Implementing Clinical Decision Support (CDS) Systems: The Experiences of AHRQ's Demonstration Projects—Annual Report

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Introduction

Clinical decision support (CDS) is "any system designed to improve clinical decisionmaking related to diagnostic or therapeutic processes of care."[1] CDS systems are often computer-based, which allows the user to take advantage of the consistency and capacity of computer systems to process information from the patient record and to deliver appropriate recommendations to providers at the point of care.

In 2008, the Agency for Health Research and Quality (AHRQ) funded two demonstration projects in support of the design, development, implementation, and evaluation of guidelines-based CDS. The demonstration projects were awarded to Brigham and Women's Hospital for the Clinical Decision Support Consortium (CDSC) project and Yale University School of Medicine for the GuideLines Into Decision Support (GLIDES) project. Each project is funded for $2.5 million for a 2-year period, with an option for AHRQ to continue funding the projects for up to an additional 3 years. Both projects have multiple goals, including (1) incorporating novel CDS tools into multiple electronic medical record (EMR) systems, (2) sharing lessons learned during implementation with the vendor community, and (3) evaluating the processes and outcomes of the projects. The demonstration projects include a technical expert panel (TEP) that helps identify methods to maximize the impact of the projects at the implementation sites and in future settings.

Westat provides overall monitoring and dissemination support for the AHRQ CDS demonstration projects and supports the TEP. Westat's role is to convene project representatives and the expert panel, and through the expert panel meetings, to glean information about the facilitators and barriers to the successful implementation of guidelines-based CDS in primary and specialty care practices.

This report describes the accomplishments, challenges, and lessons learned from the AHRQ CDS Demonstration Projects during the second year of their projects. The goal of the report is to highlight the individual and aggregate products of the CDS demonstration projects. Westat developed this report by reviewing existing resources, reports, and plans from each CDS demonstration project as well as from the support project conducted by Westat. This report focuses on the second year of the CDS demonstration projects (February 2009 to April 2010). Accomplishments from the first year are summarized as a baseline for second year progress. The report concludes with overall lessons learned and strategies for the third year of both projects.

Overview of the AHRQ Clinical Decision Support (CDS) Demonstration Projects

Background

CDS can support the delivery of high-quality health care by providing intelligently-filtered, patient-specific knowledge at the point of care. CDS "encompasses a variety of tools and interventions such as computerized alerts and reminders, clinical guidelines, order sets, patient data reports, and dashboards, documentation templates, diagnostic support, and clinical workflow tools."[2] CDS applications range from "electronically available clinical data (e.g., information from a clinical laboratory system or information from a disease registry), electronic full-text journal and textbook access, evidence-based clinical guidelines, and systems that provide patient and situation-specific advice (e.g., EKG interpretation and drug-drug interaction checking)."[3]

AHRQ recognizes the potential of CDS to enhance its goals of ensuring safety and quality in health care. It also recognizes that there is a need to develop consensus around the use of CDS in promoting safe and effective health care.

In support of enhancing utility and adoption of CDS in the broader provider community, AHRQ has awarded funds for development, implementation, and evaluation of CDS. The AHRQ Health IT Portfolio's CDS Initiative includes a variety of activities:

- Two demonstration projects.
- Technical expert panel representing various stakeholders involved in various components of the CDS initiative.
- Series of white papers on CDS.
- Step-by-step guide for implementing CDS.
- Podcast series on CDS.
- Community Outreach—town hall meeting.
- Published report on challenges and barriers to implementing CDS.
- Funded grants.

AHRQ's CDS Demonstration Projects

Among the various CDS projects funded by AHRQ there are two CDS demonstration projects: Yale Medical School is leading the Guidelines into Decision Support (GLIDES) project, which focuses on asthma and obesity; Brigham and Women's Hospital leads the CDS Consortium (CDSC) project, which focuses on hypertension, coronary artery disease, and diabetes. The objective of the CDS demonstration projects is to develop, implement, and evaluate guidelines-based CDS and then share lessons learned with AHRQ and the health information technology (IT) community. Each project is funded for $2.5 million for a 2-year period, with an option for AHRQ to continue funding the projects for up to an additional 3 years. AHRQ recognizes the importance of establishing this research in the context of the provider community and engaging stakeholders in the research and implementation process. Thus, these demonstration projects are supported by a technical expert panel (TEP) that reviews the findings,

provides input and feedback for recommendations and reports, and offers guidance on how findings from this initiative can be most effectively disseminated. The panel members represent academia, medicine, quality measurement organizations, vendors, and Federal agencies and have diverse experience in clinical guideline development, quality measurement, and clinical system development and implementation.

The overarching goals of these two demonstrations are to develop, implement, and evaluate best practices in using CDS. Specifically, these two projects have been charged by AHRQ to:

- Incorporate CDS into electronic medical records (EMRs) that have been certified by the Certification Commission for Health IT (CCHIT).
- Demonstrate that CDS can operate across multiple computer systems.
- Establish lessons learned for CDS implementation relevant to the health IT vendor community.
- Assess potential benefits and drawbacks of CDS, including effects on patient satisfaction, measures of efficiency, cost, and risk.
- Evaluate methods of creating, storing, and replicating CDS element across multiple clinical sites and ambulatory practices.

