



Published in final edited form as:

Am J Prev Med. 2015 November ; 49(5): 784–795. doi:10.1016/j.amepre.2015.04.006.

Clinical Decision Support Systems and Prevention:

A Community Guide Cardiovascular Disease Systematic Review

Gibril J. Njie, MPH¹, Krista K. Proia, MPH¹, Anilkrishna B. Thota, MBBS, MPH¹, Ramona K.C. Finnie, DrPH, MPH¹, David P. Hopkins, MD, MPH¹, Starr M. Banks, MPH¹, David B. Callahan, MD², Nicolaas P. Pronk, PhD, MA³, Kimberly J. Rask, MD, PhD⁴, Daniel T. Lackland, DrPH⁵, and Thomas E. Kottke, MD³ the Community Preventive Services Task Force

¹Community Guide Branch, Division of Public Health Information Dissemination, Center for Surveillance, Epidemiology, and Laboratory Services, CDC, Atlanta, Georgia

²Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, CDC, Atlanta, Georgia

³HealthPartners, Minneapolis, Minnesota

⁴Georgia Medical Care Foundation, Emory University, Atlanta, Georgia

⁵Department of Neurosciences, Medical University of South Carolina, Charleston, South Carolina

Abstract

Context—Clinical decision support systems (CDSSs) can help clinicians assess cardiovascular disease (CVD) risk and manage CVD risk factors by providing tailored assessments and treatment recommendations based on individual patient data. The goal of this systematic review was to examine the effectiveness of CDSSs in improving screening for CVD risk factors, practices for CVD-related preventive care services such as clinical tests and prescribed treatments, and management of CVD risk factors.

Evidence acquisition—An existing systematic review (search period, January 1975–January 2011) of CDSSs for any condition was initially identified. Studies of CDSSs that focused on CVD prevention in that review were combined with studies identified through an updated search (January 2011–October 2012). Data analysis was conducted in 2013.

Evidence synthesis—A total of 45 studies qualified for inclusion in the review. Improvements were seen for recommended screening and other preventive care services completed by clinicians, recommended clinical tests completed by clinicians, and recommended treatments prescribed by clinicians (median increases of 3.8, 4.0, and 2.0 percentage points, respectively). Results were inconsistent for changes in CVD risk factors such as systolic and diastolic blood pressure, total and low-density lipoprotein cholesterol, and hemoglobin A1C levels.

Address correspondence to: David P. Hopkins MD, MPH, Community Guide Branch, Division of Epidemiology, Analysis, and Library Services, Center for Surveillance, Epidemiology, and Laboratory Services, CDC, 1600 Clifton Road, Mailstop E-69, Atlanta GA 30329. dhh4@cdc.gov.

Names and affiliations of Task Force members can be found at: www.thecommunityguide.org/about/task-force-members.html.

Author affiliations are shown at the time the research was conducted.

Conclusions—CDSSs are effective in improving clinician practices related to screening and other preventive care services, clinical tests, and treatments. However, more evidence is needed from implementation of CDSSs within the broad context of comprehensive service delivery aimed at reducing CVD risk and CVD-related morbidity and mortality.

Context

Cardiovascular disease (CVD) is the leading cause of death among U.S. adults (approximately 800,000 deaths annually).¹ Modifiable risk factors for CVD such as hypertension, hyperlipidemia, diabetes, smoking, obesity, and physical inactivity can be improved with provider-focused strategies such as provider reminders, audit and feedback mechanisms, and educating providers on guidelines.² Implementation of such strategies could help mitigate the burden of CVD risk factors and advance progress toward achieving objectives outlined in *Healthy People 2020*³ and Million Hearts[®].⁴

The U.S. Preventive Services Task Force (USPSTF)⁵ and other clinical practice guideline panels^{6–8} provide evidence-based recommendations for CVD risk factor screening; practices for CVD-related preventive care services (e.g., counseling for diet and physical activity); and management of patients with CVD risk factors. However, barriers such as lack of resources; “clinical inertia” (i.e., clinician failure to initiate or intensify therapy when indicated⁹); and lack of familiarity with guideline availability impede CVD prevention.^{10,11} Clinical decision support systems (CDSSs) could play a role in reducing some of these barriers by helping clinicians assess CVD risk and prompting appropriate actions to manage risk factors.

CDSSs are computer-based information systems designed to assist clinicians in implementing clinical guidelines and evidence-based practices at the point of care. CDSSs provide tailored patient assessments and treatment recommendations for clinicians to consider on the basis of individual patient data. Patient information is entered manually or automatically through an electronic health record (EHR) system. CDSSs are often incorporated within EHRs and integrated with other computer-based functions that offer patient care summary reports, feedback on quality indicators, and benchmarking.

