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# Using Clinical Decision Support to Maintain Medication and Problem Lists: A Pilot Study to Yield Higher Patient Safety

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# Using Clinical Decision Support to Maintain Medication and Problem Lists

## A Pilot Study to Yield Higher Patient Safety

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*Abstract*— **To investigate whether clinical decision support that automates the matching of ordered drugs to problems (clinical diagnoses) on the problem list can enhance the maintenance of both medication and problem lists in the electronic medical record, we designed a clinical decision support system to match ordered drugs on the medication list and ongoing problems on the problem list. We evaluated the capability and performance of this clinical decision support system in medication-problem matching using physician expert chart audits to match ordered drugs to ongoing clinical problems. A clinical decision support system was shown to be useful in improving medication-problem matches in 140 randomly selected audited patient encounters in three inpatient units. Enhanced maintenance of both the medication and problem lists can permit the exploitation of advanced decision support strategies that yield higher patient safety.**

*Keywords*— **clinical decision support, computerized physician order entry, electronic medical record, medical errors, patient safety.**

## I. INTRODUCTION

Medical errors may cost tens of thousands of lives in U.S. hospitals each year, more than deaths from highway accidents, breast cancer, and AIDS combined [1]. The 1999 Institute of Medicine (IOM) report emphasized that medical errors were the eighth leading cause of death in the U.S. [2]. Medical errors threaten the quality of health care and contribute to the medical malpractice crisis. Despite previous research revealing that the problem list is vital for clinicians in evidence-based practices, the state of medication and problem list documentation remains unsatisfactory [3]. A recent case report showed that the death of a female patient was ascribed to the failure to maintain her ongoing problem list by her primary care physician [4]. According to another medical report, one in every 10 patients admitted to six Massachusetts community hospitals suffered serious and avoidable medication errors [5]. In a review of 110 discharge medication lists in the Augusta Mental Health Institute of Maine, 22% contained errors [6].

Computer-assisted information technologies that support safer patient care have been widely adopted at many medical institutions in the U.S. [7]. Clinical decision support can help achieve the goal of error reduction [8]. The embedding of a clinical decision support system (CDSS) into patient care workflow provides opportunities to reduce medication errors and improve patient safety [9]-[13]. Alerts are a vital component of clinical decision support [14]-[17], and automated alerts remain an important part of current error reduction strategies [18] and [19].

Optimal medication and problem lists reflect patients' current lists of ordered medications and ongoing problems. The problem list helps physicians check against potential prescribing errors, reminds them of issues often forgotten [20], and improves communication among health care providers [21]. An accurate problem list facilitates automated decision support, clinical research, data mining and patient disease management [22]-[24]. An accurate computerized medication list is a direct outgrowth of computerized physician order entry (CPOE) and e-prescribing, while an inaccurate medication list can result in risks to patient safety and adversely affect quality of health care [25] and [26]. Proper management of the medication and problem lists can reduce potential medication and diagnostic errors.

Previous audits on 25 patient charts at the University of Illinois Hospital (UIH) revealed that problem list maintenance is haphazard [27]. In many patient charts multiple versions of the problem list coexist. Some lists lack critical problems (clinical diagnoses); other lists have many resolved or inactive problems. Similarly, many medical records contain numerous and inconsistent medication lists, which do not reflect the actual medications taken by a specific patient. Medication lists are often obsolete (containing medications no longer prescribed) or incomplete (lacking medications that are prescribed), while multiple reconciled versions of the medication list coexist in the same medical record. Most medical records make no attempt to establish medication-problem relationships or ordering by indication.

It is a major challenge to provide physicians a useful computerized information system to reduce medication errors in the electronic medical record (EMR). We designed a CDSS

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prototype to investigate whether a CDSS that assists matching ordered medications to ongoing problems on the problem list can improve the maintenance of both medication lists and problem lists on the EMR.

## II. METHODS

### A. Design

To assist physicians entering the patient's medication list and problem list in maintaining the accuracy and completeness of the EMR, we designed a Windows-based system named Problem List Expert (PLE©) to simulate both a CPOE for ordering medications and an EMR [28]. The PLE© is a stand-alone CDSS based on Microsoft Access® and programmed with Visual Basic®. The PLE© was run concurrently with UIH's EMR on UIH's Intranet server environment and could open UIH's EMR (Cerner Millennium®) by a hyperlink control. We adopted an application tool (*Screen OCR®*) in the user interface of the PLE© to expedite data entry [29]. This implementation facilitated patient data retrieval from UIH's EMR to the PLE©. Through the enhanced user interface, physicians are able to create new patient records, create problem lists, and order medications. When a new medication is ordered through the CPOE, the PLE© assists in checking if an appropriate problem is on the active problem list that is an indication for the medication ordered.