Guidelines Into Decision Support (GLIDES)

In February 2008, AHRQ awarded a 2-year, $2.5 million contract to the Yale School of Medicine to finance the GLIDES project. GLIDES is developing, implementing, and evaluating CDS demonstrations to identify optimal ways to incorporate CDS into health care delivery for the implementation of clinical guidelines for asthma and pediatric obesity.[4] This project aims to explore how the translation of clinical knowledge into CDS can be made part of routine practice and expanded to improve the overall quality of health care in the United States. It will demonstrate how knowledge from clinical practice guidelines can be converted to computer-based CDS.

Project Team

The primary contract is with the Yale University School of Medicine with collaborators from Yale New Haven Health and Nemours. The team includes multispecialty representation from primary and specialty care medicine, nursing, informatics, information systems, clinical administration, epidemiology, and quality management. Richard Shiffman, M.D., M.C.I.S., serves as project director.

Project Goals

The primary goals of this demonstration project are as follows:

- Identify and summarize best practices and processes for integrating CDS tools in electronic health record systems used in busy practice settings.
    - The demonstration project involves the implementation of CDS tools in two Certification Commission for Health IT (CCHIT) certified health IT products. Incorporation of CDS into multiple products will demonstrate cross-platform utility and will help to establish a wide range of best practices useful to the health IT vendor community.

    - ANSI Health IT Standards Panel (HITSP) standards are applied where available and applicable.
- Utilize CDS tools for measuring and improving performance and quality of care.
    - GLIDES will evaluate the demonstrated work's impact on the quality and efficiency of health care delivery, using clinical data from the EMR systems.
    - Other potential benefits of CDS systems on outcomes of care, including effects on patient satisfaction, efficiency, and quality of life, will also be considered by the GLIDES project.
- Demonstrate methods, benefits, and drawbacks of using CDS across multiple settings.
    - The demonstration projects will be tested in six ambulatory practices across the east coast of the United States. These practices cover different types of ambulatory practices, enabling the project to test the generalizability of findings and products. A critical component of the GLIDES project is the active involvement of stakeholders from multiple disciplines and from multiple health care groups whose needs can be addressed through CDS.
- Evaluate and disseminate findings and results.
    - The GLIDES project will evaluate all critical tasks and work products to ensure the objectives and goals of the project are met, and will produce and distribute a series of reports consistent with AHRQ expectations to disseminate the project's results. Some examples include:
        - CCHIT recommendations for certification of information systems in support of CDS.
        - Recommendations to the general guideline development community, and to the developers of the specific guidelines used by the project, on best practices in guideline development regarding CDS translation and implementation.
        - A final report of evaluation and findings, which will be presented at an AHRQ-convened conference.

Project Design and Methods

The project design involves the development of clinical decision support tools based on clinical guidelines for asthma and pediatric obesity. In the first 2 years of the project, the GLIDES team developed CDS based on two guidelines:

- The EPR3 *Diagnosis and Management of Asthma* from the NHLBI (2007).[5] The asthma decision support tool assists in classifying severity and level of control of asthma by prompting for relevant data collection, summarizing impairment and risk, and suggesting appropriate pharmacologic interventions. Clinicians are further aided by facilitated prescription writing and completion of asthma action plans and medication authorization forms.
- *Screening and Interventions for Overweight in Children and Adolescents* (2007)[6] from the Expert Committee on the Assessment, Prevention, and Treatment of Child and Adolescent Overweight and Obesity likewise demonstrated challenges of implementation of a guideline for prevention. The obesity prevention CDS tool aims to identify risk factors (e.g., parental obesity, birth weight, growth patterns) and highlight them for busy clinicians. By viewing these risk factors, clinicians are aided in prioritizing the

importance of a discussion of nutrition at the visit. It also summarizes and prompts clinicians to discuss a variety of critical nutrition anticipatory guidance.

The CDS tools developed based on these guidelines were implemented on two electronic medical records systems (EMRs)—GE Centricity and Epic. The GE Centricity system is used at Yale practice settings, and the Epic EpicCare system is used at Nemours. The CDS tools were implemented in a total of six clinical practices across two organizations in three phases (Table 1).

Table 1. GLIDES implementation sites

Phase	Condition	Site	EMR System
1	Asthma	Yale Specialty	GE Centricity
2	Obesity	Yale Primary Care	GE Centricity
		Nemours Delaware PC	EpicCare
	Asthma	Nemours Orlando	EpicCare
		Nemours Jacksonville	EpicCare
		Nemours Pensacola	EpicCare
3	Asthma	Yale Primary Care	GE Centricity
		Nemours Delaware PC	EpicCare

The six practices are in geographically and organizationally diverse locations.

- **Yale Primary Care Center** is an academic, inner city, ambulatory care center that serves a low-income, multiethnic, and Medicaid and uninsured population with generally low levels of health literacy. Clinicians in training there (residents and nurse practitioners) will take skills in interaction with clinical decision support tools to geographically dispersed primary care and specialty practices when they finish their training.
- **The Pediatric Specialty Center at Yale Children's Hospital** serves children from a wide range of socioeconomic segments. It is manned by academic pediatric subspecialists, postdoctoral fellows, and advanced practice RNs.
- The **Nemours multispecialty centers in Orlando, Jacksonville, and Pensacola** each has a unique culture and flavor. Community-based subspecialists provide care to a wide spectrum of patients including both those with private insurance and Medicaid coverage.
- The 41 pediatricians and 11 advanced practice registered nurses who practice in the 14 **Delaware Valley Nemours-**affiliated primary care practices cover a broad geographic area and their patients span a wide demographic range.