CDSSs aimed at preventing CVD include one or more of the following:

- tailored reminders to screen for CVD risk factors and CVD-related preventive care, clinical tests, and treatments;
- assessments of patients’ risk for developing CVD based on their history, risk factors, and clinical test results;
- recommendations for evidence-based treatments to prevent CVD, including intensification of existing treatment regimens;
- recommendations for health behavior changes to discuss with patients, such as quitting smoking, increasing physical activity, and reducing excessive salt intake; and
- alerts when indicators for CVD risk factors are not at goal.

A recent systematic review by Bright and colleagues¹² evaluated the effects of CDSSs on quality of care measures (i.e., clinician practices) and clinical outcomes related to morbidity and mortality for numerous conditions (e.g., cancer screening, immunization, CVD prevention). They analyzed 148 RCTs of CDSSs implemented in clinical settings to aid decision making and found that CDSSs improved healthcare process measures related to performing preventive care services, ordering clinical tests, and prescribing treatments; however, the review found sparse evidence on the effectiveness of CDSSs on clinical outcomes.

The subset of studies from the review of Bright et al.¹² that focused on CVD prevention was of specific interest for this Community Guide systematic review, which focused on the potential role of CDSSs in CVD prevention. This review examined the most up-to-date evidence on effectiveness of CDSSs in improving screening for CVD risk factors; clinician practices for CVD-related preventive care services, clinical tests, and treatments; and improvements in CVD risk factors. This review also assessed the applicability of findings for various U.S. populations and settings, as well as considerations for CDSS implementation.

Evidence Acquisition

Detailed systematic review methods used for The Community Guide have been published previously.^{13,14} For this review, a coordination team was formed, composed of CVD subject matter experts from various agencies, organizations, and academic institutions, together with systematic review methodologists from the Community Guide Branch at CDC. The team worked under the oversight of the independent, unpaid, nonfederal Community Preventive Services Task Force.

Conceptual Approach and Analytic Framework

The coordination team's conceptual approach to evaluate CDSSs for CVD prevention is depicted in Appendix Figure 1 (available online). CDSSs assist clinicians by providing recommendations for screenings, preventive care services, and treatments, thereby increasing clinician practices such as those recommended by the USPSTF (e.g., screening for high blood pressure and diabetes, smoking-cessation counseling, and use of aspirin).⁵ Increased uptake of these practices should increase both the number of patients identified with CVD risk factors and clinician knowledge about risk, leading to an increase in appropriate clinical tests ordered and treatments prescribed by clinicians for management of these risk factors in concordance with evidence-based guidelines. Improvements in clinician practices should lead to improved outcomes for hypertension, hyperlipidemia, and diabetes, as well as improved health behaviors and patient satisfaction with care, ultimately leading to reduced morbidity and mortality from CVD and improved health-related quality of life.

Search for Evidence

Existing systematic review—The search for evidence first involved locating existing systematic reviews on this topic. The review of Bright and colleagues,¹² accompanied by an Agency for Healthcare Research and Quality (AHRQ) report,¹⁵ employed methods

comparable to Community Guide standards.^{13,14} Further, conceptualization of that review was closely aligned with the Community Guide team's approach. The review identified studies evaluating CDSSs published from January 1975 to January 2011.

Because Bright et al.¹² and AHRQ¹⁵ examined CDSSs across all health topics, the coordination team considered that evidence a comprehensive source of studies on effectiveness of CDSSs aimed at CVD prevention. Therefore, studies from Bright and colleagues/AHRQ were screened by two Community Guide reviewers independently to identify CDSS studies focused on CVD prevention for inclusion in this review.

Update search—To ensure this review used the most current evidence, an update search was conducted in October 2012 using the Bright et al.¹²/AHRQ¹⁵ search strategy, along with key CVD terms found at www.thecommunityguide.org/cvd/supportingmaterials/SS-CDSS-2013.html.

Inclusion Criteria for Cardiovascular Disease Prevention Studies

In addition to meeting the definition for CDSSs as stated in the reviews of Bright and colleagues¹² and AHRQ,¹⁵ studies evaluating CDSSs for CVD prevention were included in this Community Guide review if they

- were conducted in a high-income country¹⁶;
- reported at least one primary outcome of interest relevant to identification and management of CVD risk factors;
- were focused on study populations in which the majority (> 50%) did not have a history of CVD (e.g., myocardial infarction, stroke); and
- employed a study design that compared a group receiving CDSS with a usual care group or used an interrupted time series design with at least two measurements before and after CDSS implementation. *Usual care* is described here as interventions that did not include any new intervention activities (other than minimal activities such as providing brochures or pamphlets). Usual care was whatever routine care was offered at a given primary care site. It is probable that usual care varied across different health systems and settings.

Data Abstraction and Quality Assessment

Each study that met inclusion criteria was abstracted by two reviewers independently. Abstraction was based on a standardized abstraction form (www.thecommunityguide.org/methods/abstractionform.pdf) that included information on study quality, intervention components, participant demographics, and outcomes. Disagreements between reviewers were resolved by team consensus.

