Information technology for detecting medication errors and adverse drug events

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It is estimated that over three-quarters of a million people are injured or die in hospitals each year from adverse drug events (ADEs). The majority of medical errors result from poorly designed healthcare systems rather than from negligence on the part of healthcare providers. In general, healthcare systems rely on voluntary reporting, which seriously underestimates the number of medication errors and ADEs by as much as 90%. This paper reviews the causes and impact of medication errors and ADEs. It also reports studies that have used information technology (IT) to detect and prevent medication errors and ADEs. Significant reduction of medication errors and ADEs requires systemic implementation of IT, improvements in the reporting of errors, and integration of the components of the healthcare systems’ information systems. At the present time, most healthcare systems should be able to use IT to detect and prevent ADEs.

Keywords: adverse drug events (ADEs), information technology (IT), medication errors
medication errors and ADEs; and (3) the use of information technology (IT) to detect ADEs; and concludes that tools are available to detect and reduce the number of ADEs in healthcare settings. The following journals were searched for articles on the use of IT to promote drug safety: Journal of the American Medical Informatics Association, International Journal of Medical Informatics, JAMA, NEJM, Lancet, BMJ, Archives of Internal Medicine, and Drug Safety, among others.

2. Medication errors and adverse drug events

Not all medication errors result in ADEs. A study by Bates et al. [10] found 530 medication errors out of 10,070 drug orders. A total of 40 ADEs were detected. This translated into ∼ 1 ADE in 100 medication errors, while 7 in 100 errors had the potential to cause an ADE.

In addition, medication-related errors that may result in ADEs are frequent among hospitalised patients as well as among out-patients. One study found preventable ADEs in 2 out of every 100 patients admitted to the hospital [11]. The study estimated that each ADE increased the cost of hospitalisation by $4,700. For a 700-bed hospital, the increased cost due to ADEs was estimated to be $2.8 million annually or $2 billion for the USA as a whole. A study of out-patients also found a rate of 5.5 ADEs per 100 patients who visited primary care physicians associated with Brigham and Women’s Hospital in Boston due to medication-related errors [12].

Determining the true rate of medication errors and ADEs has been difficult since most errors are unreported. One study focused on errors made during the dispensing and administration stages of the drug delivery system [13]. The study found that the current method of collecting data on the types and frequency of medication errors using incident reports grossly underestimates errors. Only 36 errors were reported on incident reports and 84 errors were reported on anonymous questionnaires. On the basis of direct observation, the investigators estimated that 51,200 errors would have occurred in dispensing and administering medications over a period of 59,470 patient-days. A second study was performed in an Army out-patient pharmacy [14]. In this study, prescription errors were separated from dispensing errors. The overall dispensing error rate was 3.8%.

Manual chart review has been shown to be effective in identifying medical errors and adverse events but is costly [15]. However, direct observation can detect errors missed by chart review. One study compared the use of retrospective chart review to direct observation in detecting medication errors [16]. Chart review estimated the error rate to be 0.2%. In contrast, direct observation detected an error rate of 9.6%.

Detecting ADEs is also problematic. Most hospitals rely on voluntary reporting of ADEs. This practice may result in the detection and reporting of as few as 10% of ADEs [17-20].

3. A systems approach to medication errors

Traditional approaches to error detection and reduction in healthcare have emphasised training, guidelines and sanctions. Medical and nursing education focuses on knowledge and adherence to protocols. Errors are treated as individual mistakes or failings and are punished largely by peer sanctions. Ultimately, healthcare provider errors may be punished through malpractice tort litigation [21].

At the same time there is growing awareness that the majority of medical errors result from poorly designed healthcare systems rather than primarily from negligence on the part of healthcare providers. Preventing and reducing medical errors and ADEs requires attention to the methods of detection used and the prevention of errors at each stage of the delivery system. Systemic modifications reduce the overall likelihood that an error will occur and permit detection and intervention before the error causes harm to a patient [22-26]. Several studies have utilised a system approach to study medication errors.

This approach is much more likely to lead to improvement in the detection and prevention of medication errors that can lead to ADEs. For example, one study of ADEs identified 16 causes of systems failure that resulted in medication errors that resulted in an ADE or had the potential to result in an ADE [24]. The highest percentage of errors that resulted in preventable ADEs was made during the ordering stage (49%). Errors resulting in preventable ADEs were also made at all other stages: transcription (6%), dispensing (4%), and administration (34%) [27]. Of all the ADEs, 1% were fatal, 12% were life-threatening, 30% were serious, and 57% were significant.

Failures in seven subsystems related to the delivery of medications accounted for 78% of the medication errors that occurred. The most frequent system failures and resulted from a lack of knowledge about drugs. A second major systems failure resulted from the unavailability of patient-specific information at the time that the prescription was written. In a number of instances the allergy defence system failed even when information concerning patient allergies had been included in the medical record. Manual transcription of physician orders was another major source of errors. Errors also occurred because of the complexity of the system used to track medications from ordering to administration.

This problem was compounded by problems in interservice communication. Information about medication errors and ADEs was not routinely provided to physicians, nurse and pharmacists. As a result, there was little follow-up to prevent a similar error from occurring again on hospital units.

