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*BMJ* 2000;320:788-791
doi:10.1136/bmj.320.7237.788

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The author is also professor of anaesthesia at Stanford University School of Medicine, Stanford, California.

Competing interests: The author is the secretary of the Anesthesia Patient Safety Foundation. He also licensed simulation technology to CAE-Link in 1992, for which he received a licence and royalties on the sale of patient simulators. He is also, periodically, a paid consultant to MedSim, the company that now owns the rights to the licensed simulation technology.

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Using information technology to reduce rates of medication errors in hospitals

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BMJ 2000;320:788–91

Data continue to show that medication errors are frequent and that adverse drug events, or injuries due to drugs, occur more often than necessary. In fact, the frequency and consequences of iatrogenic injuries seem to dwarf the frequency of other types of injuries that have received more public attention, such as aeroplane and automobile crashes. A recent meta-analysis reported an overall incidence of 6.7% for serious adverse drug reactions (a term that excludes events associated with errors) in hospitals. Between 28% and 56% of adverse drug events are preventable.

Though the reasons this issue has received so little attention are complex, the reasons that medical injuries occur with some frequency are perhaps less so; medicine is more or less a cottage industry, with little standardisation and relatively few safeguards in comparison to, say, manufacturing. In fact, most of the systems in place in medicine were never formally designed, and this holds for the entire process of giving drugs.

Take, for example, the allergy detection process used in our hospital several years ago, which was similar to that used in most hospitals at the time. Physicians, medical students, and nurses all asked patients what their

Summary points

Although information technologies are widely used in hospitals, relatively few data are available regarding their impact on the safety of the process of giving drugs.

Exceptions are computerised physician order entry and computerised physician decision support, which have been found to improve drug safety.

Other innovations, including using robots to fill prescriptions, bar coding, automated dispensing devices, and computerisation of the medication administration record, though less studied, should all eventually reduce error rates.

The medication system of the future will include these and other technologies, all electronically linked.
available information, in identifying links between
two pieces of information, and in doing boring repetitive
tasks, including checks for problems. The best
medication processes will thus not replace people but
will harness the strengths of information technology
and allow people to do the things best done by people,
such as making complex decisions and communicating
with each other.

Computerised physician order entry
Computerised physician order entry (CPOE) is an
application in which physicians write orders online.
This system has probably had the largest impact of any
automated intervention in reducing medication errors;
the rate of serious errors fell 55% in one study and
the rate of all errors fell 83% in another.\textsuperscript{10} Computerisation
of ordering improves safety in several ways: firstly, all
orders are structured, so that they must include a dose,
route, and frequency; secondly, they are legible and the
orderer can be identified in all instances; thirdly, informa-
tion can be provided to the orderer during the
process; and fourthly, all orders can be checked for a
number of problems including allergies, drug interac-
tions, overly high doses, drug-laboratory problems
(giving a patient a drug when they have a known
biochemical factor that predisposes them to risk), and
whether the dose is appropriate for the patient's liver
and kidney function (fig 2). A large decrease in the
number of errors can be achieved by computerising
the process even without providing much decision
support; in one study even a simple system reduced
medication errors by 64%.\textsuperscript{11}

Computerised decision support is also valuable for
reducing the frequency of adverse drug events, even
when not linked to computerisation of the ordering
process. In an elegant series of studies, the group from
LDS Hospital in Salt Lake City, Utah, showed large
reductions in adverse drug events due to antibiotics.\textsuperscript{12}
Also, a community hospital in Phoenix, Arizona, used a
computerised alert system to target 37 drug-specific
adverse reactions—for example, arrhythmia caused by
digoxin—for which they looked for patients receiving
digoxin who had hypokalaemia.\textsuperscript{13} They detected
opportunities to prevent injury at a rate of 64 per 1000
admissions; 44% of the true positive alerts had not
been recognised by the physician.\textsuperscript{14} This approach
works partly by helping clinicians to associate key

Using information technologies to
prevent medication errors
Several interventions involving information systems
have been shown to reduce medication errors consid-
erably, and many others have promise but have not
been sufficiently studied. Among these are computer-
ised physician order entry, computerised physician
decision support (which is often, though not necessarily,
linked with order entry), robots for filling prescriptions,
bar coding, automated dispensing devices, and
computerisation of the medication administration record (fig 1).