Bright et al.¹² used AHRQ methods¹⁷ to assess threats to validity for included studies. Their quality scoring was applied to the subset of CDSS studies focused on CVD prevention¹²; similar Community Guide quality scoring methods^{13,14} were used for studies identified in the update. Threats to validity—such as poor descriptions of the intervention, population,

sampling frame, and inclusion/exclusion criteria; poor measurement of exposure or outcome; poor reporting of analytic methods; incomplete data sets; loss to follow-up; or intervention and comparison groups not being comparable at baseline—were used to characterize studies as having good, fair, or limited/poor quality of execution. Studies with limited/poor quality of execution were excluded from analysis.

Primary Outcomes of Interest

Primary outcomes included quality of care outcomes and outcomes related to CVD risk factor management (Appendix Table 1, available online).^{18–23} Quality of care outcomes measured evidence-based clinician practices as determined by the USPSTF for screening⁵ and clinical guidelines for management of CVD risk factors.^{6–8} These practices were categorized as screening and other preventive care services, clinical tests, and prescribed treatments prompted by the CDSS and ordered or completed by the clinician.

Secondary Outcomes

Although CDSSs focused principally on improving clinician practices, distal outcomes focused on improving patient health behavior associated with CVD risk were also reported. Specifically, changes in smoking behavior, diet, physical activity, BMI, and medication adherence were analyzed.

Analysis

Because the focus of this review was on CVD prevention and included RCT and non-RCT study designs, a meta-analysis was not conducted—unlike Bright and colleagues,¹² who conducted a meta-analysis from RCT data on all quality of care outcomes. Therefore, descriptive statistics that facilitated simple and concise summaries of study result distribution were used for primary and secondary outcomes.

For each study, absolute percentage point (pct pt) changes were calculated for dichotomous variables for groups receiving clinical decision support compared with usual care. Difference in differences of the mean were calculated for continuous variables for groups receiving clinical decision support compared with usual care (Appendix Table 2, available online).

For the overall summary measure, the median of effect estimates from individual studies and the interquartile interval (IQI) were reported for each primary outcome. Conclusions on the strength of evidence on effectiveness are based on the subset of CVD prevention studies identified from Bright et al.¹² and those identified through the update search, taking into account the number of studies, quality of available evidence, consistency of results, and magnitude of effect estimates, per Community Guide standards.

Study and population characteristics, and effect modifiers described previously, were summarized using descriptive statistics.

Evidence Synthesis

Search Yield

The search process from both the Bright and colleagues^{12/AHRQ¹⁵} reviews and the updated search is shown in Appendix Figure 2 (available online). Bright et al. identified a total of 323 studies examining CDSSs across all health topics. Following screening by two independent Community Guide reviewers, a total of 57 articles^{24–80} representing 50 unique studies of CDSSs for CVD prevention were identified. Of these, 46 studies^{24–68,80} met inclusion criteria; however, seven studies^{35,40,49,57,59,62,64} judged to be of limited quality of execution were excluded from analysis. The update search (January 2011 through October 2012) identified 14 articles representing 13 unique studies.^{81–94} Of these, seven studies^{81–87} met the inclusion criteria; however, one study⁸⁶ was judged to be of limited quality and therefore excluded from analysis. From the combined searches, a total of 45 studies^{24–34,36–39,41–48,50–56,58,60,61,63,65–68,80–85,87} qualified for analysis in this review. Analyses were conducted in 2013.

Study and Intervention Characteristics

Twenty-six studies were from the U.S.,^{24,25,28,29,31,34,36,39,44,45,47,51–54,56,58,63,65,67,80–82,84,85,87} with the remaining studies conducted in Canada (five studies)^{41,48,61,66,83}; Europe (11 studies)^{26,27,30,33,37,38,42,46,50,67,68}; Australia (two studies)^{32,60}; and New Zealand (one study).⁴³ Most studies implemented CDSSs in outpatient practices; two studies^{54,55} were in a hospital setting. Nineteen studies^{25,34,36,39,44,46–48,51,53–55,58,60,61,63,82,84,87} were conducted in practices with an academic affiliation, and three studies^{25,28,80} took place in Veterans Affairs facilities. Studies focused on screening for CVD risk factors (six studies)^{36,42,43,48,66,67}; hypertension management (seven studies)^{25,33,37,39,50,51,63}; lipid management (six studies)^{24,27,33,68,81,84}; and diabetes management or CVD prevention among a diabetic population (15 studies).^{26,29,30,38,41,44,45,47,52,58,60,65,82,85,87} Further, 11 studies^{28,31,32,34,46,53–56,61,80} addressed other disease areas in addition to CVD prevention. Quality limitations assigned to studies were usually attributable to differences in patient demographics between intervention and comparison groups at baseline, possible contamination, and incomplete descriptions of study populations, interventions, and methodology.

