Notification of Real-time Clinical Alerts Generated by Pharmacy Expert Systems

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We developed and implemented a strategy for notifying clinical pharmacists of alerts generated in real-time by two pharmacy expert systems: one for drug dosing and the other for adverse drug event prevention. Display pagers were selected as the preferred notification method and a concise, yet readable, format for displaying alert data was developed. This combination of real-time alert generation and notification via display pagers was shown to be efficient and effective in a 30-day trial.

INTRODUCTION

Washington University Medical Informatics operates the pharmacy expert systems DoseChecker\textsuperscript{1,2} and PharmADE\textsuperscript{3,4} to examine medication orders for patients at Barnes-Jewish Hospital (BJH). BJH is a 1,400-bed university teaching hospital in St. Louis, Missouri and is the flagship hospital of BJC Health System. The pharmacy department at BJH comprises approximately 100 pharmacists at 7 inpatient satellite pharmacies, fills 1.6 million medication orders and dispenses 6 million doses per year.

DoseChecker examines medication orders for under and overdosing of medications, primarily those that are renally eliminated. It checks orders against a calculated creatinine clearance that is based on serum creatinine lab results, age, gender, height and weight. Medication orders are also re-examined when new serum creatinine results become available. DoseChecker also helps enforce other facility-specific medication dosing guidelines.

PharmADE operates as a safety net to catch orders for absolutely contraindicated medication combinations that occasionally slip though the pharmacy system order entry process. The specificity of the warnings that are generated by the commercial front-end screening system during the pharmacy order entry process is low and pharmacists get many nuisance alerts. As a result of this and the sheer volume of orders processed, important contraindication warnings can be missed. Similar systems have been shown to be effective in detecting and preventing Adverse Drug Events (ADEs) in various clinical settings\textsuperscript{5,6,7,8}.

Both DoseChecker and PharmADE generate alerts when potentially inappropriate medication orders are detected. Alerts generated by both expert systems contain patient demographics and relevant medication and lab data. DoseChecker alerts also give a new recommended dose for the medication that caused the alert. PharmADE lists the medications involved and describes the contraindication. Alerts are assigned a priority by the expert system that indicates the urgency with which the alert should be acted upon.

DoseChecker and PharmADE have been operating in a batch mode since their inception in 1994 and 1996, respectively. In this batch mode process, data is downloaded and integrated into the data repository in an over-night extraction process\textsuperscript{9,10}. When the integration is complete, the expert systems run to examine new medication orders and re-examine orders that are still open. Alerts are generated and faxed to the appropriate satellite pharmacy at 0700 hours. A clinical pharmacist verifies the legitimacy of each alert and contacts the physician for changes when necessary.

Recently, the Medical Informatics team converted DoseChecker and PharmADE to run in real-time using data feeds from a clinical data repository\textsuperscript{11}. Operating these systems in real-time presented the opportunity to further improve patient care by delivering alerts to pharmacists in the most appropriate and timely manner, facilitating changes to medication orders before inappropriate doses are administered.

The method of alert notification and the content of the information delivered were seen as key to the
success of the real-time expert system deployment\textsuperscript{12,13,14}. Alerts must be delivered reliably and with the right level of detail. Interruptions to the clinical pharmacist’s workflow must be balanced against potential improvements in efficiency. This paper describes the alert notification strategy that we developed and tested in a 30-day trial with 11 clinical pharmacists at BJH.

The 30-day trial also tested important real-time notification concepts, such as ensuring alert delivery and escalation to a backup pharmacist if alerts were not acted upon. Those results are reported elsewhere\textsuperscript{15}.

METHODS

Selecting a Notification Delivery Method

Among the factors considered when making the decision about the best method for delivering the alerts were:

1) urgency of the alert;
2) potential impact to the workflow of the pharmacist;
3) amount of information the pharmacist needed to act on the alert; and
4) pharmacist mobility.

The alert delivery methods considered included cell phone, voice mail, e-mail, fax and display pager.

Direct notification via cell phones was ruled out in this case, since they are not in common use by the pharmacists. More importantly, there are problems with cellular coverage in several key areas in the hospital and this did not lend itself to delivery of urgent alerts.

Voice mail, e-mail and fax are common tools in the hospital and all are similar in that they can be handled well in “batch mode”. These communications methods integrate well into the workflow of the pharmacist, but are not well applied in situations where mobility is needed, nor where immediate notification is desired.