In the first phase, the CDS tools for asthma were implemented at Yale Specialty clinic. The second phase consisted of implementing the CDS for obesity at Yale Primary Care and at Nemours Delaware Primary Care, and the CDS for asthma at the Nemours Jacksonville and Pensacola multispecialty centers. The third phase consisted of implementing the CDS for asthma at Yale Primary Care and Nemours Delaware Primary Care (PC).

Implementation in each phase was followed by complete evaluation to identify and address issues and risks. These evaluation findings were used to inform the next phase to help improve the implementation process at each stage.

Clinical Decision Support Consortium (CDSC)

A month after the award to Yale for the GLIDES project, AHRQ awarded a second 2-year, $2.5 million contract to the Brigham and Women's Hospital to fund the CDSC project. The CDSC project goals are to assess, define, demonstrate, and evaluate best practices for knowledge management and CDS across various ambulatory care settings and technology platforms at scale.[7]

Project Team

The CDSC involves researchers from nine different organizations including: Partners HealthCare System's Clinical Informatics Research and Development (CIRD), the Regenstrief Institute, Veterans Health Administration, University of Texas School of Health Information Science, Oregon Health Sciences University, Kaiser Permanente, NextGen, Siemens Medical Solutions, and GE Healthcare. All organizations involved in the CDS Consortium project are intimately involved in creating and providing CDS tools and services in electronic medical records used in both academic settings as well as community-based physician office practices. The primary contract holder for this project is Brigham and Women's Hospital, and the team is led by project director Blackford Middleton, M.D., M.P.H.

Project Goals

The overall goals of the project include the following:

- Identify best practices for CDS features, functions, and knowledge management and make recommendations to vendors and certification authorities.
    - Current knowledge management lifecycle practices (i.e., guideline transformation and implementation) will be assessed at clinical sites in the CDSC to identify best practices across academic and vendor settings.
    - The findings will be disseminated through academic publications and presentations, as well as the appropriate reports for AHRQ. A second method of dissemination for the findings of this research will be to make insights and knowledge artifacts available to the AHRQ National Resource Center for Health Information Technology.
- Facilitate the translation and specification of clinical knowledge into human- and machine-readable artifacts and share knowledge via a portal or Web interface. CDSC will define best practices for knowledge representation, data representation, and specification of knowledge content formats for both human-readable expression of content, and expression of content for Web services implementation.
- Demonstrate CDSC services in existing EMRs at scale.
    - CDSC will create a knowledge portal and repository to be used as collaboration platforms for the creation of CDS tools. The knowledge portal and repository will store decision support narratives and knowledge specifications in executable forms from the diverse members of the CDSC.
    - CDS demonstrations at various institutions (including the Regenstrief Institute and the Veterans Health Administration) will use publicly available Web services.

    - For each local implementation, a critical component of the work is to develop, implement, and evaluate a CDS dashboard. The CDS dashboard informs the end user as to his or her compliance with CDS recommendations produced in the demonstration projects.
- Evaluate effectiveness of CDSC services.
    - User satisfaction, system performance, and the efficiency of collaborative knowledge engineering will be assessed. The CDS services demonstration will include proof of concept assessment, usability assessment, evaluation of the pilot implementation, and user satisfaction assessment.
    - CDSC will assess the requirements for generalization of the best practice through survey assessment of essential EMR requirements for improved adoption of CDS knowledge content in human readable form, or as publicly available Web services.
    - CSDC will identify best practices for deploying clinical decision support services in the context of electronic health records in ambulatory care practices through survey assessment of organizational barriers and enablers, and assessment of best practices of the CDS Consortium membership, as well as qualitative assessment of the implementation and deployment of the CDS demonstration projects.
    - The CDSC project will coordinate sharing and publication of the clinical decision support content and best practices developed by the project team.

Project Design and Methods

The CDSC project began with an assessment of the knowledge management lifecycle and supporting infrastructure. The team will use information from the lifecycle assessment to define best practices for translating narrative clinical guidelines into an array of reader-friendly educational materials and public Web services.

The CDSC's technical development work and implementation strategy are envisioned to occur in a centralized way, with organizations accessing and downloading CDS tools through a server-based portal. The CDS tools are designed to run on standardized data produced by the local EMR, with minimal on-site support. An evaluation will be conducted to document lessons learned from each implementation site.

The guidelines to be implemented are:

- *The 2007 Diabetes Management Standards of Care from the American Diabetes Association*.[8] The diabetes management tool defines conditions for clinician and patient reminders for hemoglobin A1c checks, ophthalmologic exams, foot exams, and urine protein screening and defines conditions for advising when to start or adjust diabetic medications.
- The American College of Cardiology's guidelines on *Anti-platelet Therapy Prescribed for Patients with Coronary Artery Disease* and the *U.S. Preventive Services Task Force recommendation on Aspirin for the Primary Prevention of Cardiovascular Events*.[9] This CDS tool is to be used by clinicians of patients with either diabetes or coronary artery disease who have indications to be on an anti-platelet but are not currently prescribed an anti-platelet are advised to start either aspirin or clopidogrel. The tool provides reminders as appropriate.