CDSS interventions were usually implemented across multiple healthcare sites (median, 7.0 intervention practices per study; IQI=1, 17.5). Median duration of intervention was 12 months (IQI=6, 18.5) and the median number of included clinicians was 24 (IQI=13, 68), with a median of 1,190 total patients (IQI=588, 3545) per study. CDSS users were usually physicians (39 studies),^{24–26,28,29,31,33,34,36–39,41,43–48,50–56,58,61,63,65–68,81–85,87} followed by nurses (12 studies)^{24–26,29,36,41,45,47,50,61,63,84}; physician assistants (five studies)^{24,25,31,36,45}; and pharmacists (two studies).^{51,60} Most interventions used locally developed CDSSs (24 studies),^{24,25,27,28,31,37–39,44–48,51,54,55,58,61,63,65,66,83,85,87} and were integrated within EHRs (29 studies).^{24,28–30,32–34,37–39,42,43,46,50–52,54–56,63,66–68,80,82–85,87} Decision support was usually delivered to the clinician synchronously during patient visits (38 studies),^{24–28,30,33,34,36–39,41–44,46,48,51–56,58,60,61,65–68,80–85,87} and CDSS

recommendations were usually system-initiated when delivered automatically without a clinician request (37 studies).^{25–34,36,39,42,44–48,51–54,56,58,60,61,63,65–68,80–85} Most CDSSs were tailored to provide support for chronic disease management (24 studies)^{24–29,37–39,41,44,45,51,52,58,63,65,80–85,87}; pharmacotherapy (17 studies)^{30,33,46,47,50,52,55,58,60,63,65,66,81,82,84,85,87}; preventive care (15 studies)^{28,31–34,36,42–44,53,54,61,67,68,80}; and lab test ordering (13 studies).^{26,34,36,44,47,52,53,55,82–85,87} Detailed evidence tables are available at www.thecommunityguide.org/cvd/supportingmaterials/SET-CDSS-2013.pdf.

Population Characteristics

Median age of patients was 60.3 years, and slightly more women than men were included (Table 1). From studies that reported race/ethnicity, the median for the proportion of study populations identifying as white was 58.5% (14 studies)^{24–26,29,36,39,45,48,53–55,81,85,87} and 47.5% for participants identifying as black (nine studies).^{24,25,29,39,51,53,58,81,87} Few studies reported income level,⁴⁵ education attainment,^{31,41,45,51,83} or insurance status.^{31,36,39,53,83,87}

Quality of Care Outcomes

Completed or ordered screening and other preventive care services—Figure 1 displays individual effect estimates (with 95% CIs) for absolute change in guideline-based screening and other preventive care services completed or ordered by clinicians from 17 studies^{24,28,32,33,36,43,48,53,54,61,67,80–83,87,92} comparing CDSSs with usual care. Studies are shown according to the type of completed or ordered screening or preventive care service. The y-axis lists the study author, year of publication, and comparison group values at last follow-up. Effect estimates to the right of zero indicate increases in guideline-based screenings and preventive care services completed or ordered by clinicians when prompted by CDSSs, compared with usual care. There was an overall median increase of 3.8 percentage points (pct pts) (IQI= −0.08, +10.6) from 17 studies with 32 outcome measures. Most outcome measures in the favorable direction were statistically significant ($p < 0.05$).^{28,43,48,53,61,67,82,92} Additionally, five studies^{41,44,60,68,83} that could not be plotted because of differences in reported outcome measures demonstrated substantial improvements in guideline-based screening and preventive care services.

Ordered or completed clinical tests—Figure 2 shows individual effect estimates from seven studies reporting the proportion of guideline-based clinical tests completed or ordered by clinicians. Studies are displayed by the type of clinical test ordered or completed for patients diagnosed with hypertension, hyperlipidemia, or diabetes. Effect estimates to the right of zero favor an increase in guideline-based clinical tests completed or ordered by clinicians when prompted by CDSSs. Seven studies^{47,52,56,73,82,85,87} with 19 outcome measures reported a median increase of 4.0 pct pts (IQI=0.7, 7.0) in the proportion of guideline-based clinical tests completed or ordered by clinicians when prompted by CDSSs, compared with usual care. Most reported outcome measures were statistically significant ($p < 0.05$).^{47,52,73,82,85,87} Two additional studies^{29,83} that could not be included in the analysis demonstrated a substantial increase in guideline-based completed or ordered clinical tests.

