Governance for clinical decision support: case studies and recommended practices from leading institutions

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ABSTRACT

Objective Clinical decision support (CDS) is a powerful tool for improving healthcare quality and ensuring patient safety; however, effective implementation of CDS requires effective clinical and technical governance structures. The authors sought to determine the range and variety of these governance structures and identify a set of recommended practices through observational study.

Design Three site visits were conducted at institutions across the USA to learn about CDS capabilities and processes from clinical, technical, and organizational perspectives. Based on the results of these visits, written questionnaires were sent to the three institutions visited and two additional sites. Together, these five organizations encompass a variety of academic and community hospitals as well as small and large ambulatory practices. These organizations use both commercially available and internally developed clinical information systems.

Measurements Characteristics of clinical information systems and CDS systems used at each site as well as governance structures and content management approaches were identified through extensive field interviews and follow-up surveys.

Results Six recommended practices were identified in the area of governance, and four were identified in the area of content management. Key similarities and differences between the organizations studied were also highlighted.

Conclusion Each of the five sites studied contributed to the recommended practices presented in this paper for CDS governance. Since these strategies appear to be useful at a diverse range of institutions, they should be considered by any future implementers of decision support.

INTRODUCTION AND BACKGROUND

Clinical decision support (CDS) represents a critical tool for improving the quality and safety of healthcare. CDS has been defined in many ways, but at its core, it is any computer-based system that presents information in a manner that helps clinicians, patients, or other interested parties make optimal clinical decisions. For the purposes of this paper, we will limit our attention to real-time, point-of-care, computer-based CDS systems, such as drug–drug interaction alerting, health maintenance reminders, condition-specific order sets, and clinical documentation tools. A substantial body of evidence suggests that, when well-designed and effectively implemented, CDS can have positive effects for healthcare quality, patient safety, and the provision of cost-effective care.1 2

Although the benefits of decision support are numerous, only a small number of sites in the USA have achieved significant success with it.3 A variety of challenges limit the wide adoption of CDS, but a critical one is the difficulty of developing and maintaining the required knowledge bases of clinical content.4 5 Effective CDS often requires extremely large knowledge bases of clinical facts (eg, drug-interaction tables). This content must be engineered (or purchased) and must also be kept current as clinical knowledge, guidelines, and best practices evolve.6 The knowledge bases that are developed must reflect both universal best practices and local practices and needs. Knowledge management is an iterative process that involves both the creation of new content and the continuous review and revision of existing content.

To develop these clinical knowledge bases and ultimately work toward “meaningful use” of CDS, organizations must implement and operate governance processes for their clinical knowledge.5 7 These governance processes take many forms. Some organizations use existing clinical committees to develop and screen decision-support content (such as a Pharmacy and Therapeutics Committee) or appoint a single person to review and approve content (such as the Chief Medical Informatics Officer), while others develop new committee structures along with intranet-based content creation, review, and approval systems. Governance can vary widely depending on the type and size of the organization. For example, large organizations, such as academic medical centers and government-run hospitals, can potentially develop and implement CDS internally, while smaller organizations, such as group practices and community hospitals, may need to rely on a partnership with a commercial vendor.

Careful consideration of governance issues when developing and implementing CDS can be as important as the quality of the decision support itself. In the absence of effective governance practices, implementation of CDS may fail, despite the purchase or development of a sophisticated system. A notable example of this issue is the decision-support system at Cedars-Sinai Medical Center that had to be shut down because of usability issues.8 Employing better governance practices throughout the design and implementation phases, such as increased end-user involvement, can potentially stave off these types of problems.
Although governance and other organization factors have been noted as an essential aspect of high-quality CDS and requisite data warehousing and management, limited research exists about optimal and real-world CDS governance practices. Outside of the healthcare industry, a variety of models have been proposed to describe knowledge management and IT governance practices. These models emphasize the need for continuous knowledge management, the value of studying real-world governance best practices and the importance of well-planned implementation. Researchers also note the substantial investment required to implement IT and knowledge management systems and the uncertainty associated with these investments, further underscoring the need for effective governance.

