Continual Development of a Personalized Decision Support System

Dina Demner-Fushman[a], Charlotte Seckman[b], Cheryl Fisher[c], George R. Thoma[a]

[a] U.S. National Library of Medicine, NIH, Bethesda, MD, USA
[b] School of Nursing, University of Maryland, Baltimore, MD,, USA
[c] NIH Clinical Center, Bethesda, MD, USA

Abstract

Improving the safety, quality, and efficiency of care with the help of clinical decision support tools is one of the core objectives in the meaningful use of Electronic Health Records. Successful adoption of support systems depends on the quality of delivered information, its relevance to the clinical task and individual patient, integration of the system with the entire clinical workplace, and ease of use of the system. This paper presents continuous development and evaluation, as well as lessons learned in development and maintenance of an evidence-based system that supports development of individualized patient care plans. Since its deployment in August 2009, the Evidence-Based Practice InfoBot (EBP InfoBot) system is in daily use at the NIH Clinical Center and responds to 21 requests a day, on average.

Keywords:

Information Systems, Clinical Decision Support Systems, Electronic Health Records, Patient Care Planning.

Introduction

To ensure safe patient-centered care, clinicians need timely access to information for: 1) developing plans of care, 2) patient education, 3) communication of safety alerts, 4) medications, and 5) other orders and procedures. [1]. Electronic health records (EHRs) are the ideal medium for including this information in the clinical workflow so that it could potentially improve the safety, quality, efficiency and effectiveness of care [2]. Some commercial systems provide clinical decision support (CDS) that considers patients' age, gender, race, pregnancy status, smoking history, co-morbidities and lab results [3]. Some EHR systems include Infobuttons that provide access to information maintained by third parties, such as access to MedlinePlus® information through MedlinePlus Connect[1]. Alternatively, this information could be accessed using OpenInfobutton [4]. Clearly, the Infobuttons standard [5] and the publicly available tools that implement the standards provide a means for including decision support (that could be personalized to some extent) into EHRs and clinical workflow. Therefore, the Evidence Based Practice (EBP) Infobot focuses on further personalization of information, both to the patient and to the clinical task by: 1) extracting EHR information that will allow patient-specific personalization of support, 2) accessing sources of evidence to support development of individualized plans of care, and 3) providing an overview and details-on-demand display of the evidence in the EHR.

The EBP InfoBot is a passive CDS system comprised of a thin client that pulls information from the National Institutes of Health (NIH) Clinical Center EHR, Sunrise Enterprise™ 5.5, and provides a user interface to display the decision support dashboard generated by the National Library of Medicine (NLM) InfoBot server. The server processes information sent by the client and pulls pre-specified resources to generate the dashboard. The EHR fields that provide information about the patient, the sources of evidence needed to develop plans of care, and the design of the evidence dashboard were initially outlined in a focus group with the NIH interdisciplinary teams' representatives.

To evaluate the initial design, we implemented a mock-up prototype system that emulated a real-time CDS system [6]. The results of a formal evaluation of the prototype defined the next steps in development and deployment of the real-life system. Striving to keep the support system current and relevant, we adhere to the initially adopted spiral model of system development.

The importance of continuous evaluation and user-feedback based (re)designing of systems was recently emphasized in a systematic review of 42 CPOE design aspects [7]. Our paper presents four years of such continuous development and evaluation of a system that supports development of individualized patient care plans. We first present a usability evaluation of the prototype system and the evaluation results that enabled the implementation of our first embedded support system. The paper then discusses an intermediate focus group evaluation conducted in anticipation of a major EHR upgrade and the steps taken to seamlessly integrate the support system with the new EHR. We conclude the paper with the log-based analysis of the patterns of use of the system for the past four years, lessons learned in development and maintenance of the system, potential value to practitioners and plans for evaluation of the contributions of the system to delivery of care.

Methods and Procedures

The continuous evaluation of the system consists of 1) a usability evaluation of the prototype (with emphasis on the usefulness of the information provided by the system, rather than technical usability that was addressed in one question), 2) a focus group discussion of the system about half a year after its deployment, 3) continuous online survey linked to the InfoBot system display (henceforth, "information dashboard") to evaluate post-implementation usability concepts, and 4) monthly analysis of system logs. The system underwent a major re-design based on the results of the usability evaluation and a substantial re-design of the information dashboard based on the results of the focus group evaluation.