Prescribed or ordered treatments—Figure 3 displays individual effect estimates of included studies reporting the proportion of guideline-based treatments prescribed or ordered by clinicians when prompted by CDSSs, compared with usual care. Effect estimates are displayed by type of prescribed or ordered treatment medication. In 11 studies^{24,30,33,39,47,51,54,63,66,82,87} with 20 outcome measures, the overall median increase was 2.0 pct pts (IQR= -0.75, +8.55). Most reported individual outcome measures were statistically significant ($p<0.05$).^{30,33,39,47,66,82,87} Additionally, six studies^{27,46,50,58,65,68} with 11 study arms, not plotted because of differences in the way outcomes were analyzed, showed mixed results for this outcome; five study arms reported favorable results, five study arms reported unfavorable results, and one study arm reported no change in treatments prescribed by providers.

Cardiovascular Disease Risk Factor Outcomes

Appendix Table 3 (available online) displays results for CVD risk factors, specifically blood pressure, lipid, and diabetes outcomes. Findings were inconsistent in 15 studies^{25,33,38,39,41,45,50,51,58,63,65,71,82,83,85} reporting blood pressure outcomes, 13 studies^{27,33,38,41,45,58,65,71,81–83,85,92} reporting lipid outcomes, and 12 studies^{29,38,41,45,52,58,65,82–85,92} reporting diabetes outcomes.

Morbidity, Mortality, and Patient-Centered Outcomes

For morbidity, five studies reported no significant changes for outcomes related to emergency department visits,⁵¹ hospitalizations,^{45,63} and CVD events.^{42,83} One study⁶³ with two intervention study arms reported on mortality and found that the group in which providers received education on hypertension guidelines plus CDSS alerts had lower mortality (by 1.90 pct pts) compared with provider education alone. The second intervention study arm, in which providers received education on guidelines plus CDSS alerts, and patients received educational material on hypertension self-management, reduced mortality by 1.60 pct pts.

For patient-centered outcomes, one study reported health-related quality of life. Murray et al.⁵¹ found that patients treated by physicians who received evidence-based treatment recommendations via CDSSs for hypertension generally had better health-related quality of life as measured by the Short Form–36 subscales⁹⁵ compared with patients managed by pharmacists receiving these hypertension reminders or usual care ($p>0.05$). However, no clinically relevant differences were found for quality of life assessments using the Bulpitt and Fletcher subscales.⁹⁶

Health Behavior Change Outcomes

Six studies^{26,38,41,65,82,83} reported changes in smoking status among patients. The proportion of non-smokers in the CDSS intervention arms increased by a median of 2.3 pct pts (IQR=0.1, 3.4) compared with usual care. Another five studies^{37,38,41,45,83} reported minimal changes in BMI (median reduction, -0.10). Few studies reported changes in physical activity,^{41,45,83} diet,^{45,83} and medication adherence,⁶³ and summary measures were not calculated.

Clinical Decision Support Systems Combined With Other Interventions

A small proportion of studies examined CDSSs in combination with other interventions to provide a multicomponent approach to overcome barriers at the patient, provider, or organizational level. Five studies^{29,39,51,52,83} examined CDSSs implemented with team-based care, an organizational, systems-level intervention where primary care providers and patients work together with other providers, primarily pharmacists and nurses, to improve the efficiency of healthcare delivery and self-management support for patients. Two studies^{41,53} implemented CDSSs along with generic patient reminders. For screening and preventive care services and clinical testing, these multicomponent studies found larger increases compared with the overall effect estimates for CDSSs, but for prescribed treatments, their effect estimates were similar to the overall estimate for CDSSs (Appendix Table 4, available online).

Applicability of Findings

Findings from this review are applicable to the U.S. healthcare system, especially among large outpatient primary care settings. Most CDSSs in the included studies were developed locally by healthcare systems in concert with providers. CDSSs were added to preexisting EHRs in approximately one third of studies. In most studies, CDSSs were designed to offer recommendations to providers without user requests for information, and most were designed to deliver decision support as part of clinical workflow. Few studies reported whether providers were required to respond to CDSS recommendations.

Information on race/ethnicity was reported only in one third of studies, and data on SES were limited. In most study populations, patients had one diagnosed risk factor among diabetes, hypertension, and hyperlipidemia. However, findings are likely applicable to diverse population groups with comorbid CVD risk factors.

Additional Benefits and Potential Harms

CDSSs can serve as tools to enhance the effectiveness of organizational, system-level interventions such as team-based care and the patient-centered medical home. No harms to patients from CDSSs were identified in studies in the review or in the broader literature.

