MEDINFO 2007
HISA Ltd Australia
© 2007 The authors. All rights reserved.

Development of Case-based Medication Alerting and Recommender System:A New Approach to Prevention for Medication Error

Kengo Miyo[a], Yuki S. Nittami[a], Yoichiro Kitagawa[a], Kazuhiko Ohe[a]

[a] *Department of Planning, Information and Management, the University of Tokyo Hospital, Japan*

Abstract

The purpose of this study was to develop a new alerting and recommender system for preventing medication errors. In recent years, alerting systems have been widely implemented, but because these systems apply a same static threshold for all patients in all cases, they produce excessive alerts and subject physicians to "alert fatigue". We believe that the most commonly-written prescription for a patient's status is the safest one. From this standpoint, we developed a real-time case-based medication alerting and recommender system linked to a database of past prescriptions. When a physician issues his or her prescription, our system dynamically compares it with past ones for similar patients in the database. An analysis of the 10 most frequently-used drugs in the University of Tokyo Hospital revealed that our system reduced the number of false alerts compared to the traditional static alert method. Our system contributes to the creation of alerts that are appropriate for patients' clinical conditions and based on physicians' empirical discretion.

Keywords:

case-based alerting; decision support systems, clinical; medical order entry systems; medication errors; prescriptions, drug

Background

In recent years, computerized physician order entry (CPOE) systems have been introduced to health care institutions worldwide [1, 2]. In Japan, the use of CPOE systems for medication has become widespread [3], and their implementation rate in hospitals with 500 or more beds was 70% as of 2005 [4]. The use of CPOE system is expected to contribute to efficient health care delivery and reduce physicians' time costs [1, 3, 5].

CPOE systems also contribute to improvements in health care quality, particularly in regard to safety [6–8]. To decrease errors in medical treatments, several systems with real-time data input checks have been developed, for example, to detect inappropriate dosages or drug combinations. In these systems, as soon as a physician clicks the "issue prescription" button, the system compares input data on dose regimen and concomitant drugs to data on dosage limitations and contraindicated drugs stored in a master table file. If the prescription contains inappropriate data, the system displays an alert. Alert systems that use static threshold data stored in a master table file are called *static alert systems.*

Although static alert systems are generally useful, excessive alerts can be produced because the systems check off patient status and treatment policies. Excessive alerts cause physicians to pay less attention to the alerts [9], which then lose their effectiveness. In other words, the few important alerts are overlooked amid a lot of meaningless ones. Peterson et al. described physicians in this situation as being in a state of "alert fatigue" [7, 10]. Particularly in university hospitals, where doctors treat many patients whose cases run counter to standard treatment, the risk of overlooking alerts cannot be ignored.

Physicians need to receive appropriate alerts. In this paper, the term *appropriate alert* refers not to an alert generated based on whether the data match standards determined by drug notes, but rather to an alert generated based on whether the present treatment differs greatly from actual treatment records. Our purpose in this paper is to suggest a new approach for generating appropriate prescription alerts. We believe that most commonly written prescription is the safest one, and we considered past records stored in HIS as the gold standard. From this standpoint, we developed a real-time case-based system that alerts physicians when their prescription deviates from this gold standard.

System design

System structure

The overview of our system is shown in Figure 1. The system consists of existing HIS and a database of past prescription records, as well as an alert engine. MySQL version 5.0 was chosen as the database for our system. All prescription data from the University of Tokyo Hospital (UTH) for 2000 through 2005 were extracted from HIS and stored in the database. For the alert engine, both Perl version 5.8, PHP version 5.1, and Apache version 2.0 were used.