---

[1] http://www.nlm.nih.gov/medlineplus/connect/overview.html

Prototype Usability evaluation

We chose a non-experimental, descriptive research study design utilizing a purposive sample. The mock-up prototype system provided evidence for information automatically extracted from 4,335 de-identified interdisciplinary team notes for 525 patients. The following fields were extracted from the EHR: hospital unit, protocol number(s)[2], chief complaint, interdisciplinary problem (IDP) category, and IDP free text describing the problem, planned intervention and its goal. We processed the narrative part of the notes and automatically extracted biomedical terminology from 4,219 notes, which allowed us to automatically link resources to 260 patient records that contained these 4,219 notes (in addition to resources available for chief complaints and protocol numbers for all patients).

We identified four specialty areas (Pediatrics, Oncology & Hematology, Medical & Surgical, and Behavioral Health) and randomly selected 15 records from each (60 total out of 260 records with linked resources). We then recruited 16 research nurses from medical/surgical, behavior health, pediatrics, and hematology/oncology units. These nurses were representative of the intended end-users (members of the interdisciplinary teams) and were trained in evaluating evidence sources. These clinicians were divided into four groups of four based on their specialty area and evaluated 15 records each in their specialty area. They were provided a view that included chief complaint, protocol name, and free text from interdisciplinary problem entries for each patient in their evaluation set. The evidence presented for review included patient-specific definitions of clinical terms, nursing standards of practice and procedures, and review articles from the Cochrane Database of systematic reviews. Evaluators scored the relevancy and usefulness of the presented information to each patient case via an online form.

Focus group evaluation

The focus group assembled in March 2010 included 20 members of interdisciplinary teams and represented Nursing, Social work, Pharmacy, and Nutrition. The moderators of the focus group prepared 30 interdisciplinary problems and a questionnaire to guide the discussion. The following questions were discussed:

1. Was the information relevant to the patient cases presented?

2. Did you find the information (for example, definition, nursing standard of practice and procedure, review articles) useful/helpful in your clinical care?

3. Was the information dashboard easy to use? What would have made it easier?

4. How often would you use the information dashboard? What would make you use it more often?

5. Did you access / read the articles?   Why or why not?

6. When would you use the information dashboard? Would you use it for selected patient cases?

7. Is there anything we haven't asked that you think we should know?

Post Implementation Usability Survey

An online survey is accessible from the information dashboard shown in Figure 1 and Figure 2. It consists of five items that

---

[2] The protocol number identifies the clinical trial that enrolled the patient. One patient may be enrolled in more than one trial.

evaluate relevancy and usefulness of the information delivered for the patient whose record was accessed when the user chose to take the survey. For the first two items, five types of delivered information are evaluated on a five point Likert scale. The five types of information are: 1) clinical terms extracted from the notes and their definitions, 2) standards of practice, 3) evidence-based articles, 4) information about medications, 5) patient education material. Items 3 and 4 are also evaluated on a five point Likert scale. The 5th item provides a text field for additional comments. The questionnaire items are:

1. The content presented in EBP InfoBot for the items below were RELEVANT to the patient data provided:

2. The information items below were USEFUL in developing a plan of care for this patient:

3. Was it easy to navigate to the supplied documents in EBP InfoBot? (the scale ranges from *Yes, it was intuitive* to *No, it was always difficult to find what I needed*)

4. Overall, the information found in EBP InfoBot was: (the scale ranges from *Too much* to *Not enough*).

5. Please add any comments you have about content or usability of the EBP InfoBot feature.

The survey also collects information about the users' clinical roles, highest educational degrees, age, gender, affiliation with one of the NIH Institutes or Centers, and their regular shift (day, evening, night).

System logs

The EBP InfoBot system registers all users' actions within the EBP InfoBot tab. The system registers the initial access to the information dashboard and the search requests automatically generated using information extracted from the notes. The system captures the date and time of access, and links followed from the dashboard. The dashboard provides a mechanism for judging each retrieved article for relevance and usefulness to the patient's case. These judgments are also captured in the log files.