Conclusion

Summary of Findings

Based on Community Guide rules of evidence,¹³ there is sufficient evidence that CDSSs are effective in improving screening for CVD risk factors and clinician practices for CVD-related preventive care services, clinical tests, and treatments. In general, studies that combined CDSSs with other interventions found larger improvements. Findings for CVD risk factor outcomes are inconsistent, and meaningful conclusions cannot be drawn. Few studies reported on health behavior change, morbidity, mortality, health-related quality of life, and patient satisfaction with care; therefore, conclusions could not be reached. Economic information on CDSS implementation was sparse.⁹⁷

Limitations

Although Bright and colleagues¹² conducted a formal meta-analysis, this was not considered for the present review primarily because of heterogeneity in study designs. Bright et al. only analyzed data from RCTs, whereas this review took a more inclusive approach and analyzed data from RCTs and quasi-experimental and observational study designs. Hence, descriptive statistics were used to summarize findings for this review, as well as applicability and generalizability of results to various U.S. populations and settings. Second, visual inspection of funnel plots investigating the relationship between effect size and sample size suggest potential publication bias for quality of care outcomes; this may be due to CDSS studies that resulted in positive outcomes having a greater likelihood of being published. Finally, a subgroup analysis based on effect modifiers was not conducted because of substantial heterogeneity with the factors and features incorporated within each CDSS; delivery formats of the systems; and focus of the CDSS (e.g., disease management, pharmacotherapy, preventive care).

Evidence Gaps

Overall, most studies did not collect data on the impact of CDSSs on CVD risk factor outcomes, morbidity, or mortality. Most available evidence is from studies on the effectiveness of CDSSs when implemented alone in the healthcare system rather than as part of a coordinated service delivery. Thus, more evidence is needed about implementation of a CDSS as one part of a comprehensive service delivery system designed to improve outcomes for CVD risk factors and to reduce CVD.

Evidence is also needed on longer-term evaluations of CDSSs. These evaluations might account for issues associated with the initial integration of CDSSs with care workflow. More studies are needed to assess the effectiveness of CDSSs for other providers, such as nurses and pharmacists. Additional assessments on the impact of CDSSs in reducing health disparities and improving patient satisfaction with care are needed.

Discussion

This Community Guide systematic review examined the effectiveness of CDSSs to prevent CVD and provided the basis for the Community Preventive Services Task Force recommendation on use of CDSSs to improve quality of care outcomes for clinician practices related to CVD prevention.⁹⁸ Findings from this review are consistent with those found in the review of Bright and colleagues,¹² which examined the effect of CDSSs on multiple disease conditions. Another review by Souza et al.⁹⁹ also found CDSSs to be effective for improving CVD-specific quality of care outcomes; moreover, a CDSS review by Montgomery and colleagues¹⁰⁰ found a favorable effect on quality of care for hypertension management. More recently, a systematic review that focused on “meaningful use” regulations, by Jones et al.,¹⁰¹ found robust evidence supporting the broad use of CDSSs; however, information on implementation was sparse.

Healthcare systems are shifting to comprehensive, interoperable, point of care-based computer systems that provide patient-specific decisions instantaneously. Also, with patients demanding instant access to their medical records, and healthcare systems seeking new ways

to improve productivity, efficiency, safety, and cost savings, health information technology and CDSSs represent a shift in how providers and patients will interact moving forward. Although CDSSs are tools that aid clinicians in adhering to guidelines, more research is needed on their impact on patient outcomes. This review suggests that current CDSSs hold promise to improve quality of care outcomes but could be supplemented with more-intensive health system–level interventions—such as team-based care and provider performance feedback mechanisms—to reduce CVD risk.

Bright and colleagues¹² conducted meta-regression analysis in their review and found six key features of successful CDSSs:

- use of a computer-based generation of decision support instead of manual processes;
- promoting action rather than inaction;
- providing research evidence to justify assessments and recommendations;
- engaging local users during system development;
- linking with electronic patient charts to support workflow integration; and
- providing decision support results to patients as well as providers.

Additionally, three features of successful systems previously identified by Kawamoto et al.¹⁰² were confirmed by Bright and colleagues¹²:

- automatic provision of decision support as part of workflow;
- provision of decision support at the time and location of decision making; and
- providing recommendations rather than assessments alone.

As shown in Appendix Table 5 (available online), the present review identified four features likely to be associated with positive process of care outcomes:

- provision of support as a part of clinician workflow;
- provision of recommendations rather than assessments alone;
- provision of decision support at the time and location of patient contact; and
- integration with charting order entry system to support workflow integration.

In 2009, the U.S. government enacted the Health Information Technology for Economic and Clinical Health (HITECH) Act¹⁰³ to provide incentives for rapid implementation and adoption of EHRs for clinicians and hospitals. Through the “meaningful use” regulations in the HITECH Act, hospitals and eligible professionals must implement and adopt clinical decision support rules as a component of “certified” office EHR systems, in order to qualify for payment incentives.¹⁰⁴ The HITECH Act authorized incentive payments totaling \$27

billion over 10 years for eligible professionals to collect a maximum of \$44,000 and \$63,750 in Medicare and Medicaid payments, respectively.¹⁰⁵

Future research should investigate CDSS interventions in practice-based settings to better understand barriers encountered by implementers and challenges posed by generic, mass-produced EHR software not tailored to practices' needs. Additionally, current "meaningful use" and implementation standards should be further evaluated. The effectiveness of CDSS interventions from this review is applicable to the U.S. healthcare system, outpatient primary care settings, and patients with multiple CVD risk factors. Implementers may need to adapt systems to meet their specific needs to improve outcomes for patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors acknowledge Michael Schooley and the Division for Heart Disease and Stroke Prevention, CDC, for their support at every step of the review. Gillian Sanders (Duke Evidence-Based Practice Center), Lynne T. Braun (Rush University College of Nursing), and Ninad Mishra (National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, CDC) provided guidance during the initial conceptualization. Randy Elder, Kate W. Harris, Kristen Folsom, and Onnalee Gomez (all from the Community Guide Branch, CDC) provided input at various stages of the review and the development of the manuscript.