In order to establish effective governance practices and realize the potential of IT and knowledge management systems, a broad understanding of the institutional pressures organizations face and real-world assessment of these institutional pressures is both valuable and necessary.

Any organization embarking on a new initiative to develop decision support (or simply expanding an existing mandate) faces the choice of how to design its governance structures and the underlying technology to support these efforts. In this paper, we show how five diverse healthcare organizations developed their governance structures and discuss some of the tools they are using to support these activities. We examine each organization’s governance, content management, and technical approaches. After presenting the approaches, we synthesize the lessons learned and develop a set of recommended practices in the three areas. For the purposes of this paper, we refer to “governance practices” as any formal leadership structure, governing bodies, and institutional policies related to the development and implementation of clinical information systems. In general, “governance” refers to the process by which an institution decides on what content will be implemented and how this will occur. In contrast, “content management” refers to the organizational structures and clinical information systems used to view, manage, and update clinical content on an ongoing basis following implementation. Content management allows for continuous tracking of existing CDS systems and allows institutions to generate reports for committee review. In this paper, we analyze both of these interrelated issues at each of the participating sites.

METHODS
This work is part of a larger initiative called the Clinical Decision Support Consortium. The Consortium is focused on sharing CDS content and is pursuing several related aims, including the creation of knowledge representation standards, development of CDS services, and execution of a number of demonstrations of Consortium decision-support content at sites across the country. One of the foremost aims of the Consortium, however, is the study of decision-support best practices including governance practices.

Members of the Clinical Decision Support Consortium research team conducted three site visits and five comprehensive surveys (the three original sites plus two validation sites) at institutions across the country to learn about their CDS capabilities and governance practices with the goal of distilling a set of recommended governance and content management practices based on observations and interviews during field research. Our sampling strategy for these visits was purposive; we selected five exemplary institutions with a history of successful CDS research and utilization.

The team used the Rapid Assessment Process for all fieldwork. At each site visit, a team of four to seven researchers (physicians, nurses, pharmacists, and informaticians) traveled to the site and conducted interviews with decision-support developers and information system leaders, as well as observations of clinical end users. Interviews were tape-recorded, and detailed field notes were captured for each observation. Each day at midday and in the evening, the team debriefed and modified the approach as needed. During these meetings, the research team reviewed field notes, discussed their observations and worked to identify themes and recurring patterns. After returning from the site visit, audio recordings were transcribed, and field notes were typed. The research team, lead by trained ethnographers, identified themes in the data using a grounded theory approach. NVivo 8 qualitative data-analysis software (QSR International, Victoria, Australia) was used to facilitate the process. Field notes and transcripts of interviews were read into NVivo, and then recurring concepts and themes were identified by the team members using the software. The data collected during site visits covered the entire breadth of CDS, including issues such as user interface and technical considerations. For this analysis, only data coded under the themes of content management and governance were reviewed in detail.

After conducting the initial analysis in NVivo, and identifying several hundred concepts across several thousand lines of notes and transcripts, the team used a card-sorting technique to develop an initial set of governance and content-management practices we had observed in the field and then distilled these practices into a summary set of themes. We then developed questions based on these themes and sent written questionnaires to a purposive sample of five sites: three from our initial site visits and two new sites to validate and extend our initial findings. We also asked each site to fill out an inventory of decision-support content at their site based on the six key categories of CDS developed by Osheroff et al.

The five organizations studied are Partners HealthCare System in Boston, Massachusetts; the Mid-Valley Independent Physicians Association (MVIPA) in Salem, Oregon; Vanderbilt Medical Group, in Nashville, Tennessee; Veterans Health Administration (VA), a national healthcare delivery organization headquartered in Washington, DC; and the University of Texas Physicians’ Practice Plan, in Houston, Texas. Site visits were conducted at Partners HealthCare, MVIPA and the VA Health System in Indianapolis.