The core of the PLE© is three linked database tables: the medication data dictionary, the problem data dictionary, and medication-problem relationships. There were over 1,000 drugs in the University of Illinois drug formulary added to the PLE©. Other key components of the PLE© are a patient data repository and a user interface. We had successfully adopted the PLE© to maintain the electronic problem list on the EMR. The PLE© is designed to determine the accuracy and completeness of the medication and problem lists.

Fig. 1 shows the infrastructure and workflow of the PLE© implementation, where the problem list obtained from UIH's EMR is termed the Reported Problem List; the medication list obtained from UIH's EMR is termed the Medication List; the list of medication-problem associations based upon clinician expert review is termed the Audited Problem List. The order of data entry was the patient's Reported Problem List, Audited Problem List, and Medication List, which were saved in the Patient Data Repository without patients' identities. The PLE© first examined the existence of entered items in the Medication Data Dictionary and the Problem Data Dictionary. The PLE© adopts machine learning and data mining algorithms for knowledge updating and discovery. New data will be automatically added in the corresponding data dictionaries accordingly.

We utilized natural language processing to match medications to problems. The matching algorithm in the PLE© examines each medication on the Medication List by linking its indications to the indications for those problems on the Audited Problem List through the defined association in the Medication-Problem Relationship table of the PLE©. Any mismatching medications detected by the matching algorithm in the PLE© were recognized as medication errors. Several common types of medication errors (caused by unnecessary,

inadvertent and missing medications) and diagnostic errors (caused by inactive and deficient problems) may risk patient safety and need to be fixed by physicians during chart audits.
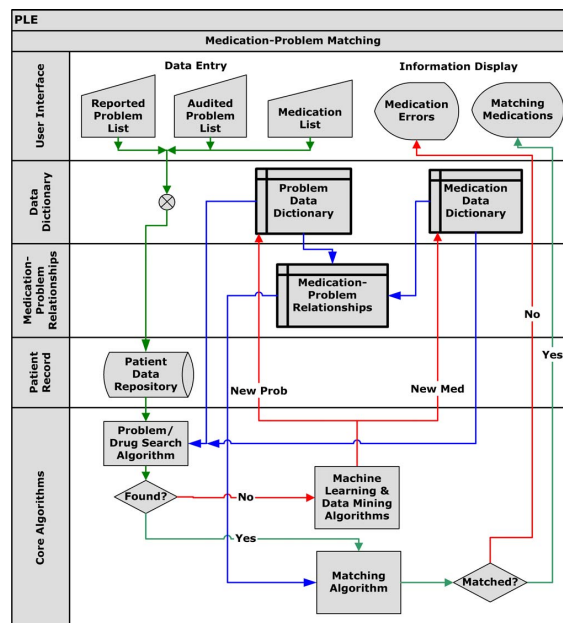


Figure 1.   The infrastructure and workflow of the PLE© implementation

### B. Statistical Analysis

Statistical analysis methods were used to analyze the datasets and results from this study. ANOVA was used to investigate whether clinical decision support enhanced the maintenance of medication and problem lists. Paired t-tests were carried out for comparing (1) the variance of the medication-problem matching outcomes before and after expert chart review, and (2) the improvement rate (%) of medication-problem matches on the problem list after expert chart audits by comparing the counts of the Reported Problem List and the Audited Problem List in all reviewed patient charts in three inpatient units at UIH. The descriptive statistics determined the means and standard deviations of the counts on the Reported Problem List, the Audited Problem List, the Medication List, the addition of suggested problems, unmatched medications on the Medication List, and unmatched problems on the Audited Problem List. The frequency statistics determined the top three items on both medication and problem lists that were unmatched. SPSS 15.0 for Windows was used to perform these data analysis tasks.