Display pagers work well for delivering urgent messages. Most clinicians already carry pagers and are familiar with their use. Many have begun to use display pagers to extend pager functionality beyond numeric messages. Disruptions to workflow are reduced using display pagers since enough information can be included in the message to allow the recipient to prioritize their response without having to obtain additional patient data.

Coverage is still an issue since some areas of the hospital are shielded by electromagnetic equipment such as MRI machines. This shortcoming can be partially overcome through use of a paging service that stores pages when they are not deliverable. Alerts delivered via this service are stored and delivered when the pager comes back into range. SkyTel\textsuperscript{TM} provided this paging service at our location.

Formatting Alerts for Display Pager

After selecting the display pager as the preferred delivery method, the content and format of the alert messages to be sent was determined. The format used in batch mode for printing and faxing DoseChecker and PharmADE alerts contained thousands of characters. The goal was to distill this information to the minimum needed to inform the pharmacist of the problem and recommend corrective action. It was also important to maintain readability and ensure understandability of the display pager text.

The Motorola PageFinder\textsuperscript{TM} pagers we used were capable of displaying 500 characters per message. Given this amount of text, we were able to define the key pieces of data needed by the pharmacist and establish a format for the alerts that conveyed all needed information in a readable and understandable layout.

The essential information needed by the pharmacist to verify the legitimacy of a DoseChecker alert included:

1) patient identification and demographics - medical record number, patient name, age, height, weight and ideal body weight;
2) medication order information - order number, medication name, amount, route and frequency;
3) new recommended medication dose - amount, route and frequency; and
4) relevant lab results - last three serum creatinine and calculated creatinine clearance values.

Information included in a PharmADE alert is slightly different. The patient identification and demographics are the same, but medication order information is given for both contraindicated medication orders. Relevant lab results may also be given, and no new recommended dose is needed.

Once this essential data was identified, a layout that incorporated it was designed (Figure 1). The header of the alert display identifies the alert generating application, and shows the date-time stamp when the
alert was generated and the priority of the alert (Figure 1 - Section 1). The body of the alert display employed the use of section headers and vertical bars to enhance readability. A section in the display was created for the patient (Figure 1 - Section 3), medication order (Figure 1 - Section 4), DoseChecker recommendation (Figure 1 - Section 5) and lab results (Figure 1 - Section 6). A section was also created for the alert identifier (Figure 1 - Section 2).

| 01: DoseChecker ----+ (1) |
| 10/13/1997 07:35 |
| **Priority=02** |
| ALERT -------------+ (2) |
| 0002345 |
| PATIENT -----------+ (3) |
| MR: 23456789 |
| SAMPLE, JOSEPH |
| AGE=59/SEX=M |
| LOC=083ICU |
| WT=092KG/HT=68IN |
| IBW=085 |
| DRUG ORDER--------+ (4) |
| ORDER NO= 12 |
| 10/12/97 12:00 |
| IMIPENEM |
| 500 MG |
| Q6H IV |
| RECOMM. DOSE------+ (5) |
| 500 MG |
| Q12H |
| DATE --------+SC--+CC (6) |
| 000D 0720 3.2 29 |
| -01D 1709 1.8 44 |
| -03D 0400 0.9 99 |

Figure 1. DoseChecker Alert Formatted for Display Pager

It became clear that more than 500 characters would be needed to show all of the required information. To accommodate these needs and to ensure readability of the display, an abbreviated format was created for tabular data. A columnar display was used to shorten the display of relevant lab data considerably. The section header for lab results was coded to identify the columns and vertical bars were used to separate columns in the data.

A relative date format was used to shorten the date-time stamps for lab test result dates. As shown in Figure 1 - Section 6, the lab result date is shown relative to the day of the date-time stamp of alert generation. In this example, a relative lab result date of 000D 0720 means the lab result was collected the same day the alert was generated at 0720 hours. Similarly, -01D 1709 means this result was from one day previous to the alert generation at 1709 hours.

A report was coded to materialize the text sent to the display pager using Report Workbench from Sybase. A query technique was developed within Report Workbench to help format the alerts. In this technique, headers and formatting text are included in the query that retrieves the data for the report, so that this formatting can be omitted when there is no data for that section. For example, lengthy medication names may need to be shown on multiple lines (Figure 1 - Section 4), but space would be wasted reserving space for the medication name when it is short enough to fit on one line.