Based on these case studies, we develop a theoretical framework for studying decision-support governance and present a set of recommended practices that other institutions might consider as they develop their own governance approaches. Because formal governance models for decision support are relatively new, no interventional (or even wide-scale observational) evidence exists for the effect of various CDS governance practices, and there is no particular regulation relevant to such practices. Thus, for the purpose of this paper, we refer to “recommended practices” as practices which the sites identified as critical to their success and which appear to have face validity. We believe that this is the best proxy for consensus available, given the relative novelty of inquiry in the area of CDS governance.

RESULTS
Overview of organizations
These five organizations encompass a variety of academic and community hospitals, and comparatively small and large
Table 1: Overview of the organizations' characteristics

<table>
<thead>
<tr>
<th>Organization</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Mid-Valley Independent Physicians</td>
<td>More than 17,000 practitioners in 140 clinics at 88 medical specialties and subspecialties</td>
</tr>
<tr>
<td>University of Texas Physicians'</td>
<td>More than 2000 practitioners in 96 clinical visits yearly, with more than 12,000 ambulatory admissions yearly</td>
</tr>
<tr>
<td>Practice Plan</td>
<td>200,000 inpatient admissions yearly</td>
</tr>
<tr>
<td>Vanderbilt Medical Group</td>
<td>More than 1400 practitioners in 88 clinics in 80 medical specialties</td>
</tr>
<tr>
<td>Partners HealthCare</td>
<td>More than 7000 practitioners; 2.0 million ambulatory visits yearly; 5.5 million outpatient visits yearly</td>
</tr>
<tr>
<td><em>Veteran's Health Administration</em></td>
<td>262 practices; more than 40,000 patients</td>
</tr>
</tbody>
</table>

Supports numerous types of CDS, such as clinical reminders, order checks, order sets; comprehensive chronic disease-management systems including patient registries; barcode medication administration; patient web portal with virtual visits.

In addition to the broad demographic characteristics in table 1, we found that each site had at least one example of each of the six decision-support types in the Osheroff taxonomy, suggesting that each site had sufficient breadth of content to necessitate some level of decision-support governance.

Despite having similar breadth of CDS, the sites varied dramatically in the depth of decision support they had. For example, the number of different condition-specific order sets ranged from less than 50 to more than 500, and the number of unique clinical alerts ranged from less than 50 to more than 700. This pattern of differing “depths” of CDS implementation accounts in large part for the differences in the structure, complexity, and size of the clinical governance infrastructure that each organization has developed.

Governance approaches

All five sites in our analysis had at least some degree of decision-support governance, although the form and pattern of governance models differed greatly. Table 2 describes the approaches, including CDS-related staff, committees, governance process, tailoring of content, levels of governance, and tools for soliciting and managing user feedback. The five organizations are listed left to right across the top according to size, starting with the two smaller strictly ambulatory sites that use commercial systems. They are followed by the two academic health centers with locally developed inpatient as well as outpatient systems. The national VA health network, in the final column, is the largest and includes inpatient, outpatient, long term, and home-based care. Table 2 compares governance styles and structures across each of the five case studies. See appendix 1, available as an online data supplement (http://www.jamia.org), for further detail on the case studies.

Variation in governance strategies was observed across the five sites. CDS-related staff ranged from a small staff responsible for overseeing a vendor system to large academic informatics departments that included numerous clinicians, informaticians, and software developers. Most sites employed the use of committees to govern development, implementation, and maintenance of CDS systems, although committee structure and overall organization varied. In some cases, content was purchased from an outside vendor, and in others it was developed by in-house staff based on institutional needs. Sites also varied in the degree to which they allowed tailoring of CDS content in individual practices or hospital services. Some form of regular review was common across all sites studied, although mechanisms of user feedback varied significantly in form and frequency.