## III. MEASURES

We trained the PLE© with 100 test cases to fine-tune the matching algorithm and added new items in the medication data dictionary, the problem data dictionary and medication-problem relationships in the knowledge base using machine learning and data mining algorithms. We evaluated the capability of the PLE© in medication-problem matching using clinical expert chart audits on 140 patient encounters in three

inpatient units of UIH: 70 on a general medical floor, 27 on a Neurology unit and 43 on a Rehabilitation unit, respectively.

We assessed the performance of the PLE© in determining the accuracy and completeness of the Audited Problem List, the count of problems suggested by the PLE©, the improved ratio of medication-problem matches after chart audits, and the count of mismatched medications and problems on the Medication List and Reported Problem List.

## IV. RESULTS

The PLE© automated the maintenance of the medication and problem lists and detected likely medication-problem mismatches as visible medication and diagnostic errors on the screen of the EMR. The PLE© detected that approximately 11% of patient records had no problems of any kind listed on the Reported Problem List, and approximately 11% of patient records were perfectly matched (i.e., the count on the Reported Problem List equaled the count on the Audited Problem List). The remaining 78% of patient records showed various levels of problem deficiency on the Reported Problem Lists. The mean counts (± standard deviations) of problems and medications on the Reported Problem List, Medication List and Audited Problem List for each patient on a general medical floor and Neurology and Rehabilitation units are listed in Table I. The problem list non-compliance ratio was calculated to determine the deficient state of the problem list. The problem list non-compliance ratio was $0.53 \pm 0.27$, $0.56 \pm 0.35$, $0.49 \pm 0.31$ on a general medical floor, Neurology unit and Rehabilitation unit respectively, where the ratio was equal to one minus the quotient of the mean count on the Reported Problem List and the mean count of the Audited Problem List.

TABLE I. THE CAPABILITY OF CHART REVIEWS IN THREE INPATIENT UNITS AT UIH

| Predictor Variable | Inpatient Unit | | |
|---|---|---|---|
| | General Medical | Neurology | Rehabilitation |
| Count of items in the Reported Problem List (RPL) | 2.9 ± 2.2 | 2.0 ± 2.1 | 4.5 ± 4.6 |
| Count of items in the Medication List | 10.8 ± 5.1 | 12.2 ± 5.0 | 14.1 ± 4.0 |
| Count of items in the Audited Problem List (APL) | 5.8 ± 3.0 | 4.2 ± 2.6 | 7.7 ± 4.0 |
| Problem list non-compliance ratio[a] | 0.53 ± 0.27 | 0.56 ± 0.35 | 0.49 ± 0.31 |

[a]Problem list non-compliance ratio = 1 - Quotient (RPL, APL)

The PLE© is able to suggest the addition of non-specific problems for medications ordered for treating types of problems which are generally unlisted on the problem list: for example, medication BISACODYL for treating "constipation," medication FAMOTIDINE for treating "gastric acid," medication ACETAMINOPHEN and IBUPROFEN for treating "pain," etc. This feature in the PLE© assists in reducing the likelihood of medication-problem mismatches. The capability and performance of the PLE© on medication-problem matches in each inpatient unit were expressed by the mean counts (± standard deviations) of (1) the addition of non-

specific problems on the Audited Problem List, (2) unmatched problems on the Audited Problem List, and (3) unmatched medications on the Medication List (as seen in Table II). The improvement rate of medication-problem matches on the problem lists was equal to the variance of the percentages of matched medications on the Medication List in the individual inpatient unit before and after expert chart audits. The results showed that nearly 50% of medications became matched in three units because of chart audits as well as the addition of non-specific problems suggested by the PLE©.

TABLE II. THE PERFORMANCE OF THE PLE© ON MEDICATION-PROBLEM MATCHES

| Predictor Variable | Inpatient Unit | | |
|---|---|---|---|
| | General Medical | Neurology | Rehabilitation |
| Count of the addition of non-specific problems suggested by the PLE© | 2.0 ± 1.6 | 3.3 ± 2.0 | 4.6 ± 2.3 |
| Count of unmatched problems | 1.6 ± 1.7 | 1.3 ± 1.3 | 3.0 ± 2.4 |
| Count of unmatched medications | 1.4 ± 1.8 | 3.1 ± 2.2 | 2.1 ± 1.7 |
| Improvement rate (%) of medication-problem matches after chart audit[b] | 49.7 ± 25.4 | 46.9 ± 20.6 | 49.9 ± 26.1 |

[b]Significant at $p < 0.001$

Among 254 unmatched medications in the total of 70 audited patient charts on the general medical floor, the top three were identified as lansoprazole (14%), heparin (10%), and docusate (6%). Among 441 unmatched medications in the total of 70 audited patient charts on the Neurology unit (N=27) and Rehabilitation unit (N=43), the top three unmatched medications were identified as docusate (10%), acetaminophen (8%), and bisacodyl (7.7%). These medications are generally ordered without specific indications, and the PLE© suggested adding non-specific problems on the problem list (as stated in Table II).

