

Asynchronous Pharmacy Decision Support Within a Multi-Institutional Telemedicine Infrastructure

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Our health system does not yet have physician order entry to facilitate synchronous pharmacy decision support. To fill a needed gap to screen drug orders, we leveraged an enterprise clinical data repository to develop and implement two asynchronous, rule-based expert systems for screening drug dosage regimens and drug-drug interactions (DoseChecker and PharmADE, respectively). Originally deployed in batch mode operating once every 24 hours, these systems now operate in near real time and use a variety of notification technologies for routing clinical alerts. When a new prescription satisfies an alerting rule, an alert is generated and then routed to a responsible pharmacist. Database triggers are also used to generate alerts for existing orders on the basis of changing patient laboratory data. Both expert systems have had a demonstrable effect on prescribing errors, even though the intervention is downstream from the ordering process and is essentially transparent to the ordering physician. Asynchronous decision support is an effective means of correcting prescribing errors and improving the drug-ordering process.

INTRODUCTION

Adverse drug events (ADEs) kill as many as 98,000 annually in the United States, ranking it in the top 10 leading causes of death. The cost of ADEs for hospitalized patients is estimated to be \$2 billion per year¹. Although human error is the cause of preventable ADEs, a significant failure lies in the lack of information systems that are specifically designed to detect errors that could potentially lead to an ADE.

Expert system screening of drug orders is an option for preventing ADEs related to prescription errors. PharmADE and DoseChecker, developed by the Division of Medical Informatics, Washington University School of Medicine, are examples of such systems. We have previously described these asynchronous expert systems, which screen drug orders for drug-dosing errors and drug interactions on the basis of patient-specific information^{2,3}. As originally implemented, these expert systems were executed once daily after a batch download of data from hospital systems⁴. They now continuously monitor drug orders and pertinent laboratory

results, executing once every 10 minutes. The remainder of this paper describes the implementation of these systems in real time.

METHODS

There were five major tasks associated with the development of a real-time monitor:

- Acquiring the data needed by the expert system in real time
- Deciding what data to screen and when
- Reviewing the rule set to reevaluate technical assumptions made during batch-mode design development
- Developing a notification strategy for alerts generated by the expert systems
- Evaluating the performance of expert system rules in disparate health care environments

Real-Time Data Acquisition

The sizable effort of acquiring real-time data was simplified by the introduction of an enterprise clinical data repository and enterprise HL7 message sources. As described previously, we designed a method of data retrieval utilizing the enterprise repository information and supplemental HL7 data to populate a data mart in real time⁵. By this method, we were able to obtain pertinent data within seconds of their entry into the hospital mainframe systems.

Continuous Monitor Development

We devised a screening process whereby all drug orders are queued to be screened as soon as they are stored in the data mart. When new nondrug, pertinent information is stored in the data mart (e.g., age, weight, height, labs), all future and active drug orders for that patient are queued to be screened. To avoid multiple alerts for the same drug order, we utilized batch-mode duplicate alert processing to ensure that only new alerts were stored and processed. A significant difference between batch-mode monitoring and continuous monitoring centered on estimated creatinine clearance (CrCl). It was necessary to begin processing CrCl values and storing them in the data mart as serum creatinine values arrived. This ensured that the expert system did not need to recalculate these at each run.

Preimplementation Technical Rule Set Review

Most of the changes associated with the conversion to real time centered around two areas:

(1) screening drug orders when no serum creatinine or encounter information existed and
(2) determining how soon an order should be screened, since we had orders with future start times (approximately 20 percent). We determined that in most cases, we received serum creatinine values within 8 hours of the drug order. Therefore, we altered the rules to screen on the basis of an assumed, normal serum creatinine value only after 8 hours had passed since the drug order was entered. Similarly, after several trials, we decided to screen future orders that were within 12 hours of their order start time.

Notification Strategy

Pharmacists were directly surveyed regarding their preferences for alert notification modality. When given the option of choosing a single alerting modality, 50 percent of pharmacists preferred alpha pagers, with smaller percentages preferring fax or e-mail notification. However, it was clear that not all alerts were regarded with equal weight, and a means for prioritization was needed, with higher priority alerts being delivered by alpha pager and lower priority alerts being delivered in batch by fax or e-mail. Finally, for high-priority alerts, the pharmacists desired a paper copy of the alert as a worksheet in addition to the alpha page. All of these features have been incorporated into the production versions of DoseChecker and PharmADE. Reminder alerts and an escalation feature help ensure that high-priority alerts are attended to promptly. Alert information can also be viewed by means of a secure Web interface, which also can be used for alert outcome feedback. Faxed alert forms can also be used for alert outcome feedback.

Rule Performance in Disparate Environments

We measured agreement rate with clinical alerts in two user groups (pharmacists and physicians) at two facilities: Barnes Jewish Hospital (BJH) and Christian Hospital Northeast (CHNE). BJH pharmacists agreed with and contacted physicians regarding 1,960 of 5,273 alerts (37 percent); CHNE pharmacists agreed with and contacted physicians regarding 420 of 1,588 alerts (26 percent). When pharmacists contacted physicians with these alerts, physicians agreed to change the order 72 percent (1,417 of 1,960) of the time at BJH and 50 percent (210 of 420) of the time at CHNE. The effective rate of agreement (pharmacist+physician) was 27 percent (1,417 of

5,273) at BJH and 13 percent (210 of 1,588 at CHNE). With initial implementation of the expert systems in batch mode at BJH, we saw similar low rates of agreement, and pharmacist education and experience with the expert systems and physician interaction resulted in increased rates of agreement over time. We anticipate a similar phenomenon with the real-time systems.

CONCLUSION

We have previously shown that an asynchronous alerting strategy for prescription errors results in error reduction and improvement in the prescribing process^{2,3}. The potential benefit of screening prescriptions to patient care is obvious, but cost savings are more difficult to quantify. If we assume an ADE rate of 7 percent, the cost of an ADE ranges from \$1,900 to \$5,900; and if we assume that 28 to 56 percent of ADEs are preventable⁶, we can extrapolate this to show that the cost associated with ADEs per 1,000 admissions ranges between \$37,240 and \$231,280. Asynchronous alerting is a rational and viable alternative or supplement to synchronous alerting.

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