Results

We first present the results of the usability study, then the changes to the system design and the information dashboard that resulted from this evaluation. We then present the results of the focus group discussion and the changes to the information dashboard based on the results of this discussion. Finally, we present the results of the online survey and the user log analysis.

Usability evaluation of the mock-up prototype

Relevance and usefulness for care plan development

The clinicians evaluated three types of information (term definitions, standards of practice, and articles) for each of the 15 cases in their respective specialties. Across the four clinical specialties, the majority of cases had relevant definitions (73.4%) and standards of practice (65.4%). The judgments on relevancy of the articles were divided between neutral (45.7%) and relevant (47.8%). The overall mean relevancy score ranged from 3.57 – 3.86 indicating that term definitions, standards of practice, and articles were mostly relevant to the cases. Similarly to the relevance of evidence, for all clinical specialties, the majority of cases had useful definitions (66.1%) and standards of practice (63.5%). The evaluations of the usefulness of the

articles were divided between neutral (47.4%) and useful (44.0%). The overall mean usefulness score ranged from 3.51 – 3.71 indicating that term definitions, standards of practice, and articles were mostly useful for clinical care. Table 1 presents the results of the evaluation of usefulness of the information for care plan development. Mean scores for relevancy and usefulness for the Medical/Surgical and Oncology/Hematology specialty areas were higher than for the other two groups indicating the documents were somewhat more relevant and useful for them. This might be explained by fewer Cochrane reviews and randomized clinical trials in Pediatrics and Behavioral Health.

Ease of use, information amount and potential future use

The majority of the testers indicated that the system was intuitive (62.5%) or easy to use after a little practice (25%). Only 12.5% indicated that some of the system's functions were not easy to use. Similarly, 43.8% indicated the system delivered about the right amount of information and 31.2% of the testers expected somewhat more evidence, but were relatively satisfied with the delivered amount. However, 25% of the testers deemed that not enough information was provided.

Table 1 – Questionnaire item: EBP InfoBot information is useful in clinical care.

Evidence type	N	Mean (SD)	% disagree	% neutral	% agree
Definitions	236	3.71 (0.98)	15.3	18.6	66.1
Standards	52	3.67 (1.04)	13.5	23.0	63.5
Articles	232	3.51 (0.96)	8.6	47.4	44.0
N=number of responses			(1=strongly disagree, 5=strongly agree)		

With respect to use of a similar system if it were included in the workflow, the testers responded as follows: 3 would use the system at least once a day; 4 would use it several times a week; 5 at least once a week; and 4 less than once a week.

System Design (based on prototype evaluation)

Encouraged by the response that showed the majority of evaluators (75%) would use the EBP InfoBot about once a week or more, we implemented the system that provides individualized evidence for care plan development. The initial plans (that motivated the design of the mock-up system) for an asynchronous system that will pull the EHR database for new information about each patient, prepare evidence and hand it over to the EHR for display on demand were too complex to be implemented in practice. We therefore implemented a real time system that is brought into motion when a clinician accesses the EBP InfoBot tab in the NIH Clinical Center EHR, which is referred to as the Clinical Research Information System (CRIS). The process starts with a stored procedure that assembles the progress notes, medication lists, chief complaints and clinical trial protocol numbers into a request to the NLM InfoBot server. The server prepares the response in the form of the HTML page that is displayed in CRIS.

Focus Group evaluation

Answering the question about relevancy of the presented information to the case, the focus group participants pointed out several errors in the problems list that was sent to the InfoBot server: for some patients the problem list was wrong (e.g., from a previous admission) and for some it was not the latest update

of the current problem list. For all patients, only the first protocol number was extracted, but many patients had more than one protocol number. For the search query generation rules, the InfoBot server focused on the Chief Complaint, however, the nurses pointed out that the Chief Complaint issues do not pertain to nursing care decisions.