Among 98 unmatched clinical diagnoses (problems) on the general medical floor, the top four problems were identified as "Other + NOS[†] hyperlipidemia" (12%), "Anemia, NOS" (4%), "NOS essential hypertension" (4%), and "End-stage renal disease" (4%). Among 139 unmatched problems on the Neurology and Rehabilitation units, the top four problems were identified as "Abnormality of gait" (5%), "Communicating hydrocephalus" (4.3%), "Anemia, NOS" (2.9%), and "Urinary incontinence" (2.9%). Two problems, "End-stage renal disease" and "Communicating hydrocephalus" were also identified as problem orphans, which meant that they lacked a defined medication-problem relationship in the PLE©.

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[†] NOS = Not otherwise specified

## V. DISCUSSION

We have initiated an innovative CDSS to facilitate matching of prescribed medications on the medication list to medical diagnoses on patients' problem lists and found that it can enhance the maintenance of both medication and problem lists. This study is in keeping with the mission of the Agency for Healthcare and Research Quality (AHRQ)[‡] in the U.S.: improve outcomes and quality of health care. Creation of a safer care environment can prevent more patient injuries and improve cost-efficiency.

In Table I, higher values of the problem list non-compliance ratio ($\geq 0.5$) indicate that an average of nearly half of problems on the Reported Problem List were previously missed in the three units before chart audits assisted in reduction of significant diagnostic errors. We had conducted an online survey in 2007 by assessing practice patterns of physicians at UIH related to issues in problem list documentation [30]. The results of this survey revealed that the majority of respondents were reluctant to maintain medication and problem lists and that the quality of documentation remained inadequate.

The outcomes in Table II suggest that clinical expert chart audits could improve the medication-problem matching ratio up to 50% in three inpatient units ($p < 0.001$). The PLE[©] could suggest the addition of non-specific problems on the problem list to enhance medication-problem matches. Our CDSS strategy complies with the Patient Safety and Quality Improvement Act of 2005 in the U.S. [31]. Maintaining accurate and complete medication and problem lists aligns the current list of ordered medications and the current list of ongoing problems for each patient. The improvement in medication and problem list documentation leads to more improvement in quality of care and ultimately yields higher patient safety. Another study drew a similar conclusion that integrating a clinical decision support mechanism into the process of medication order placement promoted relatively accurate addition of problems to the problem list on the EMR at UIH [32].

Unmatched medications and problems (in Table II) represent the existence of likely "medication orphans" and "problem orphans" that lack comprehensive medication-problem relationships in the PLE[©]. We plan to optimize the data mining algorithm in the PLE[©] to enhance the addition of new items in its medication data dictionary, problem data dictionary, and relationship table. We will also construct a user-friendly interface to achieve this function.

The limitations of this pilot study include: (1) the lack of direct data exchange mechanisms from UIH's EMR to the PLE[©] made the patient data entry procedure time-consuming; (2) the implementation of *Screen OCR*[®] was occasionally not stable while running on UIH's Intranet server and needs to be fixed; (3) the multiple versions of medications adopted in the UIH drug formulary restrict the effectiveness of medication-problem matching. Reconciliation of multiple versions of medications will be on top of the list of our next phase.

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[‡] http://www.ahrq.gov

## VI. CONCLUSION

We initiated an innovative CDSS method to enhance the maintenance of both medication and problem lists. Chart audits suggest that physicians' compliance with maintaining medication and problem lists on the EMR remains deficient in three inpatient units at UIH. The results revealed that a CDSS could improve the completeness of the medication and problem lists if a medication-problem mismatch occurs. Enhanced maintenance of both the medication and problem lists can permit the exploitation of advanced decision support strategies that yield higher patient safety. Underlying clinical decision support in the CPOE assists physicians in improving the quality of patient care, in keeping with their particular needs and goals.

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