It is essential to state at the outset, however, that
information technologies are not a panacea, and that
they may make some things better and others worse;\textsuperscript{15}
the net effect is thus not entirely predictable, and it is
vital to study the impact of these technologies. They
have their greatest impact in organising and making
available information, in identifying links between
allergies were. This information was recorded at several
sites in the medical record, though there was no one
central location. The information was also required to be
written at the top of every order sheet, although in prac-
tice this was rarely done. The pharmacy recorded the
information in its computerised database, but it found
out about allergies only if the information was entered
into the orders, and often it was not. Checking by physi-
cians and pharmacy and nursing staff was all manual.
This information was not retained between the inpatient
and outpatient settings, or from admission to admission.
Not surprisingly, about one in three orders for drugs to
which a patient had a known allergy slipped through.\textsuperscript{3}
This system has been replaced by a system in which all
allergies are noted in one place in the information
system, drugs are mapped to “drug families” (for exam-
ple, penicillin) so that checking of drugs within classes
can be done, information is retained over time, and
checking is performed by the information system, which
does not fatigue.

Fig 1 Role of automation by stage in the medication process. Automation of some functions may affect more than one stage

Fig 2 Computerised checking of a chemotherapy dose. The computer calculates the body surface area, displays the calculation,
and asks if it is correct. The dose is then checked against a table of
doses, with daily and weekly limits. If a dose limit is exceeded the
order is suspended until it can be reviewed and approved
pieces of data, which can be problematic given the overwhelming stream of data confronting them.

Though computerisation of ordering dramatically decreases the overall rate of medication errors, computerised decision support may be especially important for preventing errors that actually result in injury. In one study, computerised order entry with relatively limited decision support resulted in a larger decrease in near misses (84%) than in errors that actually resulted in injury (17%)—but in a later evaluation, after more decision support had been added, the rate of errors resulting in injury fell from 2.9 to 1.1 per 1000 patient days.10

Robots for filling prescriptions
Automation may also reduce error rates in filling prescriptions. Robots have been used for this in some large hospitals for some time, and more recently in smaller hospitals, and they are increasingly being used in the outpatient setting. No published data are available, but in one unpublished study a robot decreased the dispensing error rate from 2.9% to 0.6% (PE Weaver and VJ Perini, American Society of Health System Pharmacists, 1998).

Bar coding
Although few data from health care are available, bar coding of drugs also seems useful for reducing error rates.11 The major barrier to implementation has been that drug manufacturers have not been able to agree on a common approach; this should be legislated. Bar coding is widely used in many industries outside medicine; it results in error rates about a sixth of those due to keyboard entry and is less stressful to workers. Some hospitals in the United States have already successfully implemented bar coding—for example, at Concord Hospital in New Hampshire bar coding was associated with an 80% fall in medication administration errors (D DePiero, personal communication). Bar coding can rapidly ensure that the drug at hand is actually the intended one and can also be used to record who is giving and receiving it, as well as various time intervals.

Automated dispensing devices
Automated dispensing devices can be used to hold drugs at a location and dispense them only to a specific patient.12 Such devices, especially if linked with bar coding and interfaced with hospital information systems, can decrease medication error rates substantially. Without these links the effect of these devices is unclear14,15; in one study such a system was actually associated with an increase in medication errors.16

Automated medication administration record
Another key part of the medication use process is the medication administration record, on which the clinicians who actually administer drugs record what has been given. Computerisation of this part of the process, especially if linked to computerised order entry, could reduce errors and allow detection of other types of errors relating to the quantities of drugs that are to be taken “as needed.”

Computerised adverse drug event detection
To monitor how any process is performing, it is essential to be able to measure its outcomes. Traditional monitoring relies on self reporting, which radically underestimates adverse drug events, detecting only about 1 in 20.17 However, computerised data can be used to detect signals (such as use of an antidote or a high concentration of a drug) that are associated with an adverse reaction.18–20 A pharmacist can then evaluate the incident and determine whether it represents an adverse drug event, and these data can then be used for root cause analyses. In a head to head comparison with chart review and spontaneous reporting, a computerised monitor was found to detect 45% of events detected by any method, compared with 64% for chart review and only 4% for voluntary reporting.21 The cost of the computerised monitoring was only 20% of that for chart review. This is the first practical way to monitor the medication process on an ongoing basis.

