[34]	Combinaton	Retrospective cohort study	875	Sri Lanka	Weak quality
Guzek 2009[25]	Combination	Before-and-after study	1592	USA	Weak Quality
Heselmans 2020[21]	CDSS	Cluster RCT	3815	Belgium	Moderate risk of bias
Hetlevik 2000[22]	CDSS	Cluster RCT	1034	Norway	High risk of bias
Hunt 2009[26]	Combination	Before-and-after study	7456	USA	Moderate quality
Lobach 1994[15]	Reminders/prompts	RCT	58	USA	Moderate risk of bias
Lobach 1996[14]	Feedback	RCT	45	USA	Moderate risk of bias
Nilasena 1995[16]	Reminders/prompts	RCT	35	USA	High risk of bias
O'Connor 2011[20]	CDSS	Cluster RCT	2556	USA	Moderate risk of bias
O'Reilly 2014[27]	Combination	Before-and-after study	2368	Canada	Moderate quality
Ramirez 2020[29]	Reminders/prompts	Before-and-after study	1163	USA	Weak quality
Samoutis 2010[23]	Combination	Nonrandomized controlled trial	504	Cyprus	Weak quality
Schnipper 2010[17]	CDSS	RCT	7009	USA	Moderate risk of bias
Weber 2008[28]	Combination	Before-and-after study	19,494	USA	Weak quality
Zhou 2011[32]	Combination	Interrupted time series	263,509	USA	Weak quality

CDSS = Clinical Decision Support System; RCT = randomized controlled trial.

Supplementary Table 3 Clinical Outcomes Described by the Studies Included in Our Review

Outcome	Specific Outcome	Studies that Demonstrated Positive Change	Studies that Demonstrated No Change
Lipid control	Proportion of patients achieving LDL target	25,28,31,33	
	Absolute change in LDL or TC	23	21,30
	Absolute change in TC:HDL ratio	27	
	Both the percentage of patients achieving LDL target and change in absolute value	18,26	20
Blood pressure control	Proportion of patients achieving systolic BP <130 mm HG, diastolic BP <80 or both	20,25,28,31	
	Absolute change in BP values	22,23,27	20,21
	Both the percentage of patients achieving BP target and change in absolute values	18,26	
Glycemic control	Proportion of patients achieving target A1c	28,31,33,34	20,25
	Both the proportion of patients achieving target A1c and change in absolute value of A1c	18	26
	Change in the absolute value of A1c	20	21-23,27,30

BP = blood pressure; LDL = low-density lipoprotein; TC = total cholesterol.

Supplementary Table 4 Studies that Noted a Positive Change in Lipid Profile

Study	Outcome	Preintervention/ Control	Postintervention	*P* Value
Ali 2016[18]	Proportion of patients with LDL <100 mg/dL (or <70 mg/dL for those with previous cardiovascular disease)	47.1%	56.4%	< .001
	Mean LDL	122.4 mg/dL	114.5 mg/dL	Not provided (95% CI, −10.90 to −4.81)
Ciemins 2009[31]	Proportion of patients with LDL <100 mg/dL	33.1%	56.6%	< .0001
Goldfracht 2011[33]	Proportion of patients with LDL ≤100 mg/dL	26.4%	59.1%	< .0001
Guzek 2009[25]	Proportion of patients with LDL <100 mg/dL	61.3%	65.2%	.036
Hunt 2009[26]	Proportion of patients with LDL <100 mg/dL	32%	56%	.002
	Mean LDL	106 mg/dL	93 mg/dL	.002
O'Reilly 2014[27]	TC:HDL ratio	3.81	3.66	.001
Samoutis 2010[23]	Mean TC	5.85 mmol/L	5.33 mmol/L	< .0001
	Mean LDL	3.64 mmol/L	3.28 mmol/L	.0022
Weber 2008[28]	Proportion of patients with LDL ≤100 mg/dL	Improvement but percentages not specified		< .001

CI = confidence interval; LDL = low-density lipoprotein; TC = total cholesterol.