One particularly notable finding was that governance approaches differed substantially between institutions relying on vendor-based clinical information systems and those with “home-grown” internal clinical information systems (CIS). These differences were largely related to each type of institution’s involvement in CDS development, implementation and management. Organizations that rely on vendor-based CDS require governance structures largely limited to collaboration with vendors and ongoing day-to-day operational management.
Table 2  Governance approaches at each of the five sites

<table>
<thead>
<tr>
<th>Mid-Valley Independent Physicians Association*</th>
<th>University of Texas</th>
<th>Vanderbilt</th>
<th>Partners*</th>
<th>Veterans Health Administration*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDS-related staff</td>
<td>A medical director of information systems and 13 informatics staff members help support system development.</td>
<td>Most content is purchased, so CDS-focused staff is minimal.</td>
<td>Large academic informatics staff, including physicians, nurses, pharmacists, and informaticians.</td>
<td>Physicians, pharmacists, nurses, informaticians, analysts, and software developers.</td>
</tr>
<tr>
<td>Committees</td>
<td>EHR Communications and Policy Committee comprising key Mid-Valley Independent Physicians Association staff and representatives from the Mid-Valley Independent Physicians Association board of directors helps guide ongoing CDS operations and development of new content. A Physician Advisory Committee discusses and prioritizes development activities.</td>
<td>Content governed by the Chief Information Officer and an Allscripts Review Board.</td>
<td>Decentralized organization-wide committees, for example, Patient Safety and Clinical Practice Committees. System-specific committees: Horizon Expert Documentation Advisory Board (nurse charting) and user groups (Horizon Expert Orders, StarPanel). Also pharmacy and condition specific groups for example, Medication Use and Safety Improvement, Patient Falls and Vascular Access Committees. Committees are not overseen by central authority.</td>
<td>National and local software developers, clinical subject-matter experts, and local clinical application coordinators.</td>
</tr>
<tr>
<td>Process</td>
<td>Almost all content comes from EMR vendor. New development (e.g., additional drug–drug interaction rules) is primarily based on requests made by member physicians. The user community includes subject matter experts (SMEs), who are polled or convened as necessary.</td>
<td>Content purchased from commercial vendor. Day-to-day CDS operations are run by a small team that is responsible for managing all servers, desktop support, and a help desk. Significant issues escalated to the Allscripts review board.</td>
<td>Relatively decentralized. Content is typically requested by end users or committees most familiar with that subset of available tools and developed in collaboration with informatics experts by that group, or centrally.</td>
<td>Full-time clinically trained subject matter experts (SMEs) work in small teams with knowledge engineers to develop and implement CDS, using a three-stage life cycle process of knowledge creation, knowledge development, and periodic review.</td>
</tr>
<tr>
<td>Customization</td>
<td>Practices are permitted to develop their own content if desired, and NextGen system allows sufficient customization so specific templates, rules, and actions can be filtered to a specific practice without affecting others.</td>
<td>Generally not permitted.</td>
<td>Customization practices are governed by the Chief Information Officer and an Enterprise-wide Content Management Committee.</td>
<td>Performance measures established nationally on quality goals and utilization review; corresponding reminders are developed either locally or nationally. Local, regional, and national committees have input into the content developed.</td>
</tr>
<tr>
<td>CIS usage required</td>
<td>Use of CDSS encouraged</td>
<td>Use of CDSS encouraged, no paper chart</td>
<td>Use of CDSS encouraged</td>
<td>Mandated usage.</td>
</tr>
</tbody>
</table>

*Site visit conducted.

CDSS, clinical decision support system; CDS, clinical decision support; CIS, clinical information systems; EHR, electronic health record; EMR, electronic medical record.
In contrast, organizations with internally developed systems are responsible for the entire process of development, implementation, and ongoing management and assessment. These fundamental differences result in diverging governance practices, which are summarized in Table 3.

Overview of content-management approaches

Our research findings clearly revealed that sites needed coordinated ways to manage their decision-support content, particularly as the amount and complexity of the content grew.

At Partners, a great deal of the CDS content was developed as part of research projects, and balancing research and operational decision-support projects has been challenging, as research content must be maintained (or decommissioned) after the research project ends. Over the last 5 years, with the maturation of the knowledge management group’s processes, content is increasingly re-evaluated on a periodic basis, which includes analysis of usage data, such as acceptance and override rates for alerts.22 23 The most robust review mechanisms are in place for formulary drug information (dose and frequency lists), drug—drug interaction rules,24 age- and renal-based drug dosing guidance rules,25 and health maintenance reminders. For these assets, Partners conducts regularly scheduled reviews of content, at differing frequencies. In addition, on-demand reviews are prompted by user feedback and external events gleaned from regular scans of health-information sources, such as FDA and pharmaceutical company announcements and the medical research literature.