- *The U.S. Preventive Services Task Force recommendations on Screening for High Blood Pressure.*[10] The hypertension CDS defines conditions for clinician and patient reminders to monitor/record blood pressure measurements and for suggesting referrals to nutrition, cardiac rehab, and hypertension specialists.

CDSC tools and services were implemented into the longitudinal medical record at four Partners HealthCare practices:

- Massachusetts General Hospital Back Bay primary care group.
- Brigham Primary Physicians at Faulkner.
- Brigham and Women's Primary Care Associates of Brookline.
- Brigham and Women's Hospital Foxboro.

All four implementation practices were large outpatient clinics in the Boston metropolitan area.

Summary of Progress at End of Second Year

In this section, we provide details on the activities, accomplishments and deliverables for each project goal. For activities where the team encountered challenges, the reason for the difficulty and any lessons learned are described.

GLIDES

The year 2 goals of the GLIDES project focused on refining and implementing the CDS tools developed in the first year and evaluating the guideline development process and the effects of the CDS tools on clinical outcomes.

Progress on Goals 1 and 3

- Goal 1: Identify and summarize best practices and processes for integrating CDS tools into EHRs used in busy practice settings.
- Goal 3: Demonstrate methods, benefits, and drawbacks of using CDS across multiple settings.

During year 1, the GLIDES team developed a four-step knowledge transformation process, referred to as the "knowledge stack," which was used to transform narrative guidelines into computer-mediated decision support.[11] The four steps were (1) narrative guideline, (2) semi-structured level, in which the guideline is parsed into key recommendations, triggering variables, and recommended actions, (3) semi-formal level, in which developers encode some of the logic for use in EMRs, and (4) formal level where the code is customized and finalized for implementation in a specific EMR system.[11] Steps one to three were performed as centralized activities, and the fourth step of integrating and optimizing the executable code in the EMR systems was performed in collaboration with each local implementation site. The design team applied this knowledge stack process to create the Asthma SmartForm and the Obesity Prevention SmartText.

Local implementation of guidelines-based CDS tools began in the first year of the project and continued through year 2. Implementation occurred in three phases. Phase 1 was completed in the first year of the project and included the implementation of asthma CDS at the Yale Specialty Clinic. Phase 2 implementation started in the first year of the project and will continue into the

second year. Phase 2 included the implementation of obesity CDS at Yale Primary Care and Nemours Delaware and asthma CDS at Nemours Orlando, Jacksonville, and Pensacola.

Phase 2 implementation was completed during the second year of the project in August 2009. The obesity CDS was implemented at Yale Primary Care and Nemours Delaware. The asthma CDS was implemented at Nemours Orlando, Jacksonville, and Pensacola. Phase 3 implementation of the asthma CDS at Yale Primary Care and Nemours Delaware Primary Care was completed in February 2010. Phase 2 was the largest in scope with parallel rollouts occurring at five practices across two organizations using two different EMR systems.

For each implementation site, the GLIDES design team refined the CDS tools to function within the existing EMR systems, using workflow analyses and qualitative assessments as supplemental information. For all sites, the integration of the CDS tools required some updates to the CDS or EMR, and in some sites, the EMR did not have the capacity to support the CDS and workaround technologies needed to be developed.

The GLIDES team took measures to ensure providers were trained to use the system and were engaged in the project. Training plans and materials were developed for both the asthma and obesity tools. Workflow analyses conducted at the Nemours Asthma Clinics at the multispecialty centers in Orlando, Jacksonville, and Pensacola showed that training for the Asthma SmartForm was highly important because SmartForms were the least used form of documentation available to the providers. SmartForms are electronic forms that enable writing a multi-problem visit note while capturing coded information and providing sophisticated decision support in the form of tailored recommendations for care.[12] Given this challenge, the GLIDES team developed three types of Asthma SmartForm training: (1) a training manual, (2) Internet-based training, (3) and in-person demonstrations. Training for the Obesity Prevention SmartText was relatively easier due to strong leadership and provider buy-in at Nemours Delaware PC. Obesity CDS training consisted of in-person demonstrations and was led by physician champions from the site.

The GLIDES team worked with local providers to obtain buy-in, which was hoped to positively affect adoption of the new CDS tools. Providers were invited to review the tools and provide feedback about usability. Providers' suggestions were incorporated into the site-specific designs as appropriate. The CDS tools were made available for general use following training and provider review. However, broad adoption of the CDS tools is limited at all implementation sites.

Progress on Goals 2 and 4

- Goal 2: Utilize CDS tools for measuring and improving performance and quality of care.
- Goal 4: Evaluation and dissemination of project findings and results.

Evaluation of the guidelines transformation process. The purpose of the evaluation was to identify lessons learned about the guidelines transformation process, evaluate the effectiveness of the GuideLine Implementability Appraisal process, and identify lessons from the implementation process that should be communicated back to CDS developers. The GLIDES team collected qualitative data on the processes of transforming text guidelines into computer-readable decision support and implementing the newly developed CDS into existing EMR systems. Data collection activities began during the first year of the project and continued into the second year. By the end of the second year, evaluators had identified salient lessons learned and began presenting results at conferences and government-sponsored forums. Key lessons

included the recommendations for encoding guideline information in standard formats (e.g., SNOMED) and the different documentation needs of primary care physicians and specialists.