With great sadness, the authors note the untimely passing of David B. Callahan earlier this year. We greatly valued his insight and contribution to this review.

Points of view are those of the authors and the Community Preventive Services Task Force and do not necessarily represent those of CDC.

The work of Gibril Njie and Ramona Finnie was supported with funds from the Oak Ridge Institute for Scientific Education.

Appendix: Supplementary data

Supplementary data associated with this article can be found at, <http://dx.doi.org/10.1016/j.amepre.2015.04.006>.

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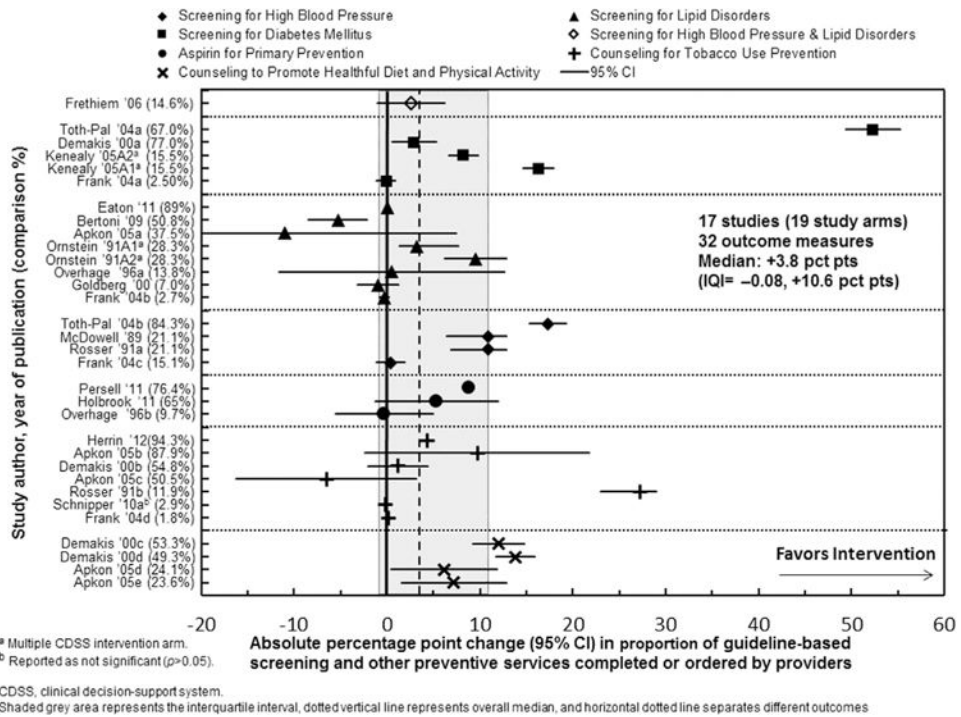


Figure 1. Changes in proportion of guideline-based screening and other preventive care services completed/ordered by providers prompted by a clinical decision support system.

