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Best practices for preventing malfunctions in rule-based clinical decision support alerts and reminders: Results of a Delphi study

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ABSTRACT

Objective: Developing effective and reliable rule-based clinical decision support (CDS) alerts and reminders is challenging. Using a previously developed taxonomy for alert malfunctions, we identified best practices for developing, testing, implementing, and maintaining alerts and avoiding malfunctions.

Materials and methods: We identified 72 initial practices from the literature, interviews with subject matter experts, and prior research. To refine, enrich, and prioritize the list of practices, we used the Delphi method with two rounds of consensus-building and refinement. We used a larger than normal panel of experts to include a wide representation of CDS subject matter experts from various disciplines.

Results: 28 experts completed Round 1 and 25 completed Round 2. Round 1 narrowed the list to 47 best practices in 7 categories: knowledge management, designing and specifying, building, testing, deployment, monitoring and feedback, and people and governance. Round 2 developed consensus on the importance and feasibility of each best practice.

Discussion: The Delphi panel identified a range of best practices that may help to improve implementation of rule-based CDS and avert malfunctions. Due to limitations on resources and personnel, not everyone can implement all best practices. The most robust processes require investing in a data warehouse. Experts also pointed to the issue of shared responsibility between the healthcare organization and the electronic health record vendor.

Conclusion: These 47 best practices represent an ideal situation. The research identifies the balance between importance and difficulty, highlights the challenges faced by organizations seeking to implement CDS, and describes several opportunities for future research to reduce alert malfunctions.

1. Background

In 2007, AMIA published "A Roadmap for National Action on Clinical Decision Support" [1]. The roadmap defined clinical decision support (CDS) as systems which provide "clinicians, staff, patients, or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care" and, further, that such a system "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" [1 p.141].

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Since that seminal paper was published, studies of CDS systems have shown that they can improve quality and safety and reduce costs [2–10]. However, it has also been shown that developing and maintaining CDS systems can be costly, time-consuming and complex [11–25].

As part of a larger project on CDS malfunctions, we have previously described different malfunctions in CDS systems [26–29], with a particular focus on rule-based alerts and reminders. We define a CDS malfunction as "an event where a CDS intervention does not work as designed or expected" [30]. Following our identification of four malfunctions in rule-based CDS alerts at the Brigham and Women's Hospital (BWH) [29], we conducted a large mixed-methods study that included: site visits, interviews with CDS developers and managers, a survey of physician informaticists, and statistical analyses of CDS alert firing and override rates, all with a goal of identifying additional examples of CDS alert malfunctions [30]. Using these methods, we identified and investigated 68 alert malfunctions that occurred at 14 different healthcare provider organizations in the United States, using a wide variety of commercial and self-developed electronic health record (EHR) systems. We also asked informants at each site about best practices for preventing malfunctions, including those already in use and those being contemplated.

One result of these efforts was the development of a taxonomy of malfunctions in CDS alerts. The taxonomy was organized under four axes: the cause of the malfunction, its mode of discovery, when it began, and how it affected alert firing [30]. The taxonomy is reproduced in Fig. 1.

After identifying and classifying the causes and effects of CDS alert malfunctions within a taxonomy, we turned our attention to strategies that represent best practices for preventing and detecting CDS alert malfunctions. In this paper, we present the results of a rigorous Delphi study of approaches for preventing, detecting and mitigating such malfunctions. This work is a continuation of our prior work on CDS malfunctions.

2. Methods

2.1. Initial identification of best practices

To identify best practices, we began by reviewing transcripts and field notes from our mixed-methods study [30]. We also analyzed our database of 68 CDS alert malfunctions to identify practices that might have prevented each malfunction. The five core research team members did this by meeting and discussing each malfunction, brainstorming possible practices for prevention of that particular malfunction, and reaching consensus on the most important best practices.

In many cases, a practice which had already been described by an interview subject in the mixed-methods study could have prevented the malfunction. In other cases, none of the practices provided by interview subjects would have prevented the malfunction, but another method was identified through existing recommendations in the literature or brainstorming and discussion by members of our research team.

2.2. Expert consensus development using a modified delphi method

2.2.1. Delphi method overview

To refine, enrich and prioritize the list of practices, we selected the Delphi method [31]. The Delphi method is one of several expert consensus methods, along with the nominal group technique and consensus development conferences [32]. The Delphi method was developed by the RAND Corporation under the name "Project Delphi", an allusion to the Oracle at Delphi which prophesied the future. In 1951, RAND conducted a classified experiment using the Delphi method for the United States Air Force to assess the number of bombs that would be needed in a hypothetical war between the United States and the Soviet Union. The results of the experiment were originally classified, but were declassified in 1963 [33].

The Delphi method has been described in detail in many articles [31,33–35]. Briefly, a Delphi study uses a panel of experts who answer questionnaires in two or more rounds. Between each round, the facilitator shares anonymous feedback from the experts and develops a revised questionnaire which takes the expert feedback into account [31]. The goal of the Delphi method is that the experts will reach a consensus that is more accurate than any of their original perspectives. Moreover, since the process is anonymous and asynchronous, it is less likely to be dominated by particularly vocal or persuasive experts, allowing each expert to share his or her perspective without being influenced by the other experts.

The method has been used widely in clinical guideline development, public health and healthcare applications [36–46]. It has also been effective in informatics research [47,48]. We selected it for our study because of its strong performance and the fact that it did not require in-person collaboration, given that our experts were geographically distributed.

2.2.2. Survey development

We used a web based data collection platform for administering each round of our Delphi study. After completing the qualitative study and database analysis described above, our research team identified an initial list of practices and sorted them into categories. A prototype of the Round 1 survey instrument was developed using this list. The instrument was presented to pilot testers (members of the research team and additional experts) who agreed to provide early feedback as pilot users of the collection instrument. After pilot testing, the research team revised the survey instrument, eliminated or consolidated some best practices and modified others to create the final survey instrument used in Round 1. A similar process was used after Round 1 to develop the Round 2 survey instrument. Our study was reviewed by the Partners HealthCare Human Subjects Committee, which found it to be exempt.

2.2.3. Expert panel

To begin our Delphi process, we identified 36 experts through a literature search and expert nomination process representing five areas of EHR and CDS expertise:

1 Representatives of medical specialty societies and policymakers involved in CDS
2 Employees of EHR software vendors who focus on CDS
3 Employees of clinical content vendors (including online medical references, drug compendia and providers of ready-made CDS content)
4 Biomedical informaticians who conduct research on CDS
5 Applied clinical informatics specialists who develop and manage CDS in healthcare organizations

To form our expert panel, we contacted potential experts by email, and personally invited them to participate in the study. Those who agreed received two rounds of surveys to complete. Many Delphi studies use only a few experts (from 6 to 12), but we felt that representation from each of the five groups was critical, so we invited several experts in each category.

2.3. Delphi Round 1

In Round 1, each category of best practice items was presented as one screen in the survey, and respondents could freely move forward and backward between the screens. For each practice, the experts were asked to indicate "whether you think the item should be included on a list of best practices to prevent CDS malfunctions" by selecting one of five responses: "Keep," "Leaning toward keep," "Leaning toward delete," "Delete," or "I don't understand what this means." Respondents were able to provide open-ended feedback about each item. On each