Dissemination work is ongoing and will continue into future project years. The GLIDES team completed more than 20 presentations of the qualitative findings from the guideline transformation and implementation processes. These findings were summarized in the GLIDES Annual Report 2009-2010.[11]

> GLIDES implemented CDS applications for two widely used EMR systems—GE's Centricity and Epic's EpicCare. Each platform presented unique technical challenges, including inherent product limitations relating to access to data, time stamping, and interface design that required local technical expertise and knowledge to resolve. Both of these EMR platforms are limited in how their presentation layer can integrate with shared services, potentially delivered via the Internet. These technical limitations, and the reliance on local technical expertise and knowledge to solve them, reinforced the GLIDES view that implementation success requires a great degree of local site knowledge and engagement. (p. 9)

The team plans to develop a manuscript for submission to a peer-reviewed journal detailing the major areas of challenge for CDS design and delivery, including such categories as knowledge transformation, workflow design, CDS logic design, user interface design, governance, training, and adoption.[13]

Evaluation of the effect of novel CDS on clinical and quality outcomes. A high-level evaluation plan that identified relevant research questions and outcomes was completed and approved during the first year of the project.[4] Detailed evaluation protocols with methods for data collection and analysis were developed for each phase of implementation. Preliminary evaluation protocols for Phase 1 were tested in the first year of the project and were planned to be executed to scale in the second year of the project.

Quantitative and qualitative methods were developed to assess the usability and use of CDS at each implementation site. The project team obtained IRB approval for all aspects of the evaluations. The GLIDES team conducted the following evaluation activities:

- Provider surveys.
- Observations of CDS use in select locations.
- Chart abstraction to assess (a) pre-implementation agreement with guidelines and (b) post-implementation concordance between CDS recommendations and provider actions.
- Key informant interviews of clinician users of CDS.
- Usage data analysis.

The mixed-methods approach used by the team proved to be especially valuable in understanding and addressing usage patterns. Following rollout of the CDS, the team collected usage data on a weekly basis. Reports showed generally low levels of usage across sites. Various qualitative approaches, such as surveys and key informant interviews, identified reasons for low usage, which were used to formulate strategies to stimulate use. In certain practices, refinements to the CDS tools were needed. In other sites, incentive programs were instituted to bolster use. Usage and usability evaluations were ongoing at the end of year 2.

In addition, the GLIDES team has developed two manuscripts based on the qualitative studies of provider attitudes toward the CDS tools. These manuscripts are entitled:

- "Are Subspecialists' Needs Different? Mixed-methods Evaluation of a Decision Support System for Pediatric Pulmonologists," E.A. Lomotan, et al.[14]
- "Disagreements with Decision Support" (working title), L.J. Hoeksema, et al.[15]

Major findings from these manuscripts were also summarized in the GLIDES Annual Report 2009-2010.[11]

> In implementing CDS tools for both specialists and primary care physicians, GLIDES identified design considerations that are more appropriate for each of these communities. Specialists may tend to believe that they do not need CDS guidance, and will benefit from critiquing approaches. Reporting and feedback on how their decisions align with guideline recommendations may be useful. Primary care physicians will be more open to a more prescriptive approach. In general, CDS implementations for specialists (pulmonologists) at both Yale and Nemours were less successful than for primary care physicians—usage levels were disappointing. However, efforts continue to incentivize and encourage adoption for all GLIDES clinical locations. (p. 9)

Summary of Accomplishments and Products During the Second Year of the Project

- Learned
  - Documented recommendations for translating narrative guidelines into machine-readable artifacts for the Health IT Standards Panel (HITSP).
  - Learned and documented processes for incorporating new CDS tools into existing EMR systems at multiple sites.
  - Learned strategies to obtain buy-in from providers prior to implementation.
- Built
  - Developed code that supports implementation of the Asthma SmartForm and Obesity Prevention SmartText in two popular EMR systems (i.e., Epic's EpicCare, GE Centricity).
- Demonstrated
  - Successfully implemented an asthma CDS tool in six clinical practices across two EMR systems.
  - Successfully implemented an obesity CDS tool in two clinical practices across two EMR systems.

Challenges Encountered During the Second Year of the Project

- Project Organization
  - The GLIDES team lead at the Nemours facilities left the project in May 2009, and the role was assumed by another member of Nemours senior leadership.[16] The new team lead continues to be supported by the same project coordinator, which provided stability through the transition.
- Technical
  - The EHRs varied in their ability to support the CDS functions and to produce the data needed for evaluation.[17] For example, the GE Centricity EMR did not support time stamping and usage data was not accessible in EpicCare. The design team created ad hoc fixes when needed.
  - The GLIDES design team solicited feedback from providers at each site to increase buy-in and stimulate adoption.[16] However, the providers produced a large number of requests, and the development team could only fulfill a limited number

of requests and stay on pace with the project timeline. The team has developed methods to prioritize and complete requests.

- Implementation
  - A workflow analysis showed that pulmonologists (asthma sites) use their computers after the patient has left the exam room, which means the CDS is occurring after the visit and not in real time.[16] While this workflow issue can be resolved, it is generally under the purview of Yale operations.
  - The GLIDES team examined usage data for existing CDS tools and found that, in certain sites, the providers' *least* preferred type of CDS was SmartForms, and the GLIDES Team planned to implement Asthma SmartForms in these sites.[13] This created an intrinsic barrier to Asthma SmartForm adoption that the team is still trying to overcome. An evaluation plan has been designed to gather usability data on the Asthma SmartForms as well as the Obesity Smart Text.