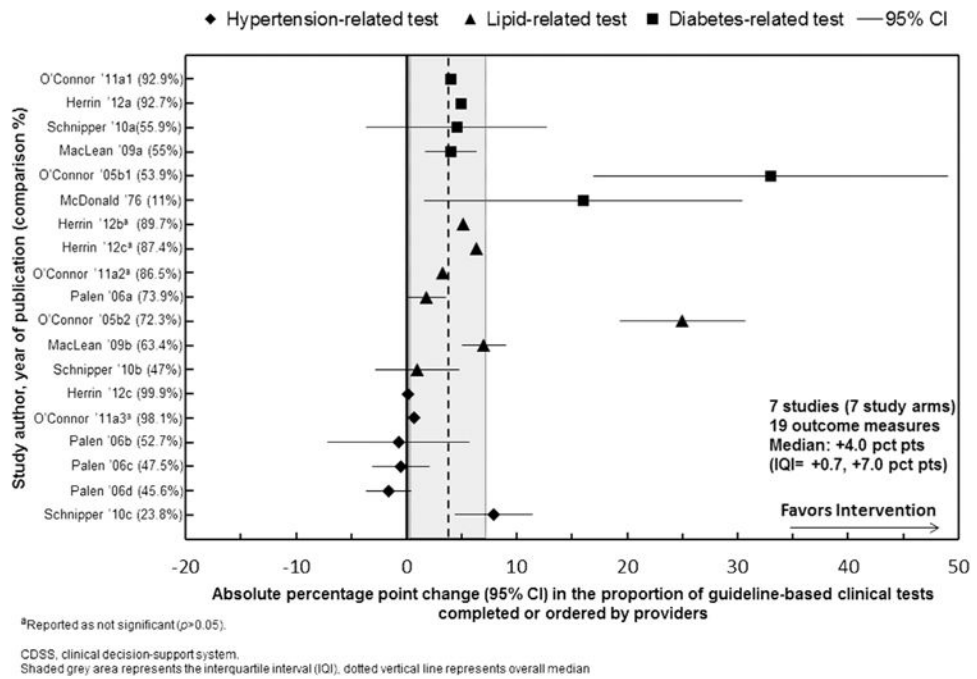


Figure 2. Changes in proportion of guideline-based clinical tests completed/ordered by providers prompted by a clinical decision support system for patients with hypertension, hyperlipidemia, or diabetes.

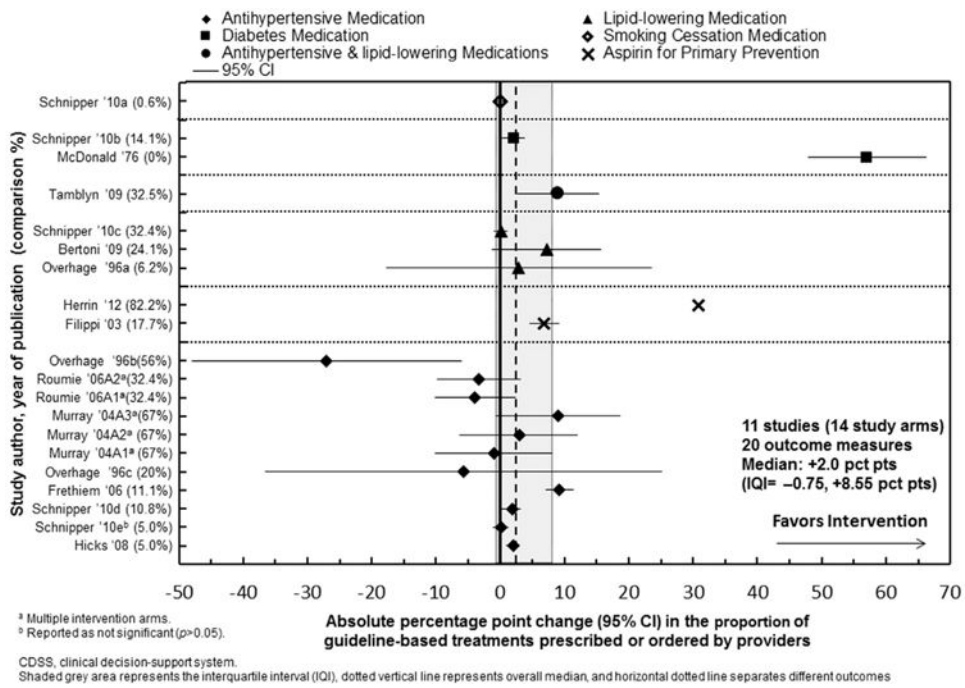


Figure 3. Changes in proportion of guideline-based treatment completed or ordered by providers when prompted by a clinical decision support system.

Table 1

Population Characteristics from Included Studies

| Characteristic | Median (IQR) | Studies reporting characteristic, <i>n</i> (%) ^a |
|----------------------------------|------------------|---|
| Age (years) | 60.3 (50.3–64.4) | 38 (84) |
| Gender (%) | | |
| Male | 45.5 (39.6–50.0) | 35 (78) |
| Female | 54.6 (50.0–60.4) | 35 (78) |
| Race/ethnicity (%) | | |
| White | 58.5 (50.0–94.2) | 14 (32) |
| Black | 47.5 (14.5–79.5) | 9 (21) |
| Hispanic | 5.7 (1.7–21.0) | 5 (11) |
| Other | 2.0 (1.5–2.1) | 7 (16) |
| Income | | |
| Low-income | NA | 1 (2) |
| Education (%) | | |
| Less than high school | 18.0 (NA) | 3 (7) |
| High school diploma | 46.7 (38.1–68.9) | 4 (9) |
| College or university | 36.4 | 2 (5) |
| Insurance status (%) | | |
| Private insurance | 39.5 (29.3–50.8) | 5 (11) |
| Medicare/Medicaid (U.S. studies) | 23.5 (18.0–39.8) | 5 (11) |
| Uninsured | 18.5 (7.7–39.8) | 5 (11) |

^aTotal number of studies (and proportion of total number of included studies) that reported specific demographic characteristics.

IQR, interquartile interval; NA, not available.