Information Technologies for the Prevention of Medication Errors

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In the last few years, medical adverse events have received growing attention. In a report published in 1999, the Institute of Medicine (IOM), relying on three studies performed during the last decade in the US, estimated that the number of deaths attributable to preventable medical errors was probably between 44,000 and 98,000 per year, and that 7,000 Americans could die annually from medication errors alone. Another well-designed study prospectively measured a rate of 6.5 adverse drug events per 100 admissions, of which 28% were preventable, with errors occurring at the stage of ordering (49%), transcription (11%), dispensing (14%) and administration (26%).

Although healthcare processes are very complex, they are actually based strongly on human reliability, which explains the high rate of adverse events. Indeed, the performance of highly trained operators has been shown to be associated with error rates in the range of 10^-2 for dispensation and even 10^-1 for calculation. When several consecutive operations are needed to perform a complete activity, the probability of error increases in relation with the number of steps. For example, a process comprising 50 steps, each being performed with a reliability of 99%, will result in a total reliability of only 61%.

Mechanisms leading to active failure are multiple and include slips, lapses, fumbles, mistakes and procedural violations. More importantly, the organisation of the working environment will have a major influence on the operator’s performance, determining the latent conditions more or less favourable to the occurrence of active errors. Only a few factors, such as illumination, sound, workload and task disruption, have so far been investigated and shown to influence the error rate.

Significant efforts are currently under way to prevent human errors and improve patient safety and great hopes have been pinned on information technologies (ITs). These developments have great interests, because they have the potential to suppress manual or cognitive steps linked to high error rates and because they target systems rather than individuals, a strategy that has been shown to be effective in reducing errors in other fields such as aviation industry.

**IT in the Medication Process**

Numerous interventions involving information systems have been developed to improve the security of three major steps of drug use in hospitals: prescription (computerised physician order entry [CPOE]), dispensation (automated dispensing systems) and administration (bar coding). The first two developments are designed to avoid the occurrence of errors, whereas the aim of the last one is to improve their detection before the drug is administered to the patient.

CPOE refers to a variety of computer-based systems that share the common features of automating the medication ordering process and that ensure standardised, legible and complete orders. Clinical decision support systems (CDSSs) are built into almost all CPOE systems to varying degrees, providing basic computerised advice regarding drug doses, routes and frequencies, as well as more sophisticated data such as drug allergy, drug-laboratory values, drug-drug interactions, checks and guidelines. Results of recent surveys in the US indicate that 4% to 15% of hospitals have an electronic medication order-entry system in place. If institutions in the process of implementing systems are included, this figure may be as high as 30%, but this relatively low rate put in evidence the recent emergence of these tools and the complexity to set them up. A large development can, however, be predicted, as some countries (e.g. the UK) or states (e.g. California) have decided to oblige hospitals to implant CPOE in the next years. In the same time, The Leapfrog Group, a consortium of companies that belong to the Business Roundtable, recommends CPOE as one of three changes that would most improve patient safety.

Automated dispensing systems are drug storage devices or cabinets that dispense medications electronically in a controlled fashion and track medication use. Centralised systems prepare and distribute individualised treatments from a central location in the hospital, whereas decentralised pharmacies reside on nursing wards. These devices are a sophistication of the traditional unit dose-dispensing system in which technicians and/or pharmacists prepare individualised...
processing and improving patient safety.

In trying to imagine what the medication system of the future could be, physicians will be ordering online, supported by a clinical decision system. The orders will be sent electronically to a robot that will automatically fill the patient cart or to a decentralised automated dispensing system manipulated by the nurses. All drugs, patients and staff will be bar coded, making it possible to perform a final check based on the electronic prescription. The concomitant use and interconnection of the three systems will probably be the most powerful way of optimising the medication process and improving patient safety.

**Interests**

Although ITs are now relatively widely used in hospitals, relatively little robust data exists regarding their impact on the safety of the medication process. Exceptions are CPOE and CDSSs, which have been found to improve drug safety. Other previously described innovations, such as automated dispensing devices, bar-coding and computerisation of the MAR, though less studied, should all theoretically have an impact on the error rates.