Plans for the Upcoming Year

Yale University was awarded a 1-year option year to continue and build on work from the first 2 years of the GLIDES project.

Implementation. In the third year of the project, the GLIDES team will implement the asthma and obesity CDS tools in two additional organizations.[18] This work will be similar to that of the second year of the project and will include building relationships with clinical and technical staff at the site; conducting workflow analyses; refining the CDS tools for integration into the local EMR system; training users; and conducting ongoing activities to engage users.

Evaluation. The evaluation team will continue to examine CDS usability and use and will expand the scope to address additional research questions. year 3 evaluations will focus on how health IT can be used to facilitate the use of clinical best practices; what the facilitators and barriers are to the scalable use of CDS products; and how health IT affects clinical outcomes, patient satisfaction and quality measurement.

Dissemination. The team will continue to disseminate findings from the first 2 years of the project. A plan to disseminate findings from the third year of the project is being developed. Potential audiences for year 3 materials include health IT policy organizations, quality measure developers, and clinical professional organizations.

CDSC

The overall goal of the CDSC project was to develop centralized services for the design and deployment of CDS tools. To this end, the CDSC team focused on (1) assessing existing technologies for best practices related to system design, (2) applying design-related best practices to the development of three novel CDS tools, (3) developing an expansive infrastructure to support the development and deployment of CDS at scale, and (4) implementing and evaluating the novel CDS tools and supporting infrastructure. The majority of the activities undertaken during the second year of the project focused on building the CDS infrastructure, and the project year concluded with demonstrations of the newly developed CDS tools and infrastructure.

Progress on Goal 1

- Goal 1: Identify best practices for CDS features, functions, and knowledge management and make recommendations to vendors and certification authorities.

During the first year of the project, the majority of project activity focused on assessment and design.[19] The Knowledge Management Lifecycle Assessment Team was responsible for assessing existing industry-leading knowledge management systems and for defining best practices for each step of the knowledge management process. These practices would then be used to inform the development of centralized CDSC infrastructure and services. Key technologies of interest were:

- External repositories of clinical content.
- Online, collaborative, interactive, internet-based tools to facilitate content development.
- Enterprise-wide tools to maintain controlled clinical terminology concepts.
- Tools for CDS users to provide feedback regarding specific CDS interventions.
- Web-based clinical content viewers.

In the first year of the project, the team developed mixed-methods tools to assess knowledge management, applied the assessment tools at five sites, and reported on the preliminary findings. In the following year, the Knowledge Management Lifecycle Assessment Team completed the final two site visits, bringing the total number of site visits to seven (Table 2).

Table 2. Sites assessed by the knowledge management lifecycle assessment team

	Site
1	Partners HealthCare (Boston, MA)
2	Regenstrief/Wishard Memorial (Indianapolis, IN)
3	Roudebush Veterans Affairs Medical Center (Indianapolis, IN)
4	Mid-Valley Independent Physicians' Association (MVIPA) (Salem, OR)
5	University of Medicine and Dentistry of New Jersey (UMDNJ) (New Brunswick, NJ)
6	Zynx (Los Angeles, CA)
7	First Data Bank (San Francisco, CA)

Preliminary analyses suggested that each system had its strengths (e.g., effective use of CDS, innovative design) and weaknesses (e.g., lack of infrastructure, poor design). Selected results were summarized in the CDSC Annual Report for Base year 2:[18]

> For example, Partners HealthCare System (PHS) has an extremely sophisticated [knowledge management] infrastructure, while Regenstrief had made significant progress in the development of "in-line" CDS. Furthermore, Mid-Valley Independent Physicians Association (MVIPA) in Salem, OR, was using vendor supplied clinical documentation templates more effectively than any of the places that had been observed.
>
> While the technical issues surrounding CDS were important and difficult, the socio-technical interaction-related issues far out-weighed all of the solely technical issues. (p. 4)

At the second year of the project, the Knowledge Management Lifecycle Team had prepared to disseminate the findings as manuscripts for publication in academic journals, conference presentations, and Webinars.

In addition, the Recommendations Team reviewed the knowledge management systems of nine leading CCHIT-certified EMR vendors, including Eclipsys, NextGen, e-MDs, SpringCharts®, GE, Allscripts™, Epic, Cerner, and eClinicalWorks. Based on these reviews, the team developed the following:

- A set of recommendations for medical specialty societies.
- Recommendations for clinical guideline development organizations.
- A set of recommendations for quality measurement developers.

Progress on Goal 2

- Goal 2: Facilitate the translation and specification of clinical knowledge into human- and machine-readable artifacts and share knowledge via a portal or Web interface.

Guidelines transformation. In the first year of the project, the CDSC team selected the guidelines (hypertension, coronary artery disease, and diabetes) that would be transformed into machine-readable CDS tools, and they specified the requirements for the guideline transformation process and the requirements for the Knowledge Management Portal (the portal) that would support the transformation. The CDSC used a four-step guidelines transformation process that consisted of (1) narrative guideline, (2) semi-structured with key information and triggers identified, (3) structured with some coding, and (4) executable with coding completed for a specific EMR system.

In the second year of the project, the Knowledge Translation and Specification Team completed level 3 "structured" coding for the three selected guidelines. The team completed models, which map out the substeps required to execute a guideline. The team also developed a stand-alone editing and reviewing tool that better supported the knowledge transformation process. The final level of coding, level 4, was completed by the CDS Services Team.