For the question about usefulness of the provided information, the focus group deemed seeing all of the patient's medications and having direct access to Micromedex as the most helpful feature that they use daily. MedlinePlus articles (used as needed for patient's education) were named as a very useful feature.
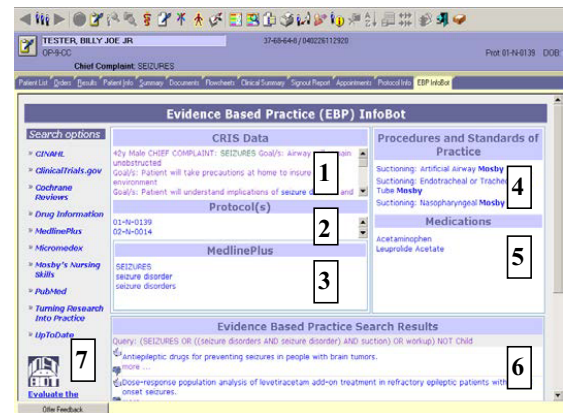

Figure 1 – EBP InfoBot tab in the NIH Clinical Center EHR, CRIS in 2009. Using the problem, procedure and drug terms extracted from the note (1) the panels provided links to MedlinePlus (3), MEDLINE® search results (6), Micromedex(5), and standards of practice (4), as well as links to the protocols of clinical trials (2) and generic links to EBP Web sites (7). This dashboard was modified as shown in Figure 2 as suggested by the focus group and the online survey participants.

All focus group participants noted that the system is very easy to use; one of the participants summarized the common opinion: "Can't think of anything easier than clicking on a link." The participants noted that they did not know about some of the InfoBot functions prior to reviewing the cases for the focus group discussion. They planned to use InfoBot more often after the evaluation that exposed them to the InfoBot functions. The focus group suggested introducing InfoBot during CRIS orientation session to increase its visibility and use.

For the question about access to articles in search results, the evaluators pointed out that the bottom-line summaries provided in the dashboard were very helpful in deciding to follow the link to the article. They did follow the links to some of the articles, but there was no time for reading. The evaluators noted that if time will be allotted for nursing rounds, they would read and discuss the articles. They noted that the interns used the articles. With respect to the question "when would you use the EBP InfoBot", the participants noted that it is useful for introducing a patient to a new nurse, as well as for developing plans of care for new or unusual patients. They routinely access the tab for information about medications. When asked what additional information might be useful, the participants asked to provide pictures of pills; develop an information dashboard for discharge planning; and show not only the interdisciplinary team notes, but also the doctors' progress notes in the dashboard.
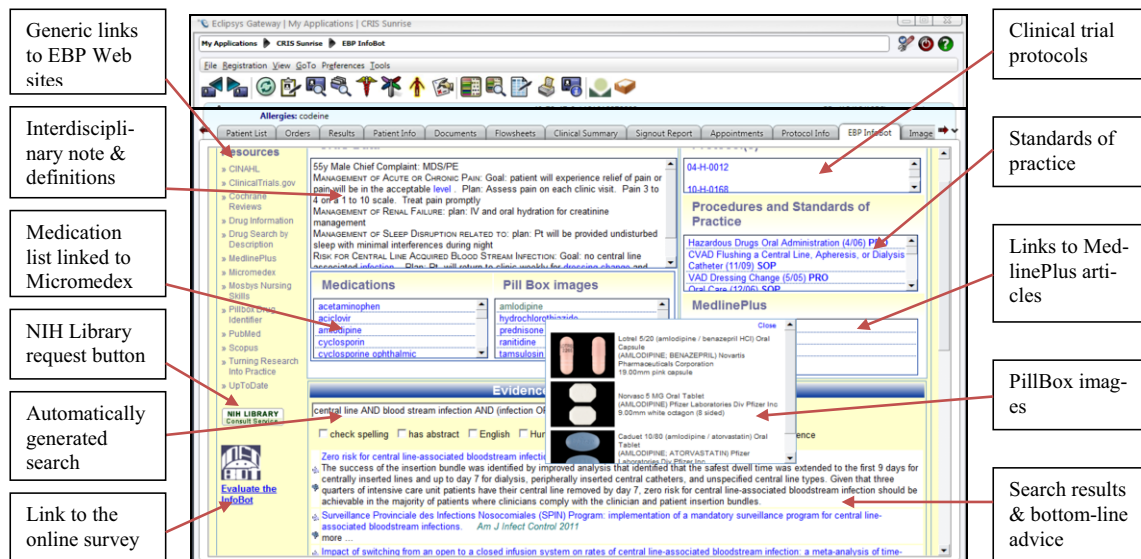
Figure 2 - The current EBP InfoBot tab in CRIS. The left-most pane provides generic links to evidence sources, a link to the online survey and a button that brings up a form to request patient-specific information to be prepared by a NIH library staff informationist. The top left pane shows the current interdisciplinary team progress note, the top right pane links to specific protocols in ClinicaTrials.gov. The middle left panes link the patient's medications to Micromedex and the NLM PillBox images of pills. The middle panes on the right link problems and drug names extracted from the note to the standards of practice and patient education information in MedlinePlus. The bottom pane displays search results that can be judged using the "thumbs up" and "thumbs down" icons displayed next to the bibliographic information and the summary of the article. The automatically generated search query is displayed above the results in a text field that can be edited to submit a new query.