The Institute for Safe Medication Practices [28] conducted a national study of the ability of hospital pharmacy systems to detect and prevent drug-related errors. The investigators found that the pharmacy system only detected about a third of these errors.

The inability of the pharmacy systems to detect errors was primarily due to systems problems. Many hospital,
information systems are not integrated. Stand-alone systems for order entry, pharmacy, and laboratories make it difficult to detect medication errors that may result in ADEs. The lack of integration also makes it difficult for providers to access drug information as well as previous patient encounter information at the time that drug orders are written. Moreover, many systems lack the capability to screen orders and alert or prompt healthcare providers when dangerous situations that could cause serious harm or death to a patient occur. Even within the medication delivery system, the prescribing, dispensing and administering stages in many instances were not electronically linked. Furthermore, dispensing and administration errors frequently occur when pharmacy systems use confusing abbreviations and generate hard-to-read labels.

Studies such as the one reported above by the Institute for Safe Medication Practices [28] suggest that piecemeal implementation of information systems may fail to detect and prevent errors. Furthermore, physician order entry systems are frequently complex and time-consuming. As a result, physicians frequently bypass many of the systems and rely on nurses, unit secretaries and pharmacists to enter orders into the information systems.

Anderson and co-workers [29] developed a simulation model to evaluate the capability of IT to detect and to prevent ADEs in hospitals. The model was used to estimate ADE rates and associated hospital costs based on five implementations of IT. These were: provision of computer-based drug information at the prescribing stage; physician computer order entry; a unit dosing system in the pharmacy; an automated medication dispensing system; and a comprehensive information system for medication delivery.

The model estimated that the various interventions, if individually implemented, would reduce ADEs by 5 – 13%. The largest reduction in errors and adverse events from a single IT application would result from physician order entry. In comparison, the implementation of a comprehensive information system for medication delivery would result in a 28% reduction in ADEs. The estimated reduction in annual hospital costs resulting from ADEs was estimated to range $285,000 – $700,000 when IT was implemented piecemeal. A clinical pharmacist reviewed the medical records of all patients on the list for potential ADEs. During an 18-month period, 631 of 731 verified ADEs were detected using automated problem lists available online.

4. Detection of adverse drug events using information technology

As the use of IT to collect, store and transmit medical data electronically becomes more widespread, this technology can be used to identify ADEs. Bates and co-workers [30] review the methodologies that use IT to detect adverse events in healthcare settings and studies that use these techniques. These tools include the collection of clinical data in electronic form, event monitoring and natural language processing. For example, pharmacy data and clinical laboratory data are usually available in coded electronic form. Also, these data are available in real-time, permitting intervention in time to prevent ADEs from harming patients. A number of studies have demonstrated how these data can be screened for ADEs [31-38].

Basic information systems may be effective in identifying and avoiding potential ADEs. One study classified hospital information systems into three levels [39]. Level 1 systems monitor medication orders for drug–drug interactions and drug allergy problems. These systems require only that patient demographics, results from diagnostic tests and current medications are available online. Level 2 systems, where all orders are entered online by physicians, provide additional protection for patients through drug-dose checking, cumulative dose checking, dose algorithms and detection of transcription errors. More sophisticated Level 3 systems provide all of the functional features of Level 1 and 2 systems as well as providing automated problem lists available online.

The study used chart reviews to identify adverse events experienced by patients admitted to Brigham and Women’s Hospital. The investigators estimated that 53% of adverse events were identifiable with the lowest level information system. A Level 2 system would have identified 58% of adverse events and a Level 3 system, 89%.

The more sophisticated systems are capable of detecting a much larger percentage of ADEs and potential ADEs. For example, a computerised system was developed at LDS Hospital in Salt Lake City, Utah, to monitor ADEs [31]. The system was programmed to generate a daily list of potential ADEs from data contained in an integrated hospital information system. Sudden medication stop orders, ordering of antidotes, and abnormal laboratory values were taken as signs of potential ADEs. A clinical pharmacist reviewed the medical records of all patients on the list for potential ADEs. During an 18-month period, 631 of 731 verified ADEs were detected by the automated system. At the same time only 9 ADEs were identified by the traditional reporting system.

Other investigators have developed and tested similar systems. Jha et al. [34] used a system based on the LDS hospital rules to identify ADEs. The detection rules were based on new medication orders, laboratory results above or below threshold values, and medication orders associated with changes in laboratory values. A daily list of alerts based on these rules was generated by the computer system. Subsequently, the patient’s medical chart was reviewed for indication of an ADE or potential ADE.

The automated ADE detection system was compared to two other strategies used to detect ADEs, chart review and voluntary reporting. A total of 617 ADEs were detected by at least one of the methods. The automated system detected 275 (45%) ADEs; chart review found 398 (65%) ADEs; and voluntary reporting detected 23 (4%) ADEs.