Knowledge management portal. During the first year of the project, the Portal Team deployed a temporary collaborative workspace (i.e., referred to as eRoom) and completed the hardware requirements for the final portal. The Portal Team also prepared for an expansion in scope based on new requirements from the Knowledge Transformation and Specification Team, who were in charge of transforming the guidelines into CDS tools.

The Portal Team reported successfully building and deploying the Knowledge Management Portal and Repository during year 2.[20] The portal supports additional features required by the Knowledge Translation and Specification team, which include increased search functions, versioning and document-relatedness functions, and the inclusion of new business cases. The Portal team also successfully deployed the guidelines-based CDS artifacts developed by the Knowledge Translation and Specification Team. The Portal team defined, built, tested, and deployed enhancements to the user interface, and the repository was built and tested alongside the portal. User guides for the portal and repository were developed as well.

Progress on Goal 3

- Goal 3: Demonstrate CDSC services in existing EMRs at scale.

Implementation of CDS services. The implementation of the CDS tools required the collaboration of the CDSC Services and the Demonstrations Teams. During year 1, the CDS Services Team prepared specifications for tools that would support implementation of CDS into

an existing EMR system. The Demonstration Team began to engage clinical practices, key technical resources, and conducted a gap analysis at the sites.

During year 2, the CDS Services Team changed its approach to the development of services that would support the sharing and integration of CDS tools across EMR platforms. The team engaged in four subprojects to facilitate the integration of the CDS tools at the demonstration site. The first subproject assembled the required data from the implementation sites and transformed it into the required input format. The second and third subprojects were created to obtain the data needed to run the CDSC rules and to translate local EMR codes into a usable format. The final subproject developed a set of classification rules to determine the patient's disease state. The products developed through these subprojects were refined and tested.

Once the subprojects were finalized, the CDS services team successfully implemented CDS tools. The demonstration was successfully operational in December 2009. In total, the implementation includes four Partners HealthCare practices:

- Massachusetts General Hospital Back Bay primary care group.
- Brigham Primary Physicians at Faulkner.
- Brigham and Women's Primary Care Associates of Brookline.
- Brigham and Women's Hospital Foxboro.

Each practice is responsible for coordination at its respective location. The Demonstration Team is nearing completion of documenting the lessons learned from the demonstration and sharing these lessons with the other implementation sites.

Implementation of dashboards for user feedback. During the first year of the project, the Dashboards Team prepared functional specifications for a tool that would convey the effects of hypertension, coronary artery disease, and diabetes CDS to the end users. The second year of the project, the team also established an automated, biweekly retrieval process of reminder data for the dashboards. These dashboards were officially deployed in January 2010. An evaluation plan was developed in conjunction with the Evaluation Team to ensure the appropriate metrics were being utilized.

Progress on Goal 4

- Goal 4: Evaluate effectiveness of CDSC services.

During the first year of the project, the Evaluation Team prepared for future evaluation activities and developed a high-level evaluation plan. In the second year, the Evaluation team worked extensively with the CDS Services, Demonstration, and Dashboards teams to operationalize a high-level evaluation plan that was approved by the CDSC Steering Committee. Assessments of the data sources and data quality were conducted to ensure the feasibility of evaluation. Evaluation work is planned to continue into the next project year.

Summary of Accomplishments and Products During the Second Year of the Project

- Learned
    - Created a mixed-methods approach for the assessment of CDS tool.

    - Learned and documented best practices for CDS knowledge management.
    - Compiled an overview of the capabilities of commercially available CDS systems.
    - Learned and documented best practices and standards for CDS rules authoring and dissemination.
- Built
    - Transformed narrative guidelines for hypertension, coronary artery disease, and diabetes into machine-readable CDS tools.
    - Designed a portal for the development and storage of CDS rules.
    - Designed a dashboard for CDS-related performance reporting to end users.
- Demonstrated
    - Implemented CDSC services (i.e., CDS rules for hypertension, coronary artery disease, and diabetes mellitus) in four ambulatory care practices.
    - Implemented the CDSC dashboard in the four ambulatory care practices.

Challenges Encountered During the Second Year of the Project

- Project Organization
    - The Knowledge Translation and Specification team faced an organizational challenge when the team lead left Partners HealthCare and joined the faculty at another institution. The team lead continues to fulfill his responsibilities and works with the CDSC staff remotely. The team has accommodated the situation by using Microsoft® Live Meeting, conference calls, and e-mail more frequently.
    - The scope of the Portal project significantly expanded based on information learned by the Knowledge Translation Team during year 1. The expansion of the scope added unforeseen complexity to the design, testing, and documentation requirements of the Portal and Repository. These challenges required the team to adjust resources and revise deadlines for deliverables for year 2.
- Technical
    - Health IT data standards continue to evolve and this evolution created a dynamic environment in which the Knowledge Translation and Specifications Team conducted its work. Increased awareness and preparation helped the team overcome this challenge.
    - The CDS Services team encountered challenges in reconciling various versions of the Continuity of Care Document (CCD) and in mapping data from the EMR to create the CCD. These challenges required increased time and resources; however, project goals were met within the designated timeline.
- Implementation
    - The Demonstrations Team found that, despite efforts to facilitate scalability, challenges remain when implementing novel CDS tools into a multiple practices. The Demonstrations Team found high variability in the CCDs produced across environments. There was also a need for ongoing on-the-ground support to ensure that the CDS tools continued working after updates were made to the local systems.
- Governance and Legal Issues

- The Knowledge Translation and Specification team began development on a server-based authoring and editing tool and was later advised that the act of saving CDSC member content on the PHS server created content liability issues. Limited resources were designated for legal counsel during the second year. The issue will be taken up again in the next project year, when the team will begin development of a stand-alone editing tool.
- The Knowledge Management Portal does not require user authentication; therefore, the team determined that there was a need for formal Terms of Use agreement to prevent possible indemnification of Partners HealthCare. The Terms of Use were successfully created and adopted during the second year.