Diffusion of these technologies
The tools that are now available should eventually be used in all hospitals; the overall approach should be analogous to that used in infection control, in which data about complications are used to continuously improve the system. Given the potential impact of these technologies, their diffusion has been surprisingly slow. One reason may be the lack of research showing how much of a difference the technologies make. Funding for such research has been relatively limited, and relatively little support has come from the developers of the technologies. Another, more important reason is lack of demand from the healthcare industry. Safety has not been a high priority in medicine, in part because the problem of safety is generally undervalued. One reason for this lack of appreciation is that medical accidents occur in ones and twos rather than in large groups; moreover, many of those involved are ill and elderly. Fortunately, public concern about the issue is substantial, and increasing, and the healthcare industry is beginning to take a more active interest.22

The medication system of the future
In future, physicians will write orders online and get feedback about problems like allergies and decision support to help them choose the best treatment. The orders will be sent electronically to the pharmacy, where most will be filled by robots; complex orders will be filled by pharmacists. Pharmacists will be much more clinically oriented and will focus on promoting optimal prescribing and identifying and solving problems. Automated dispensing devices will be used by nurses to provide drugs to patients. All drugs, patients, and staff will be bar coded, making it possible to determine what drugs have been given to whom, by whom, and when.

Conclusions
Several information technologies have been shown to improve the safety of drugs. Computerised physician order entry seems to be the most potent of these, and it can be expected to become even more useful as more data become computerised. The technology can be expected to diffuse rapidly as all major vendors are
developing such systems and many are pursuing internet based applications which would allow ordering and provide a common platform. Information technology should also improve safety in other parts of the process, including dispensing and administering, but the full benefits will not be achieved until all the components are electronically linked.

The net result of the above will be a much safer system, which will still require substantial human guidance. Moreover, the people using the system will have fewer menial tasks and a more rewarding role: physicians will discuss drug choices with patients and other providers rather than worrying about missing an allergy; pharmacists will deal with complex drug orders, counsell physicians about choices, and investigate problems that occur, rather than simply filling prescriptions; and nurses will talk with patients and monitor for adverse reactions, rather than just passing pills.

I thank Joshua Borus for help with preparation of the manuscript.

Competing interests: DB has received honoraria for speaking from the Eclipsys Corporation, which has licensed the rights to the Brigham and Women’s Hospital Clinical Information System for possible commercial development, and from Automated Healthcare, which makes robots that dispense drugs. He is also a consultant and serves on the advisory board for McKesson MedManagement, a company that helps hospitals to prevent adverse drug events, and is on the clinical advisory board for Becton Dickinson.


Gaps in the continuity of care and progress on patient safety

Richard I Cook, Marta Render, David D Woods

The patient safety movement includes a wide variety of approaches and views about how to characterise patient safety, study failure and success, and improve safety. Ultimately all these approaches make reference to the nature of technical work of practitioners at the “sharp end” in the complex, rapidly changing, intrinsically hazardous world of health care. It is clear that a major activity of technical workers (physicians, nurses, technicians, pharmacists, and others) is coping with complexity and, in particular, coping with the gaps that complexity spawns. Exploration of gaps and the way practitioners anticipate, detect, and bridge them is a fruitful means of pursuing robust improvements in patient safety.

Gaps

The notion of gaps is simple. Gaps are discontinuities in care. They may appear as losses of information or momentum or interruptions in delivery of care. In practice gaps rarely lead to overt failure. Rather, most gaps are anticipated, identified, and bridged and their

Summary points

Complex systems involve many gaps between people, stages, and processes

Analysis of accidents usually reveals the presence of many gaps, yet only rarely do gaps produce accidents

Safety is increased by understanding and reinforcing practitioners’ normal ability to bridge gaps

This view contradicts the normal view that systems need to be isolated from the unreliable human element

We know little about how practitioners identify and bridge new gaps that occur when systems change