Vanderbilt has several mechanisms to assess ongoing proper functioning of clinical content. Surveillance data are collected on order set usage, responses to decision-support pop-up alerts, and other CDS items to adjust the support to the desired outcome. Vanderbilt conducts regular reviews of content and then updates the content as clinical evidence surfaces that would necessitate a change. Vanderbilt prioritizes changes based on quality, safety, clinical volumes, and cost/benefit.

In contrast to the other academic institutions, the University of Texas, Houston Physicians’ Practice Plan relies heavily on Allscripts’ content, and updates are tied to the Allscripts’ release schedule. The Practice Plan conducts surveys of clinical users and creates monthly reports that provide all clinicians with a breakdown of the utilization of all aspects of the EHR (electronic health record) (eg, percentage of prescriptions written electronically).

CDS capabilities at the VA are constantly being updated and revised to reflect internal research activities, review of performance measures, input from regulatory groups, networking with academic affiliates, changing emphasis of national program and patient priorities, and involvement in national professional societies and working groups. Evidence-based guidelines from nationally recognized authorities are also reviewed regularly for inclusion. Additionally, the VA national pharmacy program is pursuing integration of a commercially available database for drug–drug/allergy interactions, which would be maintained and periodically updated. Evaluation of the effectiveness of the CDS is indirect and based on the measurement of outcomes it was designed to impact.

Finally, at MVIPA, the primary method of evaluating the effectiveness of CDS is ongoing field testing. Content is updated periodically through the NextGen release cycle and is first tested by MVIPA staff. Design changes that affect clinical content are reviewed by the medical director of information systems. The director also monitors regulatory requirements and prioritizes updates according to their effective dates and their impact.

Comparison of content-management approaches

The content-management practices of the organizations differed significantly based on the nature of the organizations. Academic medical centers reported that much of their content was, at least initially, developed by researchers as a part of research projects. Identifying and maintaining this content, particularly after research projects concluded, appeared to be challenging. Sites also reported developing content based on user requests, regulatory and quality reporting requirements, and other organizational priorities.

All sites reported some form of ongoing content review, but the frequency and regularity of these reviews varied. Some organizations carried out an annual review, while other organizations reviewed content based on user feedback or as new evidence became available. Sites which relied more heavily on vendor content were more likely to report periodic updates or refreshes, often tied to vendor release schedules.

Sites also mentioned and underscored the importance of field-testing content and listening and responding to user feedback. These feedback mechanisms ranged from passive receipt of reports to active feedback tools embedded in the EHR and periodic site visits and assessments. Some sites also reported monitoring usage of content in order to prioritize the most highly used content.

In addition to direct CDS-related evaluation, some sites (particularly the VA) reported a strong focus on associated quality measures. The VA also emphasizes standard practice and common data elements within and across their system of care, and is in the process of standardizing such practices when there is evidence or experience to support such efforts. Other sites, including Partners, reported less standardization.

DISCUSSION

Based on our data collection and analysis, we identified a set of recommended practices for CDS governance and content

Table 3  Comparison of governance practices at sites with internal CIS (clinical information systems) development and vendor-based CIS

<table>
<thead>
<tr>
<th>Governance</th>
<th>Internally developed CIS</th>
<th>Vendor-based CIS</th>
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<tbody>
<tr>
<td>Clinical decision-support-related staff Committees</td>
<td>Require large staff with specialized clinical knowledge</td>
<td>Fewer staff members who support system and collaborate with vendor</td>
</tr>
<tr>
<td>Process</td>
<td>More, specialized committees</td>
<td>Fewer (possibly one) centralized committee(s)</td>
</tr>
<tr>
<td>Customization</td>
<td>Content developed by committee, employing subject matter experts and knowledge engineers</td>
<td>All or almost all content comes from content vendor; system operations may be run locally</td>
</tr>
<tr>
<td>Central governance</td>
<td>Permitted, although standardization may be preferred</td>
<td>Limited or not permitted</td>
</tr>
<tr>
<td>CIS usage required</td>
<td>Content managed through organization-wide committees with distinct specializations</td>
<td>Content managed centrally by vendor</td>
</tr>
<tr>
<td>Review/monitoring</td>
<td>Use of clinical decision-support system more likely to be mandated</td>
<td>Use of clinical decision-support system more likely to be encouraged</td>
</tr>
<tr>
<td>User feedback</td>
<td>Regular usage monitoring and research evaluation</td>
<td>Regular reports from vendors</td>
</tr>
<tr>
<td></td>
<td>Variety of tools employed</td>
<td>Variety of tools employed</td>
</tr>
</tbody>
</table>