Most of the information systems used to detect ADEs have been developed and implemented in in-patient hospital settings. One system was developed to detect ADEs in an ambulatory setting [12]. Patient data from an electronic medical record was used to detect ADEs. The computer system was
programmed to search for ICD-9 codes that had been found to be associated with ADEs. A database containing the patient’s medication and drug allergy lists was also scanned. A third approach to identifying ADEs was computer-event monitoring. Rules were developed to identify new medication orders, abnormal laboratory results and changes in laboratory values that had a high probability of being associated with ADEs. Finally, a data mining tool, Micromedex MFD2 medical data dictionary, was used to electronically examine visit notes [40].

For each incident that was identified, a chart review was used to ascertain whether or not an ADE had actually occurred. The evaluation involved a period of 1 year and a review of the electronic medical records for 23,064 patients. A total of 864 ADEs were identified. Text searching identified 91% of the ADEs; 6% were identified from the allergy record; event monitoring identified 3%; and ICD-9 codes found only 0.3% of the ADEs.

5. Expert opinion and conclusion

According to the Joint Commission on Accreditation of Healthcare Organisations (JCAHO), the medication error rate is the most important indicator of the quality of the medication delivery system. It is estimated that over three-quarters of a million people are injured or die in hospitals annually from ADEs [31,41]. National hospital expenditures resulting from the treatment of persons injured by ADEs while hospitalised have been estimated to be as high as $5.6 billion per year [8,11]. Between 1983 and 1993, deaths due to prescription errors increased by 24.3% [42-43].

There is considerable evidence that medication errors that result in ADEs can be detected and prevented [44]. Information systems that include physician order entry, decision support, and alerting systems can significantly reduce errors and adverse events that result in injury to or the death of patients. For example, studies have demonstrated that computerised physician order entry systems that include decision support can significantly improve the quality of medication delivery [101,45-47]. In addition, computerised alerting systems have been shown to decrease error rates, delays in treatment, length of hospital stay, and costs [48-51]. However, experience with early hospital and ambulatory care medical information systems suggests that major organisational changes are frequently required to successfully implement IT, especially physician order entry systems [52,53].

However, in order to be effective, IT must be implemented using a systems approach. Many hospitals lack an electronic medical record that is needed to implement most decision support systems. Lack of integration of physician order entry systems, pharmacy systems, and laboratory systems is another barrier to reducing medication errors.

As demonstrated by the simulation study [29], piecemeal applications of IT have only limited results in reducing ADEs and associated hospital costs. Moreover, it was estimated that even the implementation of a comprehensive information system for medication delivery would only reduce ADEs and hospital costs by ~ 28%. Computerised systems are only part of the overall solution in preventing medication errors and ADEs [54,55]. The process of reporting medication errors and ADEs needs to be significantly improved. At present, only ~ 10% of medication errors are reported using a voluntary reporting system. Improvement in reporting will require a system where persons reporting the error do not fear punishment. Secondly, pharmacists need to be more directly integrated into the medication delivery system at every stage. Brigham and Women’s Hospital was able to reduce the ADE rate in the ICU unit by two-thirds by having pharmacists participate in patient rate with the intensive care unit team [56]. This resulted in cost savings of $270,000/year. Finally, nursing medication administration and monitoring systems need to be improved. This should include bar-coding of medications as well as improved labelling and warnings on medications with a high potential for harm to patients.

To date, most applications of IT to identify and prevent ADEs have focused on hospital in-patient settings. An important area for future research is the development and implementation of IT in ambulatory settings to identify and prevent adverse drug reactions. Because of the high volume of out-patient visits, IT has the potential to significantly improve the quality of healthcare and reduce costs. A recent report by the Center for Information Technology Leadership [57] estimated the universal adoption of ambulatory computerised provider order entry (ACPOE) systems that include decision support would avoid 2.1 million ADEs, saving $34 billion/year. However, it is estimated that < 10% of physicians in the US who practice in out-patient settings currently use any type of ACPOE.

There are significant barriers to the introduction of IT into practice settings. At present, there are limited incentives for providers to invest in IT in order to detect and prevent ADEs. The Leapfrog Group, which consists of a number of Fortune 500 companies, strongly supports computer physician order entry (CPOE) as a means of reducing medical errors, especially errors that result in ADEs. In response, some payers are offering financial incentives to healthcare providers who adopt CPOE.

The President’s Information Technology Advisory Committee Draft Report [58] calls for accelerated adoption of IT in the healthcare sector. They specifically recommend the adoption of: (1) electronic health records to maximise the information available to healthcare providers at the point of care; (2) computer-assisted decision support to increase compliance with evidence-based medicine; (2) electronic order entry in both out-patient and in-patient practice settings; and (4) interoperable electronic information interchange. In order to facilitate the implementation of these recommendations, President Bush has proposed $100 million to be spent on promising health IT.

The Centers for Medicare and Medicaid services have proposed that computerised monitoring of ADEs be mandated in in-patient settings [102]. While this is an important step in the
direction of improved patient safety, widespread adoption of the IT applications to detect and prevent ADEs will require both incentives and sanctions. Moreover, it will require a change in the current ‘blame and shame’ culture that pervades healthcare institutions at present [59].

Acknowledgement

I wish to acknowledge the assistance of M Anderson with the preparation of this paper. Portions of this paper are taken from reference [60] with permission.

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