The other comments touched on the color scheme of the tab and the layout of various panels. The results of addressing the focus group comments yielded an improved information dashboard shown in Figure 2.

Survey results

The results of the online survey, shown in Table 2, are consistent with the results of the usability study: the relevancy and usefulness are judged mostly positively for all information types.

Table 2 – Online survey results: Average judgments of relevancy and usefulness of patient specific information.

Items	Relevant	Useful
Terms & definitions	4.07	3.96
Standards of Practice	3.64	3.54
EBP Articles	3.46	3.41
Medication Information	4.11	4.04
Patient Education Materials	3.79	3.72
N=30	(1=not useful, 5=very useful)	

As in the usability study, most clinicians (86%) found the system easy to use, equally dividing the scores between 5 (intuitive) and 4 (easy with some practice); the remaining participants scored the ease of use as 3 on the 5-point scale. The results of the evaluation of appropriateness of the amount of information are shown in Figure 3.

System logs analysis

During the past four years, over 1,000 distinct users accessed the InfoBot tab in CRIS over 30,000 times. Tables 3 and 4 present the total number of users, dashboard access, and followed links by year.
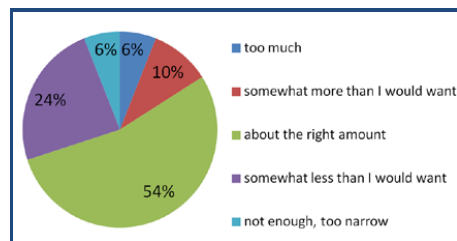

Figure 3- Online survey results for the amount of information

Table 3 –EBP InfoBot access logs

Year	N	NR	Total access	Dayly access (mean)	Generic search
2009	969	446	6,353	17.4	199
2010	1863	1078	10,048	27.5	124
2011	1279	635	6,210	17.0	918
2012	1379	677	8,735	23.9	1161
Total			31,346	21.4	2402
N= distinct users; NR = repeat users					

The patterns of use of the provided resource confirm information captured in the surveys: the most frequently followed

links are to Micromedex drug information and the protocols of the clinical trials. The least frequently followed links are to the standards of practice (69 over four years). The relevance judgments on individual articles are also infrequent, with negative judgments slightly prevailing over the positive (157 negative and 130 positive overall.)

Table 4 –Links followed from EBP InfoBot dashboard

Year	CT	MPlus	Articles	Def.	Drug Info / Pill images
2009	636	202	229	168	438 /--
2010	608	210	220	122	1008 /--
2011	284	114	90	93	414 /106
2012	274	146	213	560	509 /195
Total	1,802	672	752	943	2389 /301
CT= ClinicalTrials.gov; MPlus = MedlinePlus; Def. = Definitions					

Discussion

A valuable lesson learned in our study is that individualized decision support depends highly on the IT support for the EHR and communications between all parties providing CDS. Note the drop in the total access to the EBP tab in 2011. This drop was caused by the redesign of the interdisciplinary notes in CRIS. When the new note structure was launched, the stored procedure that sends the note to the InfoBot server was not updated and for several months the note field of the dashboard was empty and the searches were done only for medications and chief complaints (taking into account patients' age and gender). Since the tab was functioning and providing some information, the clinicians did not report the problem because it was not as obvious as complete interruption of service. This incident provides an additional lesson: CDS systems have to be monitored not only for complete failures but also for the quality and completeness of delivered information. Once the stored procedure was updated, the use of the tab gradually returned to the stable 700 – 900 accesses a month. Another consequence of failing to provide truly personalized support might be the increased use of the generic links to evidence-based sources, such as UpToDate and CINAHL. The increased use of the generic links might also indicate that we need to conduct another evaluation and a subsequent update of the system.