Plans for the Upcoming Year

The Brigham and Women's Hospital was awarded a 1-year option year to continue and build on work from the first 2 years of the CDSC project.

Implementation. The CDSC team plans to implement services in two practices affiliated with Regenstrief: North Arlington Health Center and Westside Health Center. These two clinics focus on adult/primary care medicine and utilize Regenstrief's new Careweb system as their EMR.[21] These implementations will be informed by experiences from the first implementation site.

Evaluation. Evaluation activities originally planned for the second year of the project will now occur in during its third year. The CDSC evaluation will focus on how health IT can be used to facilitate the use of clinical best practices; what the facilitators and barriers are to the scalable use of CDS products; and how health IT affects clinical outcomes, patient satisfaction, and quality measurement.

Dissemination. The team will continue to disseminate findings from the first 2 years of the project. Much of the dissemination will depend on the successful evaluation of each subproject. A plan to disseminate findings from the third year of the project is being developed. Potential audiences for materials from the third year of the project include health IT policy organizations, health IT vendors, quality measure developers, and clinical professional organizations.

Lessons Learned and Strategies for the Third Year

The GLIDES and the CDSC projects can provide valuable lessons from their experiences with developing, implementing, and evaluating CDS, which can inform upcoming project years as well as other organizations seeking to implement CDS to scale.

Technical Approach

The GLIDES and CDSC teams approached CDS development and implementation in very different ways, and each approach has its benefits and drawbacks. The GLIDES team approached guideline transformation as a centralized process and then conducted site-based customization of the CDS tools. This method was similar to practices typically used in the field, and as a result, the team encountered fewer unforeseen challenges. The CDSC's efforts to centralize implementation significantly affected their development goals, and this innovative approach led to increased challenges along the way. The CDSC team developed its guidelines with a collaborative portal, which interfaced with CDS Services for centralized implementation. The Portal and the CDS Services interface were key technical elements for taking CDS implementation to scale in a centralized way. However, this approach required the CDSC team to build prototypes of the Knowledge Management Portal and CDS Services interface, and as such, the CDSC team encountered barriers often encountered during first time development, including frequent changes in work plan and unforeseen legal requirements. While the CDSC team managed to overcome these barriers, they were still not able to implement as envisioned. Despite extensive efforts to centralize the CDS Services, the CDSC team had to provide site-by-site customization of the CDS tools due to variations in EMR technology. Moving forward, it may be important to assess whether a completely centralized, site-based, or mixed approach to CDS implementation is most feasible and desirable.

Implementation

Variations in EMR products caused challenges in the implementation of standardized CDS tools across sites. Both the GLIDES and CDSC implementation teams encountered significant differences in the capabilities of the EHRs used at the selected clinics as well as site-by-site differences in a given EMR product. The project teams compensated for the variability by customizing the CDS tools to each site. This solution was feasible given the projects' goals and timelines; however, ongoing, ad-hoc customization may not be desirable in the long-term. In year 3, the GLIDES and CDSC teams will likely continue to make recommendations to standards organizations for greater standardization in EMR nomenclature and functionality, which may support standardized CDS implementation.

The GLIDES and CDSC projects both developed methods to persuade providers to adopt and use the novel CDS tools. Both teams had success with using training manuals and in-person training session, and provider relations were improved at sites that had a strong physician champion to provide ongoing leadership. The GLIDES team, in particular, noted a marked difference in providers' receptiveness to different types of CDS. For example, SmartForms were not used as frequently as the simpler SmartText; therefore, it may be important to conduct ongoing usability and design assessments. Furthermore, primary care physicians and specialists

differed in their receptiveness to the novel tools. The GLIDES team conducted focus groups to understand the reasons for the differences between groups and found that primary care physicians view the CDS as rules and specialists see it as recommendations. In year 3, the teams will continue to evaluate the factors that are associated with CDS adoption and use and apply these lessons at future implementation sites.

Evaluation

Both the GLIDES and CDSC projects experienced challenges in completing the evaluations as scoped and within the given timeline. Moving into year 3, the teams have greater knowledge of which aspects of evaluation are appropriate for each given phase of the project. Evaluation can generally be divided into two types: formative and summative. Formative evaluation involves closely monitoring a project in its early stages and providing intervention, as needed, to keep the project on track. The GLIDES and CDSC teams successfully conducted this type of evaluation at each of its implementation sites and are now beginning to disseminate findings. Summative evaluation occurs much later in the course of the project and can measure how well the project meets higher level goals. Both the GLIDES and CDSC team had trouble completing summative evaluations because the projects were not mature enough within the original 2-year timeline. Now that the summative evaluation has been moved to year 3, the expected impact of the project and the timing of data collection will coincide, thus making the evaluation more meaningful and informative.

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