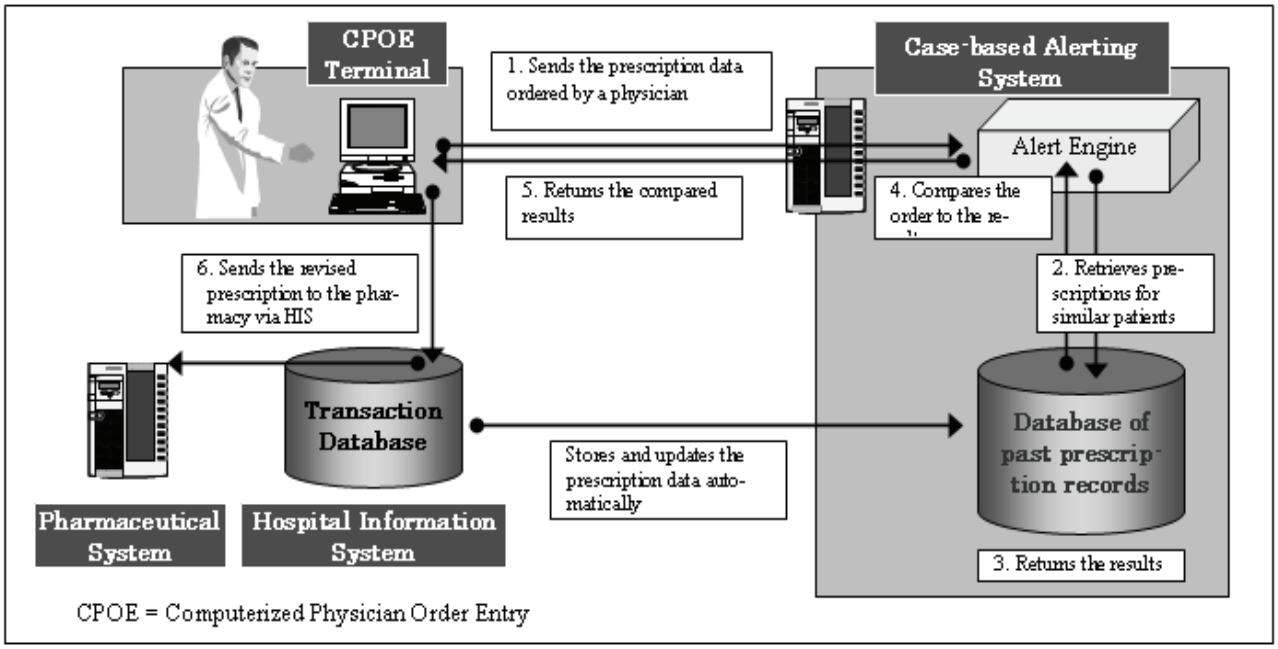

Figure 1- The structure and workflow of the case-based alert system

System feature

Our system has two major functions: alert function and decision support.

Alert function

The alert engine receives the prescription data entered by a physician before sending them to the pharmaceutical system. The alert engine compares these data to the statistical data for that same drug, compiled from past records in the database. If the alert engine finds that the entered data exceed the threshold described below, it sends an on-screen alert to the physician. Figure 2 presents an example of such a prescription alert. At present, the items that can trigger an alert are dosage, dose regimen, duration of drug administration, and concomitant drugs.

Figure 2 - A pop-up alert on the computerized physician's order entry terminal

Statistical data on past prescriptions (such as 95th percentile and standard deviation) serve as the alert threshold. Prescription data in the database are also linked to the patient in question and to his or her diseases. Therefore, the alert thresholds classified according to clinical department (specialty), disease, sex, and age can be also used.

Decision support function

The recommendation function shown in Figure 3 is used when a physician wants to know the appropriate dosage and duration of drug administration. This function pro-

vides the most frequently used value by analyzing a distribution of values of past records. The physician can reexamine his or her prescription with these recommendations in mind. As in the case of the alert function, the recommendation function takes the patient's attributes into consideration.

Interim system evaluation

The final evaluation of our system should be done by physicians who actually use it. The present system, however, is still in the prototype phase. Therefore, we here clarify some interesting aspects of our method by comparing it to traditional static alert systems. We used data on dosage for the evaluation.

Figure 3 - The window of the recommendation function

Evaluation method

We used the September 2006 the UTH prescription records for the system evaluation. We compared cases using our method to those using information about dosage limitation provided by drug notes. The alert function of our system used two thresholds. One was the 95th percentile threshold of each drug, and the other was the mean + 2. We analyzed the 10 most frequently prescribed drugs at the UTH.

Evaluation results

Results are shown in Table 1. Under both the mean + 2 and the 95th percentile thresholds, we found that the number of alerts declined for nearly one-third of the drugs compared to the existing static alert method. However, because the value of the mean + 2 for prednisolone is lower than the value described in the drug note, the number of alerts increased. The reason is that the range of prescribed dosages of prednisolone is broad (i.e., the maximum prescribed dosage was up to 120 mg, whereas the values of prescribed dosages were concentrated around 5 and 10 mg). Thus, our research showed that our system, based on physicians' empirical discretion, set different thresholds than the existing static alert methods.

Discussion

System evaluation

One advantage of our method is that the number of alerts distinctly decreased from that produced by traditional static alert methods because unlike these traditional methods, our thresholds have upper values (e.g., for drugs with high variance of dosage). Loxoprofen sodium and amlodipine are good examples. In the case of prednisolone and aspirin, the mean + 2 thresholds were lower than those described in the drug notes, which caused the increase in alerts. It is critical to warn physicians when they are about to prescribe drug dosages that they do not often prescribe, even if that dosage is within the normal range described in a drug note. This is another advantage of our case-based method. It is one of our key future tasks to determine which threshold to use: mean + 2 or 95th percentile.

Another advantage of our method is that it can issue alerts differently for each clinical department. Prednisolone, whose dosage varies greatly among departments, is a good example. Applying a threshold across the board as traditional methods do results in the production of unnecessary alerts in certain departments. Our system, however, avoids

this issue by issuing alerts based on department features, and on values such as disease, sex, and age, even for one drug. This ensures that alerts are appropriate for each patient's clinical conditions.

Although our system is in the prototype stage at present, we will start actual operation in 2007 and survey physicians' prescribing behavior and degree of satisfaction.

Availability of case-based approach

Master table maintenance is unnecessary

The traditional method, which keeps static descriptions of dosage limit and contraindicated drugs in master tables, requires a huge amount of work to maintain these tables. Our system, however, requires less maintenance because information on dosage limit and contraindicated drugs is dynamically created using already stored data. In addition, our method keeps up with medical advances. When dose regimens change, our method automatically updates the alert thresholds and consequently can issue alerts based on the current prescription trends.