Overall, the patterns of daily use, the user satisfaction with the resources, and the consistency of the findings over the four years of use of the system support the previously reported findings of the Infobutton Manager (IM) evaluations [8]. The multi-modal evaluation of the use of IM by 4,577 clinicians was based on two years of log files, 195 pop-up surveys, 108 instances of online feedback, and 70 e-mail surveys. It showed that its impact on patient care decisions has been positive.

Several of our observations indicate that the support system has become an integral part of the patient care process for many members of the interdisciplinary teams: the steady numbers of returning users, the willingness to spend some valuable time to voluntarily complete the online survey, and the immediate filing of IT requests on the rare occasions when the system is not responding to requests. In the future, we plan to quantify the functional capabilities provided by our system in an evaluation based on the four axes of the taxonomy developed by Wright et al [9]. The axes include: 1) Triggers (the events that invoke CDS); 2) Input data (the EHR data elements used by CDS); 3)

Interventions (the actions taken by CDS); and 4) Offered choices (the choices that the users can make).

In conclusion, clinicians are not only ready to use information resources, but expect the resources to be personalized and readily available. Our future research of delivering personalized information will focus on better understanding and prioritization of the problems stated in the progress notes, better alignment of information resources, expansion of support to other clinical tasks and a broader group of clinicians, as well as continuous evaluation of the functioning and impact of the system.

References

[1] Caligtan CA, Carroll DL, Hurley AC, Gersh-Zaremski R, Dykes PC. Bedside information technology to support patient-centered care. Int J Med Inform. 2012;81(7):442-51.

[2] Blumenthal D, Tavenner M. The "meaningful use" regulation for electronic health records. N Engl J Med. 2010 Aug 5;363(6):501-4.

[3] Bernstam EV, Johnson TR, Strasberg HR, Hersh WR. Personalized Medicine Requires Personalized Clinical Decision Support. AMIA Annu Symp Proc. 2011;2011:136-8.

[4] Cimino JJ, Jing X, Del Fiol G. Meeting the Electronic Health Record "Meaningful Use" Criterion for the HL7 Infobutton Standard Using OpenInfobutton and the Librarian Infobutton Tailoring Environment (LITE). AMIA Annu Symp Proc. 2012;2012:112-20.

[5] Del Fiol G, Huser V, Strasberg HR, Maviglia SM, Curtis C, Cimino JJ. Implementations of the HL7 Context-Aware Knowledge Retrieval ("Infobutton") Standard: challenges, strengths, limitations, and uptake. J Biomed Inform. 2012 Aug; 45(4):726-35.

[6] Demner-Fushman D, Seckman C, Fisher C, Hauser S, Thoma G. A prototype system to support evidence-based practice. AMIA Annu Symp Proc. 2008:151-5.

[7] Khajouei R, Jaspers MW. The impact of CPOE medication systems' design aspects on usability, workflow and medication orders: a systematic review. Methods Inf Med. 2010; 49(1):3-19.

[8] Cimino JJ. Use, usability, usefulness, and impact of an infobutton manager. AMIA Annu Symp Proc. 2006:151-5.

[9] Wright A, Sittig DF, Ash JS, Sharma S, Pang JE, Middleton B. Clinical decision support capabilities of commercially-available clinical information systems. J Am Med Inform Assoc. 2009 Sep-Oct; 16(5):637-44.

Address for correspondence

Dina Demner-Fushman, U.S. National Library of Medicine, Lister Hill National Center for Biomedical Communications, NIH/HHS, Bethesda, Maryland 20894, USA E-mail: ddemner@mail.nih.gov