According to a recent systematic review on the effect of CPOE on medication safety, at least two studies demonstrated an important decrease of between 55% and 81% in the serious medication error rate. When the results were evaluated by steps in the process from ordering to administering, it was interesting to consider that CPOE diminished ordering errors by only 19%, whereas transcription (-84%), dispensing (-68%) and administration (-59%) errors were more markedly reduced. The reduction of ordering errors is strongly dependent on the exhaustiveness of the CDSSs associated to the prescription tool. In this case, drug allergy and drug-drug interaction checks were implemented, but other supports such as adjustment of doses for renal failure and age or improved laboratory-checking capabilities would have decreased the error rate more markedly. This study also put in evidence that complete and legible physicians orders improve significantly the security of the post-prescriptions stages.

Although automated dispensing devices result in several benefits, including a net saving in personnel time, an increase of pharmacists’ availability for clinical activities and an improvement in billing efficiency, Reduction in medication errors has not been uniformly realised. No recent, well-designed study, testing the latest technologies with a connection to an electronic prescription, is actually available. Such data would be very useful to better quantify the impact of automatic dispensing on medication safety.

Bar-coding of drugs also seems useful for reducing error rates, although little data from healthcare is available. Bar-coding is widely used in many industries outside of medicine and tests have shown that bar-code scanning has an error rate of one in 10 million characters, compared with keyboard-entry error rates of one error per 100 characters. Some unpublished data suggests that an 80% fall in medication administration errors was obtained in a hospital.
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a report by

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Automated dispensing systems are drug storage devices or cabinets that dispense medications electronically in a controlled fashion and track medication use. Centralised systems (e.g. Baxter ATC-212, Homerus, Swisslog Pillpick system) prepare and distribute individualised treatments from a central location in the hospital, whereas
decentralised pharmacies (e.g. Pyxis Medstation, Omnicell Sure-Med) reside on nursing wards. These devices are a sophistication of the traditional unit dose-dispensing system in which technicians and/or pharmacists prepare individualised treatments on the basis of the prescription. They can be directly connected to an electronic prescription system or require a retranscription of a written or electronic order in the dispensing device. The decentralised pharmacies offer several interests for nurses, in particular immediate access to medications, thereby decreasing turnaround time and improved tracking of narcotics dispensing. They try to cumulate the advantages of unit dose system (individualisation to reduce error rate) and ward stocks (rapid availability of drugs). In a 2002 national survey of drug dispensing practices in the US, 80% of respondents stated that their pharmacy was centralised and, of these centralised pharmacies, 70% were not automated. An estimated 8% of hospitals used a robotic distribution system that automates the dispensing of unit doses within the centralised distribution system. A majority of hospitals (58%) with decentralised distribution systems employed automated point-of-use dispensing devices.

Bar-code scanning technology can contribute to a reduction in medication errors by ensuring the ‘five rights’ of medication administration: right patient, right drug, right dose, right route and right time. It is necessary that each of the ‘rights’ be verified before medication administration to ensure that the patient receives their medication safely, but without an electronic system, these controls are difficult to perform with good accuracy, because they often necessitate comparison with prescription data, which is not easily available at patient bed. By linking a bar-code scanning device with CPOE and/or automated dispensing software, the performance of these final checks can be improved. When ready to administer a medication, the nurse simply scans a bar code on his/her own identification badge, the bar codes of medications to be administered and then the patient’s wristband bar code. As a by-product, these systems provide a complete and accurate online medication administration record (MAR) by documenting precise administration data and making it easier for all care-givers to trace a patient’s care over time. Actually, only 1.5% of hospitals use bar-code technology in the administration process to scan and verify the correct patient and the correct drug, but nearly two-thirds of hospitals use computer-generated MARs. In trying to imagine what the medication system of the future could be, physicians will be ordering online, supported by a clinical decision system. The orders will be sent electronically to a robot that will automatically fill the patient cart or to a decentralised automated dispensing system manipulated by the nurses. All drugs, patients and staff will be bar coded, making it possible to perform a final check based on the electronic prescription. The concomitant use and interconnection of the three systems will probably be the most powerful way of optimising the medication process and improving patient safety.