Oriented to physicians' experiences

Our system promises to clarify various dose regimens in a way that is consistent with physicians' empirical discretion. By using past records, our system can alert physicians to drug combinations not empirically prescribed, even if the drugs are not described in drug notes as being contraindicated. In addition, our system can present information about recommended concomitant drugs, similar to the way interns receive advice from supervisors.

Drug	Total number of orders	Threshold from drug note	# of alerts	$M + 2\sigma$*	# of alerts	95th percentile*	# of alerts
Teprenone	3424	150 mg	14	202.3 mg	0	150 mg	14
Loxoprofen Sodium	2623	180 mg	27	244.8 mg	5	240 mg	5
Brotizolam	2666	0.25 mg	460	0.485 mg	447	0.5 mg	1
Famotidine	2238	40 mg	3	51.2 mg	3	40 mg	3
Prednisolone	2110	60 mg	32	41.9 mg	77	40 mg	77
Rebamipide	2094	300 mg	12	398 mg	12	300 mg	12
Amlodipine	1915	5 mg	392	10.2 mg	2	10 mg	2
Aspirin	1950	300 mg	0	125 mg	24	100 mg	24
Sennoside A·B	1820	48 mg	26	47.2 mg	154	48 mg	26
Mecobalamin	1849	1500 μg	1	1815 μg	1	1500 μg	1

*The system issues an alert when the dosage is greater than this value.

Table 1 - Results of interim evaluation

Possibility of graded alert

Our method provides distributions of various parameters such as dosage and dose period. As a result, our system can present graded alerts, such as 1: attention, 2: warning, and 3: prohibited. Gradings of how extensively prescription data diverge from past records enable the physician to quickly decide whether he or she should heed the message.

Limitations of our system

One limitation of our system is that it does not function well with an insufficient amount of past data. For drugs on which a hospital has few or no past records, it is necessary to combine our method with other existing techniques. Small hospitals that do not have a sufficient number of past records must import prescription data from authorized large-scale hospitals. Using data from other hospitals is equivalent to asking "In your hospital, how is this drug commonly used?"

Future direction

The alert and recommendation function can also be applied to laboratory test and radiological records. We are now considering how to make the system available for other medical practices.

Conclusions

We developed a real-time case-based medication alert system that alerts physicians when a prescription deviates from similar commonly written prescriptions in a database of stored records. We set past records stored in HIS as the gold standard. An analysis of the 10 most frequently prescribed drugs at the UTH revealed that our system reduced the number of unnecessary alerts compared to the traditional static alert method. Our easy-to-maintain system

creates alerts appropriate for patients' clinical conditions and alerts based on physicians' empirical discretion. In addition, it can provide more appropriate alerts than traditional methods, and as a result, will contribute to the prevention of errors in medical treatments.

Acknowledgments

This study was supported in part by a Grant-in-Aid to Young Scientists (B) 18790353 (2006) from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

References

[1] Kuperman GJ, and Gibson RF. Computer physician order entry: benefits, costs, and issues. Ann Intern Med 2003: 139(1): 31-9.
[2] Rothschild J. Computerized physician order entry in the critical care and general inpatient setting: a narrative review. J Crit Care 2004: 19(4): 271-8.
[3] Haruki Y, Ogushi Y, Okada Y, Kimura M, Kumamoto I, and Sekita Y. Status and perspective of hospital information systems in Japan. Methods Inf Med 1999: 38(3): 200-6
[4] Ministry of Health, Labour and Welfare, Japan. Survey of medical institutions in 2005. Oct 1, 2005; Available from: http://wwwdbtk.mhlw.go.jp/toukei/data/160/2005/toukeihyou/0005605/t0123581/A0064_001.html. Accessed: Dec 4, 2006. (in Japanese)
[5] Koppel R, Metlay JP, Cohen A, Abaluck B, Localio; AR, Kimmel SE, and Strom BL. Role of computerized physician order entry systems in facilitating medication errors. JAMA 2005: 293: 1197-203.
[6] Judge J, Field TS, DeFlorio M, Laprino J, Auger J, Rochon P, Bates DW, and Gurwitz JH. Prescribers' responses to alerts during medication ordering in the long term care setting. J Am Med Inform Assoc 2006: 13(4): 385-90.
[7] van der Sijs H Aarts J, Vulto A, and Berg M. Overriding of drug safety alerts in computerized physician order entry. J Am Med Inform Assoc 2006: 13(2): 138-47
[8] Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety. Arch Intern Med 2003: 163(12): 1409-16.
[9] Glassman PA, Simon B, Belperio P, and Lanto A. Improving recognition of drug interactions: Benefits and barriers to using automated drug alerts. Med Care 2002: 40(12):1161-71.
[10] Peterson JF, and Bates DW. Preventable medication errors: identifying and eliminating serious drug interactions. J Am Pharm Assoc 2001: 41(2): 159-60.

Address for correspondence

Kengo Miyo, Ph.D., R.N., P.H.N. Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, JAPAN; email: <miyo-sup@h.u-tokyo.ac.jp>