Supplementary Table 5 Studies that Noted a Positive Change in Blood Pressure Control

Study	Outcome	Preintervention/ Control	Postintervention	*P* Value
Ali 2016[18]	Proportion of patients with systolic pressure <130 mm Hg	45.0%	51.0%	0.010
	Mean systolic pressure	143.3 mm Hg	139.3 mm Hg	Not provided (95% CI, −5.85 to −2.22)
	Mean diastolic pressure	81.7 mm Hg	79.7 mm Hg	Not provided (95% CI, −3.00 to −1.05)
Ciemins 2009[31]	Proportion of patients with BP <130/80 mm Hg	26.9%	43.9%	< .0001
Guzek 2009[25]	Proportion of patients with BP <130/80 mm Hg	40.9%	49.4%	.03
Hetlevik 2000[22]	Mean diastolic pressure	85.3 mm Hg	82.8 mm Hg	Not provided
Hunt 2009[26]	Proportion of patients with BP <130/80 mm Hg	30%	52%	.002
	Mean systolic pressure	133 mm Hg	128 mm Hg	.002
	Mean diastolic pressure	75 mm Hg	72 mm Hg	.002
O'Connor 2011[20]	Proportion of patients with systolic BP <130 mm Hg	75.1%	80.2%	.03
	Proportion of patients diastolic BP <80 mm Hg	81.7%	85.6%	.07
	Mean systolic pressure	131.5 mm Hg	130.5 mm Hg	.56
	Mean diastolic pressure	77.1 mm Hg	76.8 mm Hg	.38
O'Reilly 2014[27]	Mean diastolic pressure	76.5 mm Hg	75.3 mm Hg	.042
Samoutis 2010[23]	Mean systolic pressure	137.1 mm Hg	133.6 mm Hg	.0022
	Mean diastolic pressure	80.3 mm Hg	77.9 mm Hg	.0001
Weber 2008[28]	Proportion of patients with BP <130/80 mm Hg	39.7%	43.9%	< .0001

BP = blood pressure; CI = confidence interval.

Supplementary Table 6 Studies that Noted a Positive Change in Glycemic Control

Study	Outcome	Preintervention/ Control	Postintervention	*P* Value
Ali 2016[18]	Proportion of patients with A1c <7	11.1%	21.5%	< .001
	Mean A1c	9.9%	9.4%	Not provided (95% CI, −0.69 to −0.32)
Ciemins 2009[31]	Proportion of patients with A1c <7	48.5%	66.8%	< .0001
Goldfracht 2011[33]	Proportion of patients with A1c ≤7%	10.0%	52.73%	< .0001
	Proportion of patients with A1c >9%	40.0%	13.0%	< .0001
Gunathilake 2013[34]	Proportion of patients with A1c <7.5	78.2%	92.1%	.0001
O'Connor 2011[20]	Mean A1c	8.1%	7.9%	.01
Weber 2008[28]	Proportion of patients with A1c <7	32.2%	34.8%	< .001

CI = confidence interval.

Supplementary Table 7 Studies that Noted a Positive Change in Recommended Screening for Retinopathy, Nephropathy, or Peripheral Neuropathy

Study	Outcome	Preintervention/ Control	Postintervention	*P* Value
Bronner 2012[30]	Composite rate of ordering the following tests: A1c, LDL and urine microalbumin-to-creatinine ratio	29%	49%	< .001
Ciemins 2009[31]	Percentage of patients with microalbuminuria testing	38.5%	71.0%	< .0001
	Percentage of patients with retinal examination	26.2%	58.0%	< .0001
	Percentage of patients with foot examination	23.4%	66.9%	< .0001
Goldfracht 2011[33]	Percentage of patients with microalbuminuria testing	67.6%	68.9%	< .001
Guzek 2009[25]	Percentage of patients with microalbuminuria testing	45.6%	66.8%,	.006
	Percentage of patients with retinal examination	43.3%	55.8%	.04
	Percentage of patients with foot examination	50.8%	85.4%	< .001
Hunt 2009[26]	Percentage of patients with retinal examination	39%	59%	.002
	Percentage of patients with foot examination	26%	79%	.002
Samoutis 2010[23]	Percentage of patients with microalbuminuria testing	0%	37%	Not provided
	Percentage of patients with retinal examination	0%	59%	Not provided
	Percentage of patients with foot examination	0%	73%	Not provided

LDL = low-density lipoprotein.