**Interests**

Although ITs are now relatively widely used in hospitals, relatively little robust data exists regarding their impact on the safety of the medication process. Exceptions are CPOE and CDSSs, which have been found to improve drug safety. Other previously described innovations, such as automated dispensing devices, bar coding and computerisation of the MAR, though less studied, should all theoretically have an impact on the error rates.

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To summarise, although the usefulness of IT in the reduction of medication errors is definite, studies measuring the impact of up-to-date technologies are lacking. The main factors leading to such an improvement are the complete and legible character of the information, the access to structured and powerful clinical decision support, the suppression of transcription steps, the reduction of possibilities for selection error and the univocal identification of drugs and patients.

**Barriers**

Although an increased use of ITs in future years seems to be unavoidable, its implantation is a real challenge and numerous experiences have failed. The cultural and organisational changes brought about by the introduction of ITs must not be underestimated. These tools should only be introduced after a careful estimation of technical (e.g. conviviality, response time, reliability), human (e.g. leadership, value to users, motivation, acceptance, time availability) and ergonomic (e.g. work flow organisation) aspects, with a special focus on new risks potentially induced by the modification of the process.

For CPOE, a tool assessing hospital readiness was recently developed including several different components such as external environment, organisational leadership, structure and culture, care standardisation, order management, access to information, IT structure and infrastructure. Assessment results for the first 17 hospitals indicated that the lowest average components score was in care standardisation, organisation culture and order management process, whereas the highest score was in organisational structure.

To prescribe a drug with an electronic tool takes more time than to write orders on paper and a study revealed that it took medical interns 9% of their time ordering with CPOE system compared with 2% with paper order systems. Although the computerised approach saved them an additional 2% of time with regard to the time spent for other duties, the net difference between the two systems was a 5% increase of their total time. To make this overtime acceptable by physicians, the clinical decision support system must be powerful and bring significant added value to the prescription.

The potential limitations of automated dispensing systems are a variety of process deviations, including nurses waiting at busy administration times, especially if there are not enough machines, removal of doses ahead of time to circumvent waiting and overriding the device when a dose is needed quickly. These procedural failures emphasise an often-raised point with the introduction of new technologies, namely that the latest innovations are not a solution for inadequate or faulty processes or procedures.

The efficacy of bar-code scanning technology is linked to the presence of a bar code on drugs, caregivers and on the patients. The bar-coding of drug unit doses is not common in the pharmaceutical industry, which enforces repackaging by the pharmacy to apply this technology. The US Food and Drug Administration (FDA) is proposing a rule that would require bar-code labels on all human drug and biological products and it can be hoped that this problem will be, for the most part, resolved in future years.

Last but not least, ITs are expensive and the financial aspect is often limiting the implantation. Savings in medication error management and time are probably greater in most, though not all, instances, but IT requires a large up-front capital investment that is often difficult to obtain from hospital managers.

**Conclusion**

ITs have a huge potential to help reduce the occurrence of medication error, but hospitals need to consider the implications that these systems will have on work flow before complete implementation occurs. Factors reported as being important for success or failure are: technical features, user-friendliness, organisation of the implementation and cultural and behavioural patterns of hospital personnel. Re-engineering of the medication process should be done using a system approach, evaluating the consecutive steps (prescription, dispensation, administration) and trying to develop a coherent information system connecting them.

Even if ITs constitute an important way of preventing medication errors, other actions such as caregivers’ education, centralised intravenous additive services and clinical pharmacy are complementary approaches that should not be forgotten. Ideally, personnel time saved during IT implementation, if any, should be redirected to these activities.

Future years will be associated with a strong development of ITs in hospitals and evaluation studies will be essential to measure system improvement. The final objective must be a significant increase in the quality of patient care.
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References