Delivering excellent CDS requires addressing many governance issues. Among these are defining who will determine if, when, and in what order new decision support will be added; developing a process for assessing the impact of new decision support on information systems’ response time and reliability; building tools to enable tracking of what decision support is in place; developing an approach for testing decision support in silico; defining approaches for dealing with rules that interact; developing solid processes for getting feedback from users and letting them know what changes have been made in the underlying systems; and building tools for automated monitoring of decision support. These recommended CDS governance practices are summarized below.

Prioritize the order of development for new CDS and delegate content development to specialized working groups

One of the most important issues is developing a sound approach for determining what new decision support will be added and establishing a timeline for development and implementation. A high-level group should prioritize new and ongoing work (eg, blood transfusion-related CDS versus CDS around medications in the neonatal intensive care unit) while specific content work groups develop the prioritized content. Ideally, knowledge-management work groups should consist of local experts in each clinical content area. This process may be carried out internally or delegated to a vendor.

Consider the potential impact of new CDS on existing clinical information systems (such as the EHR application or computerized provider order entry system)

With all new CDS content or functionality it is vitally important to consider the potential impact on all related systems upon implementation. Organizations need a sound process in place for assessing any potential impact on their larger clinical information system ecosystem (ie, EHR, computerized provider order entry, laboratory results system). For example, what are the effects of a new intervention on usability, response time and reliability of the surrounding information system? Each organization is unique in institutional structure and culture, and thus assessments must be performed de novo for each institution, regardless of whether a new CDS is internally developed or purchased from a vendor. Careful evaluation is necessary to avoid potentially problems with related and interacting CIS.

Develop tools to monitor CDS inventory, facilitate updates, and ensure continuity

Robust tools must be built to monitor and maintain existing decision support. These tools facilitate tracking of when changes were made, when updating is due, and who is responsible for these activities within an organization. Having one person who can review all content (eg, a chief informatics officer) is very helpful, but when the amount of content increases, this may not be possible. Furthermore, planning for inevitable leadership transitions is essential in order to ensure continuity and maintain up-to-date content. The volume of clinical content and rule logic contained in these systems makes these tools necessary for ensuring the system is up to date and functioning properly, and for guiding future development and implementation.

Provide multiple robust channels for user feedback and the dissemination of systems-related information to end users

Building processes that make it possible for users to deliver feedback about the decision support is critical to user acceptance. When a significant issue or problem is identified, it is also crucial to have a process for responding to user suggestions and making appropriate changes. Some organizations such as Vanderbilt have gone so far as to deliver routine, individual reports back to providers after such feedback has been addressed. All organizations will need approaches for notifying providers of important changes in decision support (eg, new alerts, changes to the interface).

Develop tools for ongoing monitoring of CDS interventions (eg, rule firings, user response)

Approaches that enable automated monitoring of systems will be increasingly important, so that one can determine how often rules are firing and how users are responding to them. Flags should be set to enable the counting of rule firing, and approaches are needed to track user responses, including when users cancel or “escape” following a warning. Often, a seemingly minor change can have a major impact on how many warnings are being delivered, and even on overall system performance. In addition to ongoing monitoring of CDS inventory (as outlined in Recommendation 3), monitoring of CDS interventions is necessary for properly assessing the impact of CDS on clinician behavior and patient care. The combination of these tools provides continuous system feedback that can guide changes and additions to the CDS system.