Additionally, different sections can be shown on the pager display for different types of alerts. This is especially important to PharmADE where different information about relevant lab values and other pertinent (but not contraindicated) medications may be shown on a contraindicated medication combination alert. For example, a cisapride-fluconazole drug-drug interaction alert may show an active medication order for olanzapine, but this information is not relevant for other drug-drug interaction alerts.

Finally, Report Workbench allows overflow values to be specified when the value of a field is larger than the space reserved for that field. Thus, when a patient’s calculated Creatinine Clearance (CrCl) is greater than 100, the display on the pager can be shown as 99, instead of the default overflow value which would be “**”. This is useful because a CrCl of > 99 doesn’t add value to the medication dosing decision, but a value of “**” would not be understandable (Figure 1 - Section 6).

EVALUATION

These concepts were tested in a 30-day trial at BJH using 11 clinical pharmacists who were responsible for 26 of the 103 wards in the hospital. These wards were primarily intensive care unit wards. The trial was conducted Monday-Friday during normal day shift hours (0700-1600). DoseChecker and PharmADE alerts generated in real-time where sent to the responsible pharmacist’s display pager. After the page was sent, a fax was generated that contained the full text of the alert and an outcomes entry form that was completed by the recipient. The outcomes
entry forms were collected to provide feedback for each alert that was generated.

The outcomes entry forms for each alert, in both the batch systems and in the real-time trial, were completed to show pharmacist agree/disagree, disagree reason, MD agree/disagree and MD disagree reason. Additionally, questions about the clinical timing of the alert and most appropriate delivery method for the alert were answered for each alert sent during the trial.

RESULTS

147 DoseChecker and 4 PharmADE alerts were delivered to the clinical pharmacists during the 30-day trial. 136 of the total 151 outcomes entry forms were returned for analysis. Overall, pharmacist agree rate increased from 39% in the batch system to 52% during the trial, an improvement of 33%.

114 of the 136 outcomes forms returned contained responses to the question regarding the most appropriate delivery method for the alert. Pharmacists said the display pager was the most appropriate delivery method 67% (76/114) of the time. The other 33% (38/114) of the responses indicated fax, e-mail, voice mail or some other method would have been preferred.

There were also 114 responses to the question concerning the clinical timing of the delivery of the alert. 74% (84/114) of the time pharmacists agreed the alerts were delivered in a clinically appropriate time frame. 23% (26/114) of the alerts were judged to have been delivered earlier than was clinically appropriate and only 3% (4/114) of the alerts were delivered later than was clinically appropriate.

Retrospective analysis of the start and stop dates of the medication orders for which DoseChecker generated an alert was completed. We found that when changes were agreed upon by the pharmacist and physician the median duration of that inappropriate order dropped from 28 hours in batch to 4 hours during the real-time trial. Further analysis is needed to determine the clinical impact of this dramatic change.

DISCUSSION

Display pagers performed well in delivering real-time alerts and, when given a choice of alerting methods, the majority of pharmacists stated that pagers were the preferred method.

Further analysis of alerts delivered earlier than clinically appropriate or where fax, e-mail or voice mail were preferred will help to adjust the priority assigned to the alert by the expert systems. For example, a DoseChecker alert generated on a medication order where the next dose won’t be given for 24 hours can be assigned a lower priority. This priority can be used to deliver the alerts via fax or e-mail allowing the pharmacist to deliver appropriate care without unnecessary disruptions to his/her workflow.

Anticipated improvements in display pagers and paging systems will also help increase efficiency. Two-way paging will allow the outcomes associated with an alert to be recorded without additional steps and workflow disruption. A set of pre-defined questions can be added to the alert display on a two-way pager and the pharmacist can return answers to these questions directly from the pager display.

CONCLUSIONS

Display pagers worked well for delivering real-time alerts from DoseChecker and PharmADE. The alerts were delivered in a timely manner and in a way that increased the efficiency of the pharmacists. The alert display format developed allowed all essential information needed by the pharmacist to be shown, while maintaining readability and understandability.

Based on the results from the trial, a combination of methods for delivering alerts will be used during production implementation of real-time DoseChecker and PharmADE. Refinements to priorities assigned by the expert systems will further increase the effectiveness of alerting in real-time by allowing the most urgent alerts to be delivered to the pharmacists via the most appropriate devices.

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References