Recommended practices for content management

The development and implementation of effective CDS also depend on sound content-management strategies. The large knowledge bases required for robust CDS necessitate frequent and thorough management in order to keep clinical content up to date. Based on our comparison of the five case studies, we define four recommended practices for content management.

Delineate the knowledge-management life cycle

The knowledge-management life cycle is an iterative and cyclical process for maintaining the large knowledge bases that CDS requires. The life cycle typically extends from recognition of...
Assessment of the impact and feedback on the intervention.

Recognition of a clinical need.

Maintenance and periodic review with modification, retirement, or replacement of the intervention (if needed).

Identification, understanding, and development of current clinical knowledge (evidence) relevant to the need.

Identification and implementation of the best possible CDS intervention that can be implemented given the EMR’s limitations.

Assessment of the features and functions of the EMR system that will be used to deliver these interventions.

Figure 1 Knowledge-management life cycle. CDS, clinical decision support; EMR, electronic medical record.

Implement user-feedback tools that encourage frequent end-user input

All of the sites provided some capability for user feedback, ranging from feedback buttons embedded in the EHR application to email, helpdesk query tracking, and clinical representation on committees. Listening and responding to feedback is an important tool for product improvement. It also has the added advantage of fostering a sense of ownership of the product by end users when they feel that their input is valued.

Considerations for smaller sites

The governance and content-management strategies we identified are most applicable for large sites with mature and robust CDS. However, small sites that are earlier in the process of developing CDS also face similar governance challenges. The primary differences are that, in general, most small sites have a limited ability to develop and monitor CDS and, as a result, tend to purchase their decision support from commercial content suppliers, rather than developing the content themselves, and tend to rely on general-purpose software tools and built-in EHR functions. In a small practice environment, some tasks, such as monitoring inventory and user feedback, may be simpler to accomplish. Overall, small sites must confront the same issues but with the added challenge of limited financial resources and personnel.

Limitations and future work

The purpose of this project was to develop an initial framework for thinking about governance for CDS and to identify a set of recommended practices based on our work. However, this approach has several important limitations, which correlate with opportunities for future work. First, we presented data on a total of five exemplary sites which are purposefully non-representative of typical practice—we believe that this approach maximized what we could learn, but it also limits the generalizability of our data. Further exploration of more sites (especially sites with more typical CDS environments) would contribute to a more well-rounded understanding of CDS governance practices, as widely applied. In addition, it may also be worthwhile to expand our assessment of CDS governance practices to include the role of professional organizations, national regulatory bodies, and clinical content vendors. The governance issues discussed in this paper are not limited to commercial EHR vendors and healthcare institutions, and in the future, we hope to investigate the role of these additional key players in CDS development and implementation. Finally, the sites studied included only US institutions, which further limits the generalizability of our findings—future study of an internationally representative collection of sites is also likely to be fruitful.

In addition, although we employed a well-established method of qualitative data collection (RAP), complementary future quantitative research could shed further light on CDS governance practices and enhance generalizability. We identified recommended practices based on consensus and expert opinion, and as a result, some effective practices may have been missed. Ideally, these practices would be studied further through a combination of observational or even experimental studies in order to more rigorously quantify the methods for and value of governance. Because of the present relative paucity of sites with advanced (or even formal) governance structures, it may yet be premature to perform such a study, but once there exists a sufficient set of institutions with reasonably robust governance practices, we believe that such a study would add great value to the literature.

Finally, we were not able to characterize the cost of CDS governance, or to study the financial implications of different governance approaches. It would be valuable to assess the comparative cost of different approaches to CDS governance across multiple institutions. However, given the small number of sites with extensive experience in CDS governance and the difficulty in determining costs of large and multifaceted...
governance structures, such an analysis was not possible at this time but would be a useful future research endeavor.

CONCLUSIONS
We have synthesized five case studies and identified a set of recommended practices for governance and content management. The five sites we studied were quite diverse; however, they had also learned many overlapping and complementary lessons about governance for CDS. Although the needs of every implementer of decision support are different, we believe that many of these recommended practices may be nearly universal and that all implementers of decision support should consider employing them.

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